# HME Management in Mega Mining: Sishen Mine – South Africa

*An investigation into various elements influencing cycle times, payloads and utilization; the three key factors determining overall Heavy Mining Equipment efficiency.*

A project report submitted in partial fulfilment
of the requirements for the Degree of
Master of Engineering Management
at the University of Canterbury.

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## Disclaimer

This report has been prepared in partial fulfilment of the requirements for the degree of Master of Engineering Management at the University of Canterbury (UC) in Christchurch New Zealand. It is intended for use by Kumba Iron Ore Ltd.

A copy of the report will be submitted to UC and the report will be made available to Kumba Iron Ore Ltd on the condition that the author, supervisor and the University will have no legal responsibility for statements or recommendations made therein. If Kumba Iron Ore Ltd intends to rely solely on the contents of this report or to implement its recommendations it must do so solely in reliance on its own judgement.

# HOW TO USE THIS REPORT

This report contains a "Main Report" and eight investigations in the form of self standing reports contained in six different appendices.

The "Main Report" is written specifically for management personnel who are time poor and will not be able to read the detailed reports contained in the appendices.

The "Mini Reports" in the appendices contain the detailed findings, methodologies and discussions for each investigation and can be consulted when more information is required concerning a specific investigation.

# EXECUTIVE SUMMARY

In order to optimise heavy mining equipment (HME) efficiency, three factors must be considered. These factors are independent of each other under normal operation condition but combine to give overall HME efficiency or overall equipment efficiency (OEE) as shown in Figure 1:

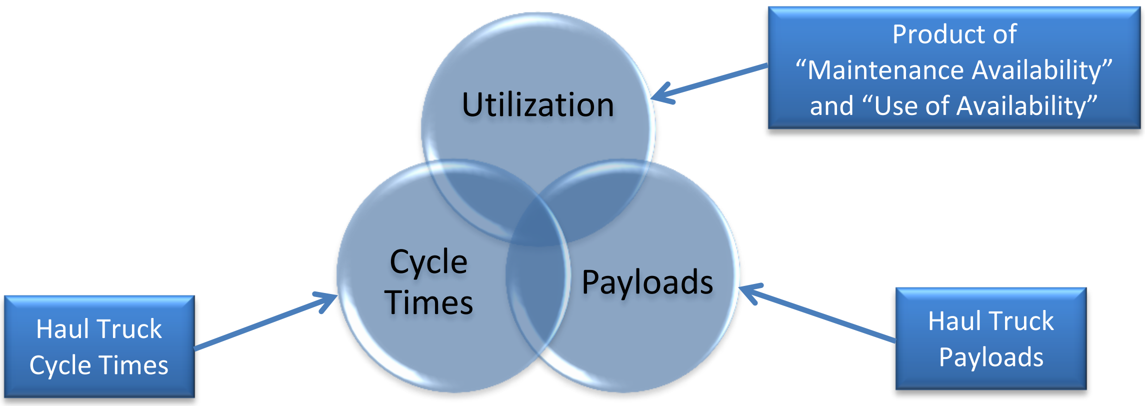



**Figure 1: Factors crucial to OEE or efficient utilization of overall HME capacity**

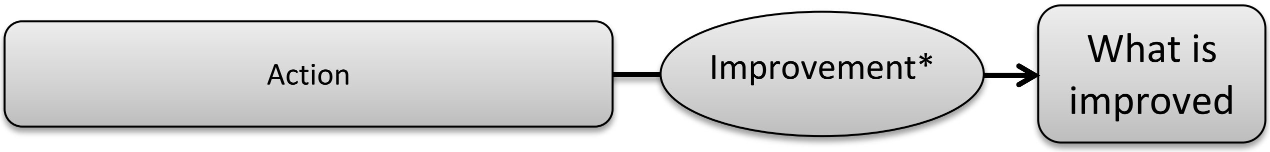
This suggests that improving any of these factors by 1% should improve the OEE at Sishen by approximately 1%. As they are independent, increasing a specific factor should not adversely affect other factors under normal conditions. It was determined that decreasing the average cycle time at Sishen by 1% increases the profit that Sishen makes by approximately R250 million per annum.

Various field studies and data analyses followed a series of initial investigations that identified eight areas that were to be investigated; these areas, what they primarily influence and how this influences OEE is shown in Table 1:

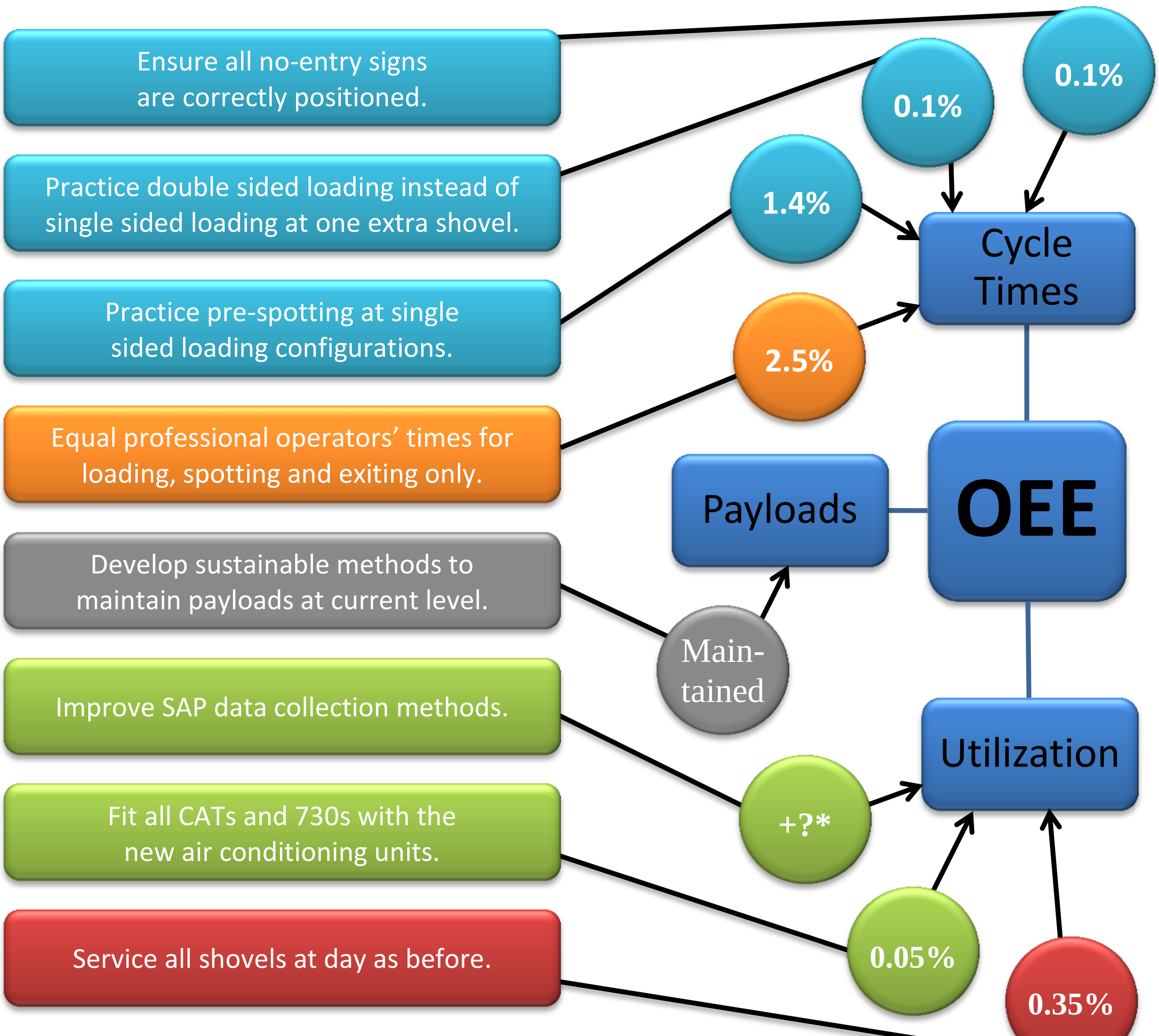
**Table 1: Summary of areas investigated and how they influence OEE**

| | Primary Influence | Main Area Affected |
|---|---|---|
| Holding Position of Dump Trucks | Spotting Times | Cycle Times |
| Double Sided Loading | Spotting Times | Cycle Times |
| Pre-Spotting (Single Sided Loading) | Spotting Times | Cycle Times |
| Benchmarking Operators | Loading and Hauling Times | Cycle Times |
| SAP (Maintenance data) | Maintenance Availability | Utilization |
| Air Conditioning Systems | Maintenance Availability | Utilization |
| Night Shift Maintenance | Availability and Use of Availability | Utilization |
| Payloads | n/a | Payloads |

The investigations revealed that various small but significant improvements can be made to two of the three factors affecting overall utilization of HME capacity. Figure 2 illustrates how the findings fit together and what what effect they have on the three key factors determining HME efficiency or OEE:




*Recall that a 1% increase equates to approximately R250 million per annum.




*Ability to make strategic decisions with SAP Data.

**Figure 2: Summary of recommendations and expected effect on the utilization of overall HME capacity**

These findings led to the the recommendations shown in Table 2:

**Table 2: Summary of primary recommendations**

| Area | Recommendation |
|---|---|
| Holding Positions | Put control measures in place to stop negligence. |
| Double Sided Loading | Ensure it is implemented where possible. |
| Pre-Spotting | Conduct an in-depth risk analysis to determine whether it is feasible. |
| Benchmarking | Provide incentives to optimise local operator performance. |
| SAP Data | Improve data collection procedures. |
| Air Conditioning Units | Install new units on 730s and CATs as soon as possible. |
| Night Servicing HME | Stop servicing front end loaders at night, continue with the trucks. |
| Payloads | Ensure sustainability to keep payloads at current levels. |

As most of the opportunities for improvement are individually small, a Kaizen type approach or mind-set where each opportunity is taken hold of and solved in a sustainable manner will be required. Without this approach, operational drift will eventually erode the improvements as they are on a number of different fronts.

Operator performance and pre-spotting hold significant opportunities for improvement:

- Operator performance is the single area that provides the biggest opportunity for improvement at Sishen; physically slow loading, spotting and exiting times alone cost Sishen R600 million per annum. Primary delays are estimated to increase this figure to around 9% without secondary delays or cascading effects being taken into account. It is thus important that long term sustainable solutions be sought. The primary suggestion is that an attractive remuneration and individual recognition scheme be put in place for HME operators. This would motivate current operators to perform better and lead to more job applications, widening the selection pool, hence enabling the selection of more talented and driven future operators.

- A 1.4% reduction in average cycle time, worth R350 million per annum, would be realised if pre-spotting was adopted. Company policy, informed by safety considerations, currently stop pre-spotting at single sided loading configurations from being implemented**.** It is strongly recommended that a proposal be made to adopt pre-spotting pending a thorough risk analysis.

# Contents

# ACKNOWLEDGEMENTS

I would like to express my thanks to the following people:

- ✓ Piet Kamfer at Sishen Mine for acting as the sponsor to the project and providing me with advice, guidance and feedback.
- ✓ Craig Barry and Gielie Loots for their guidance and advice, as well co-operation and assistance with investigations.
- ✓ Andrew Loots, Hannes Cronje and Hugo Schreuder for giving me the necessary permission to do a project at Sishen.
- ✓ Jannie Coetzee and Johan Kotze for helping me to obtain data from the dispatch system and for all their insights.
- ✓ MEM administrator Bev Hall for her friendship, help and advice.
- ✓ MEM Director Piet Beukman for supervising the project.

# GLOSSARY OF TERMS

| | |
|---|---|
| Mt | Million Tonnes |
| OEE | Overall Equipment Efficiency |
| HME | Heavy Mining Equipment |
| SAP | Data Management System |
| MEM | Masters of Engineering in Management |
| Foremen | Experienced artisan usually in charge of a crew of around 20 artisans |
| Head/GEM | General Engineering Manager, Reports to SEMs, in charge of a number of Foremen |
| SEMs | Section Engineering Manager |
| Spotting | The process where a truck manoeuvres into position to be loaded |
| PLM | Used to refer to the scale on dump trucks at Sishen |
| Aircon | Tem used to refer to an air conditioning unit |
| VIMS | Vital Information Management System, recording all data from haul trucks |
| Bakkie | A light two or four seated vehicle used to travel in the pit |
| 960 | The Komatsu 960E haul truck with a 320 ton payload |
| 860 | The Komatsu 860E haul truck with a 256 ton payload |
| CAT | The Caterpillar 793D haul truck with a 220 ton payload |
| 730 | The Komatsu 730E haul truck with a 190 ton payload |
| EO | Expert Operators |
| KPI | Key Performance Indicator |

# 1 INTRODUCTION

## 1.1 Overview: Sishen Mine

Sishen Mine is Kumba's flagship operation and one of the largest open-pit mines in the world. It operates 24/7 and in 2011 produced 38.9 million tonnes (Mt) of iron ore (1). The primary mining fleet currently consists of approximately one hundred haul trucks (Section F:3.2). Sishen is always looking to optimise the use of its heavy mining equipment (HME), which specifically includes haul trucks and shovels, to increase its productivity.

## 1.2 Background: Factors Determining HME Efficiency

In order to optimise HME efficiency three factors must be considered, these factors are independent of each other under normal operation condition but combine to give overall HME efficiency or overall equipment efficiency (OEE) as shown in Figure 3:

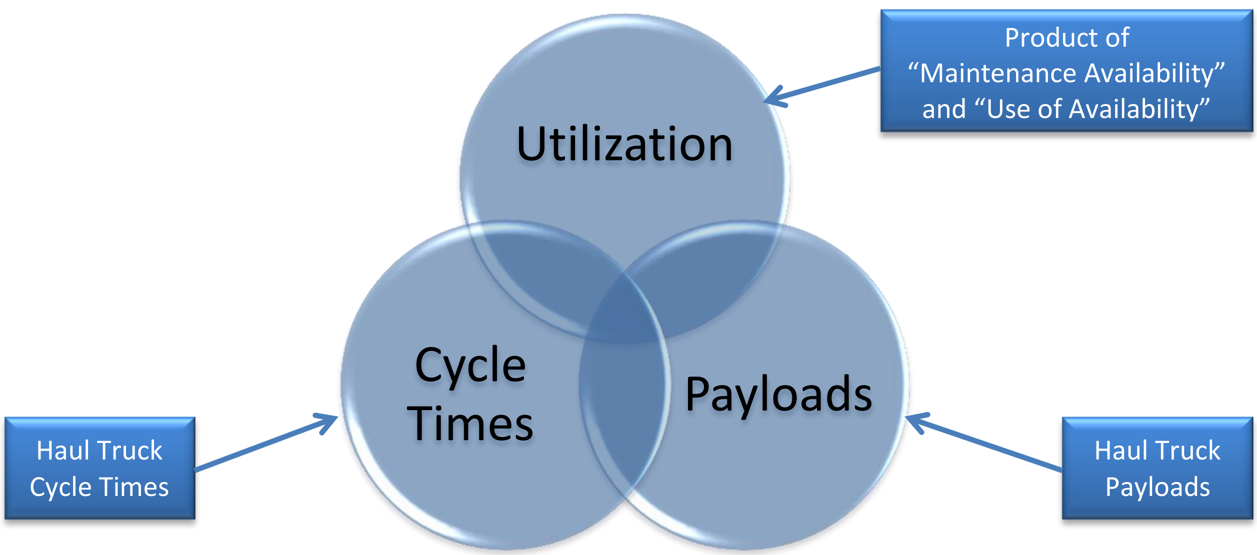



**Figure 3: Factors crucial to OEE or efficient utilization of overall HME capacity**

This suggests that improving any of these factors by 1% should improve the OEE at Sishen by approximately 1%. As they are independent increasing a specific factor should not change other factors under normal conditions; if a significant change is made, such as practising partial shovel loading passes, payloads are expected to go up at the cost of cycle times for example. A literature review confirms that similar factors have been identified by other researchers doing similar analyses ( (2) & Section A:1.4.1).

## 1.3 Purpose and Scope

This report investigates various elements that contribute to OEE as shown in Figure 3. Figure 4 illustrates what elements are studied and how they influence the three key factors influencing OEE:

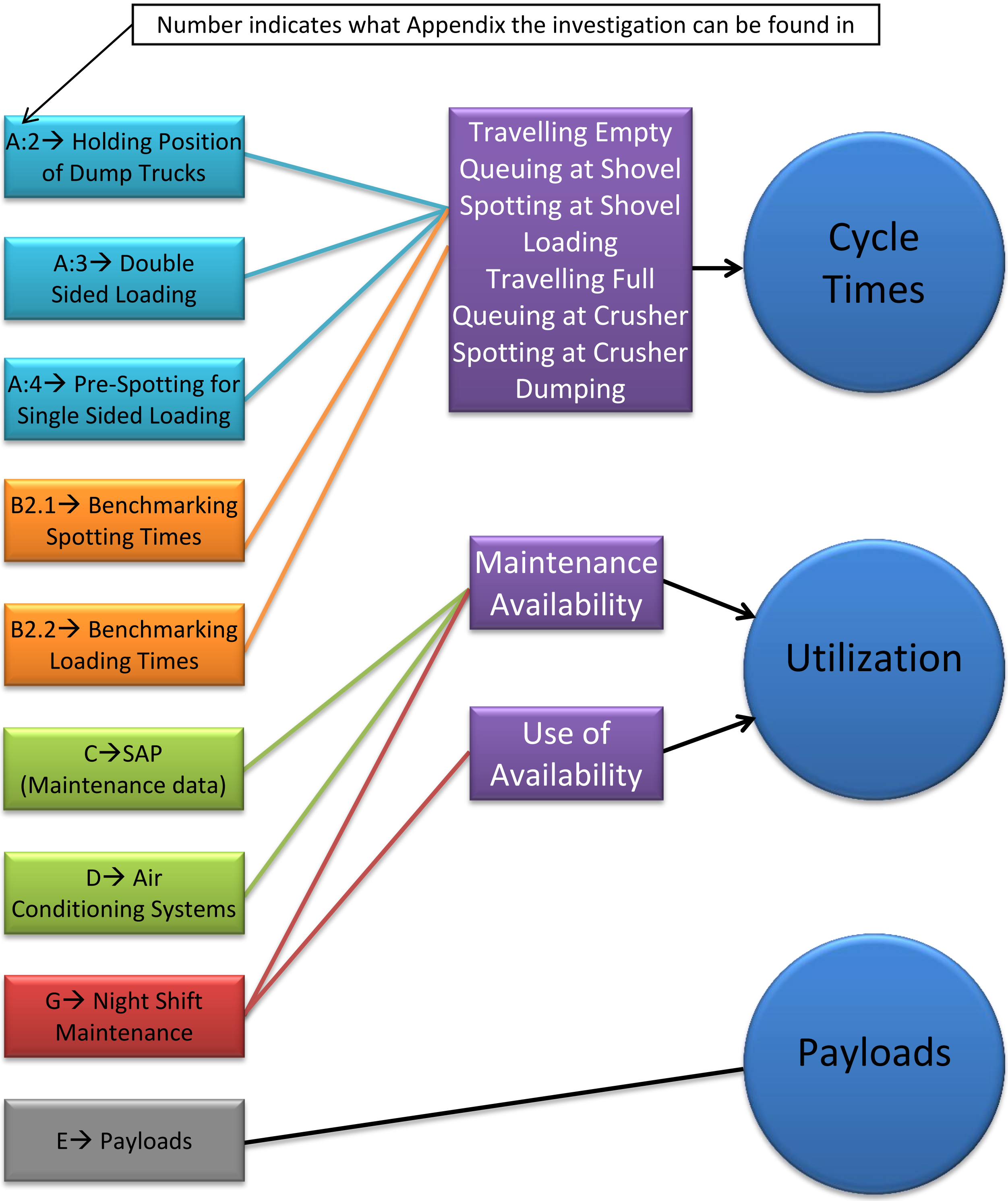



Figure 4: Scope of investigations

## 1.4 Justification and Relevance

Improvements in HME efficiency can have one of two results for a mining operation like Sishen:

- Increased production tonnage with the same equipment.
- Same production tonnage with a decreased amount of equipment.

At Sishen increased production tonnage is targeted. This is due to the following factors:

- ✓ Sishen sells a considerable portion of its product on the spot market; for the first half of 2012 28% of Sishen product was sold in this manner ( (3) & Section F:3.3).
- ✓ Sishen extracts iron ore at well under its selling price; for the first half of 2012 Sishen extracted ore at R181.9 per tonne whilst the average revenue per ton was R1,061 ( (3) & Section F:5.1).

It was determined that decreasing the average cycle time at Sishen by 1% increases the profit that Sishen makes by approximately R250 million per annum (Section F) as illustrated in Figure 5:

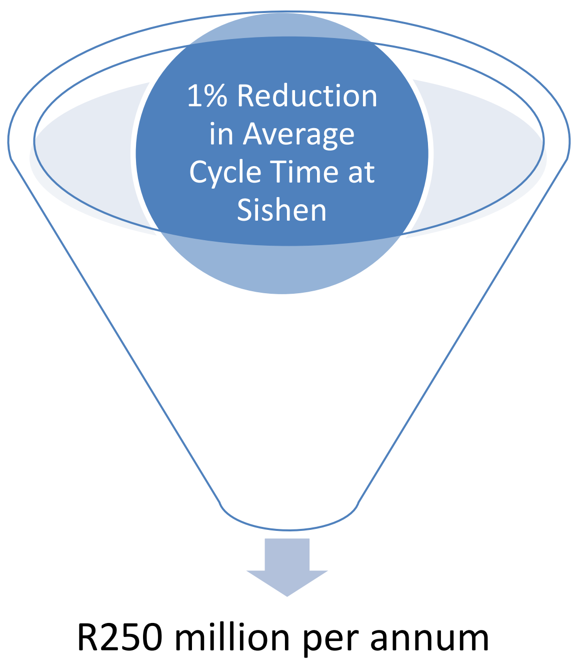



**Figure 5: Effect of reduced cycle times on profit**

As determined in Section 1.2 a similar gain is expected for a 1% increase in utilization or payload average. It is worth noting that a seemingly small percentage which might be disregarded equates to a substantial monetary gain.

# 2 LITERATURE REVIEW

The operations that this report studies at Sishen are in most cases unique or situation bound. It is however helpful to examine external practices to ensure that basic philosophies are in-line with industry standards.

A literature review of various elements can be found in the relevant sections:

- Factors Crucial to Efficient Operations (Section A:1.4.1) → "Payloads, Cycle Times, and Availability and its use" which is focussed on at Sishen was found to be typically regarded as important key performance indicators (KPIs) across the industry.
- Cycle Time Breakdown (Section A:1.4.2) → The overlying cycle time breakdown at Sishen was found to be typical, especially when an investigation of this type is conducted.
- Spotting Procedures (Section A:1.4.3) → Sishen's loading procedures were found to adhere to generally accepted safety considerations.
- Payload: Policy (Section E:2.1) → The "10-10-20 payload policy" as practiced on Sishen was found to be the industry standard.
- Payload: Loading Practices (Section E:2.2) → It was found that the execution of partial passes has not been systematically evaluated. Factors like distance, fill of last pass and truck availability should be taken into account. At Sishen partial passes are not done.
- Dispatch System (Section H:3.2) → The dispatch system used at Sishen is well known, yet Sishen has customised it do perform a range of tasks that it was not specifically designed for.

The researcher could not obtain specific work instructions outside Sishen to ascertain detailed workings such as holding position distance. Other factors like double sided loading, SAP implementation or night shift vs. day shift are highly situation dependent. No data could be found comparing seemingly basic indicators like payloads. This is due to the fact that no two mining operations are identical, as well as the competitive nature of the industry.

In summary Sishen was found to operate within common industry standards on a high level. The research did not yield information on detailed techniques however. In order to compare intricate operations to other companies physical observations might be required.

# 3 INVESTIGATIVE PROCEDURE

The exact scientific methodology followed for each investigation can be found in the appendices. This section endeavours to give a brief overview of the methods and resources used in the overall investigation.

## 3.1 Evolving Scope and Initial Investigations

It must be noted that the original project scope was changed considerably through the course of the project; changes were systematically introduced when the student and sponsor felt that work in a particular area would be more beneficial to the company. The process of selecting research areas that were finally investigated consisted of the following actions:

- Interviews with management, technical and ground staff.
- Observations, especially physical observations of operations in the pit.
- Data collected from Dispatch and SAP.
- Opportunities for improvement that were discovered during parallel studies.

## 3.2 Final Investigation and Data Collection

Once a research area was finalised, the appropriate data collection procedures were determined. They are shown in Table 3. Complete descriptions can be found in the indicated appendices.

**Table 3: Overview of methodologies for each research area**

| | Appendix | Data Collection Method |
|---|---|---|
| Holding Position of Dump Trucks | A:2.2 | Field Study, Physical Measurements |
| Double Sided Loading | A:3.2 | Field Study, Physical Measurements |
| Pre-Spotting for Single Sided Loading | A:4.2 | Field Study, Physical Measurements |
| Benchmarking Operator Spotting | B:2.1 | Field Study, Physical Measurements |
| Benchmarking Operators Loading | B:2.2 | Field Study, Physical Measurements |
| SAP (Maintenance data) | C:2.2 | Data Analysis, SAP data |
| Air Conditioning Systems | D:2.1 | Data Analysis, SAP data |
| Payloads | E | Data Analysis, Payload Forum Data |
| Night Shift Maintenance | G:2 | Data Analysis, Dispatch System Data |

# 4 FINDINGS

As shown in Table 3 this main report covers nine separate investigation compiled into six stand-alone reports. This section explicates the key information found in these reports in a compact format. Data, methodologies and detailed discussions can be found in the relevant appendices; they contain comprehensive reports covering each investigation.

In order to help the reader understand each investigation this section will cover the investigations separately; subsequent sections will tie the findings together. The following format will be used to present each investigation in this section:

- Overview and Justification
- Key Findings and Relevance
- Recommendations

## 4.1 Holding Positions

**See Section A:2 for the comprehensive report.**

### 4.1.1 Overview and Justification

When a truck arrives at a shovel it waits at a holding position marked by a no-entry sign as shown in Figure 6 before commencing its spotting procedures. Spotting times are increased if the no-entry sign is not ideally positioned at the prescribed distance of 50m from the shovel. This unnecessarily increases the cycle time of trucks. Initial observations of pit operations revealed that no-entry signs are not always ideally positioned (Section H:1.2.3).

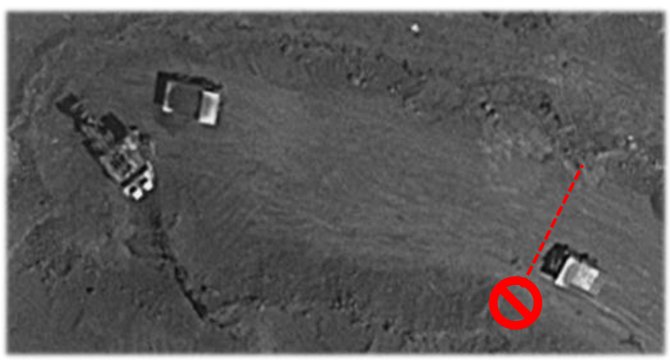


Figure 6: Truck holding position at "no-entry" sign

The frequency of misplaced no-entry signs and its impact on cycle times and hence OEE was thus investigated.

### 4.1.2 Key Findings and Relevance

On a randomly selected day three loading areas observed were found to have have no-entry signs positioned further than the specified 50m from the shovel. They were positioned as follows:

- 150m for one of the Liebher 996 shovels
- 110m for shovel S564, a P&H 2300XPB
- 80m for shovel S560, a P&H 2300XPB

This resulted in a 0.9% increase in cycle time for shovel S560 and a 2.2% increase for shovel S564. The trucks were ignoring the sign placed at 150m for the Liebher. The effect on overall operations was relatively low at a retardation of approximately 0.1% (Section A:2.2.2, Figure A12) costing around R25 million per annum. This figure would be higher if drivers always obeyed no-entry signs as only two of the three misplaced signs were being obeyed.

Ensure all no-entry signs are correctly positioned.

0.1% decrease in average cycle time
worth R25 million per annum.

### 4.1.3 Recommendations

Control measures should be tightened to ensure that no-entry signs are in position at the start of every shift. One no-entry sign placed at 65m instead of 50m has an estimated 0.04% delay on entire operations. This equates to a loss of approximately R15,000 (R250 million X 0.04 X 1/365 X 1/2) for a single shift. Neglecting to correctly position the no-entry sign should be emphasized as serious neglect and be a punishable offence. Management must specify clearly whether it is the responsibility of the shovel operator or foreman to position the no-entry signs and punish negligence.

As an alternative sustainable solution, existing electronic positioning systems could be adapted to ensure trucks always hold at the correct distance. No-entry signs should still be used to control other traffic ensuring a safe loading area.

## 4.2 Double Sided Loading

**See Section A:3 for the comprehensive report.**

### 4.2.1 Overview and Justification

Double sided loading is the practice where a shovel loads trucks on its right and left side as shown in Figure 7. This reduces the spotting times as the waiting truck can manoeuvre into position on the left side or pre-spot on the right side instead of waiting at the no-entry sign.

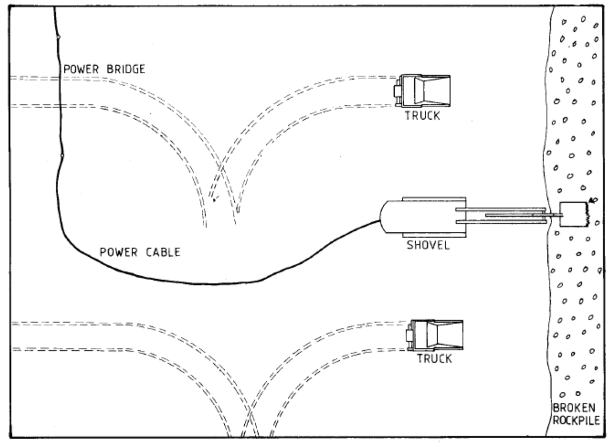



Figure 7: Illustration of double sided loading, sourced from (43)

Double sided loading is implemented where possible, yet no quantification of the benefit could be obtained. The process was thus examined and compared to single sided loading to ascertain the importance of enabling implementation.

### 4.2.2 Key Findings and Relevance

The average "last bucket to First bucket" time was 48 and 82 seconds for double sided and single sided loading respectively. This is a difference of 34 seconds which equates to 1.7% of the average cycle time of 2,000 seconds as found in Section A:1.3. 1.7% is worth approximately R425 million per annum to Sishen. Assuming 19 shovels are in operation as noted in Section A:1.3 this equates to approximately R30,000 (R250 million X 1.7 X 1/19 X 1/365 X 1/2) per shift.

Practice double sided loading instead of single sided loading at one extra shovel

0.1% decrease in average cycle time worth R25 million per annum for each shovel.

It should be noted that this only applies when a shovel has enough trucks. The percentage time reduction can be far more pronounced for shovels closer to dumping points. At Bruce A the reduction in cycle time is expected to be around 5% as opposed to the 1.7% average.

### 4.2.3 Recommendations

It is recommended that double sided loading be implemented where possible, especially for situations where the cycle time is short and enough trucks are available. Double sided loading was observed less frequently than expected and could possibly be improved. This will require planning and operations personnel to appreciate the potential benefits.

## 4.3 Pre-Spotting

**See Section A:4 for the comprehensive report.**

### 4.3.1 Overview and Justification

Pre-spotting is the process where the next truck moves past the no-entry sign and gets into position to start reversing when the loaded truck exits. This is illustrated by position 1 on Figure 8. If pre-spotting is practiced the waiting truck will take considerably less time to spot and be able to commence spotting procedures when the loaded truck passes it, and not the 50m mark. Experienced truck drivers are confident that this manoeuvre can be safely done.

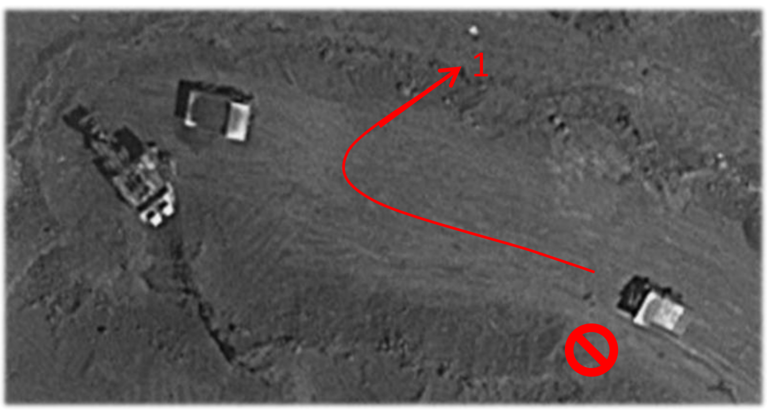


Figure 8: Pre-Spotting holding position

The benefits of pre-spotting ware determined in order to motivate a thorough risk analysis.

### 4.3.2 Key Findings and Relevance

The time that will be saved is the sum of the pre-spotting time and the time it takes the exiting truck to move from the  pre spotted truck to the 50m mark. The times as recorded are for Komatsu 860Es only and is shown in Figure 9:

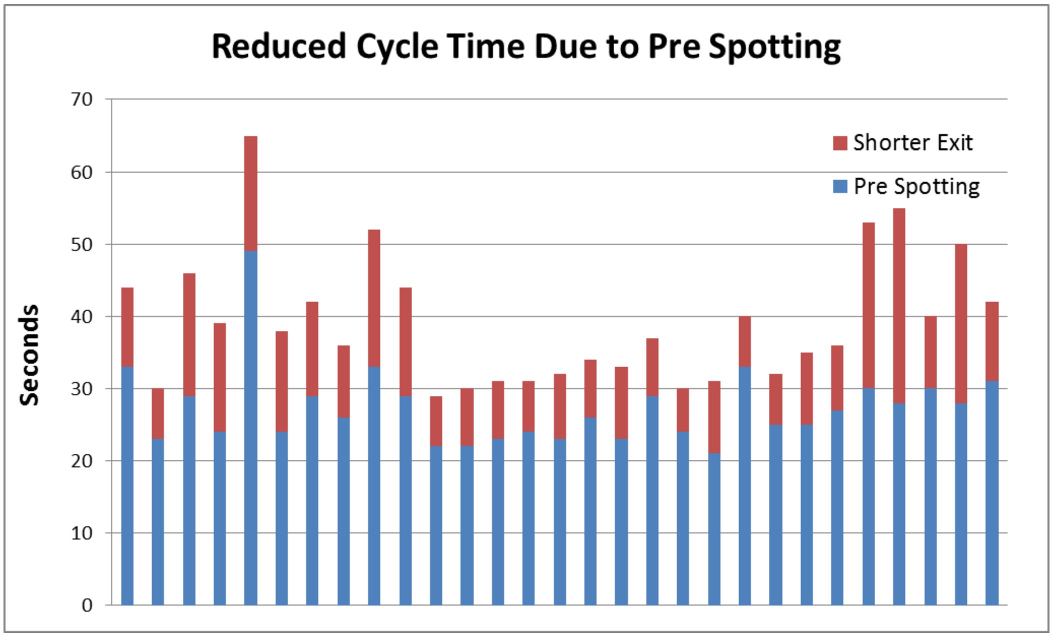
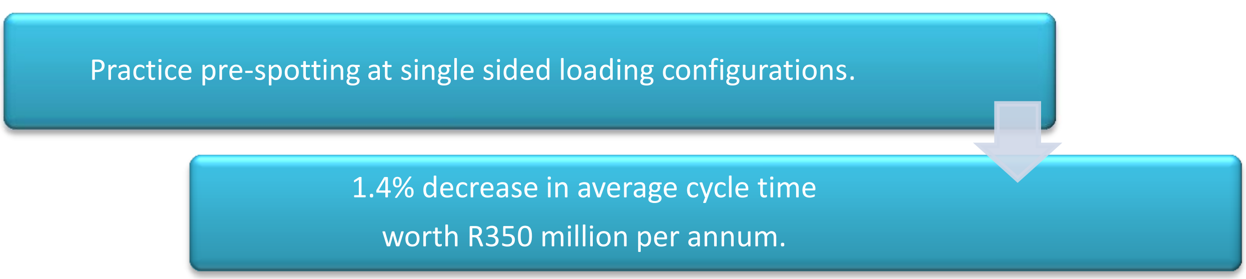



Figure 9: Time that can be saved by practicing pre-spotting

The average time calculated from the data above is 39 seconds. It was determined in Section A:4.2.2 that an additional 12 seconds is required for the shovel to get its next bucket into position so that the next truck can start its final spotting procedures. Twenty seven (39-12) seconds can thus be saved on average by practicing pre-spotting.

A 1.4% reduction in average cycle time, worth R350 million per annum, would be realised if this was adopted. Company policy, due to safety considerations, currently stop pre-spotting at single sided loading configurations from being implemented.




### 4.3.3 Recommendations

It is recommended that a proposal be made to adopt pre-spotting pending a thorough risk analysis.

## 4.4 Operator Benchmarking

**See Section B for the comprehensive report.**

### 4.4.1 Overview and Justification

Operators have a great influence on how efficiently HME is utilized. The presence of four contracted American expert operators at Sishen provided the ideal opportunity to benchmark Sishen's employee proficiency against industry leaders. A few processes were selected that could be easily and accurately measured and would provide a good gauge of the operators' general proficiency. These were:

- Final spotting times (trucks) – The time it takes to reverse into position next to a shovel.
- Exit times (trucks) – The time it takes to exit the loading area (50m) after being loaded.
- Loading time (shovels) – The time it takes to load a truck.

### 4.4.2 Key Findings and Relevance

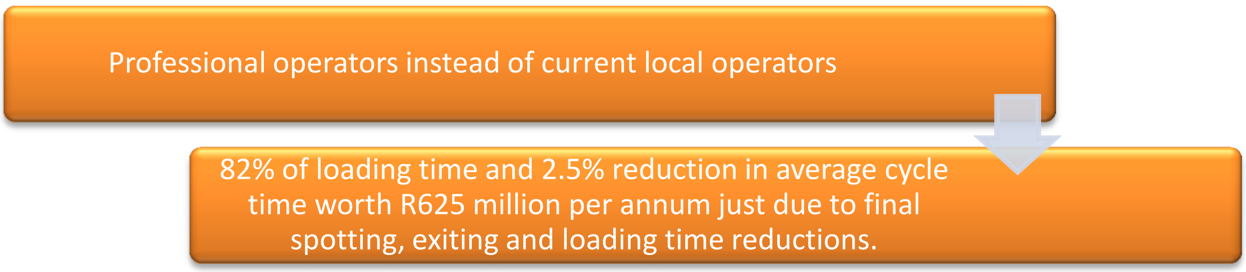
It was found that the expert operators outperformed the local operators in each of the measured processes. The amount of time by which the expert operators outperform local operators and the value of this to Sishen is shown in Table 4:

Table 4: Time by which the expert operators outperformed local operators and the value this holds for Sishen

| (Expert Operators) | *Time saved* | *Percentage of Locals' time* | *Reduction in Average Cycle Time* | *Annual Value* |
|---|---|---|---|---|
| **Final spotting time** | 10 seconds | - | 0.5% | R125 million |
| **Exit times** | 8 seconds | - | 0.4% | R100 million |
| **Loading time** | 31 seconds | 82% | 1.6% | R400 million |
| ***Total Measured*** | *49 seconds* | - | *2.5%* | *R625 million* |

The net effect can be underestimated as only a few segments of the complete cycle were measured (Section A:1.4.2),. In addition to this, first degree delays such as failing to see a waiting truck or spilling rocks on the manoeuvring area was not considered. It is estimated that these first degree delays push the 2.5% up to around 9% or R2 billion per annum. This figure is only a rough estimate based on a few measurements and extrapolations(Section B:2.2.1). If second degree delays, such as the maintenance consequences of bad driving techniques or delays caused by wrong digging angles, are considered the figure would most likely be even higher.

The physical measurements prove that local operators do not posses the same skill as the expert operators. Simply training drivers more rigorously will not solve the problem however; observed delays and inconsistent performances suggest that the local work ethic has to be improved as well.




### 4.4.3 Recommendations

It is suggested that management put structures in place in order to monitor and motivate each individual's performance. This is to be done in parallel with effective operator training and selection processes.

In the same manner as production managers are motivated by a production bonus, HME operators should be motivated. It has been found that local operators significantly curtails Sishen's efficiency and profits just due to their physical shortcomings. If remuneration and especially individual recognition schemes are attractive, better performance can be expected as illustrated by Rodriquez et al. (4).

Attractive remuneration and individual recognition schemes would motivate current operators to perform better and lead to more applications enabling the selection of talented future operators. This should be invested in as the total level of underperformance is estimated to be well above the 2.5% measured for the above selection of physical operations.

## 4.5 SAP Data

**See Section C for the comprehensive report.**

### 4.5.1 Overview and Justification

SAP data is used by the maintenance department to monitor the performance of HME. It is important that this data is reliable to ensure correct decisions are made that increase HME availability.

### 4.5.2 Key Findings and Relevance

It was found that the reliability of the SAP maintenance data is an issue impeding its use for strategic decision making. Figure 10 shows the proportion of the data that is useable after incorrect and incomplete data entries are filtered out. It also shows the proportion of data that can be used when incorrect and incomplete data is analysed and remedied:

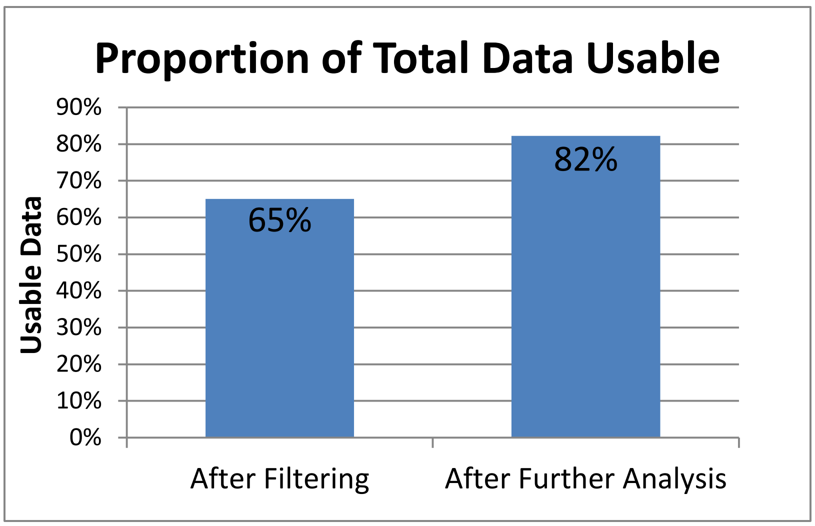
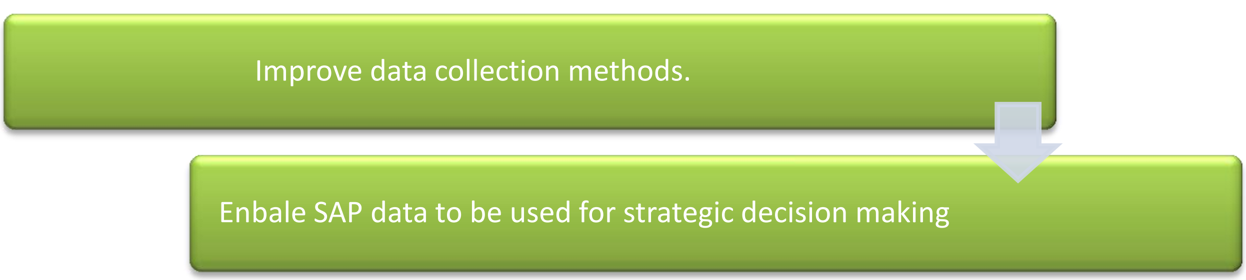



Figure 10: Number of entries and recorded times on SAP that are correct

Only 65% of entries were correct. The complex process of analysing and correcting the incorrect entries allowed 82% of entries to be used. Management is unlikely to have the time to go through the incorrect entries; they will thus only be able to make decisions based on 65% of the total number of entries.



### 4.5.3 Recommendations

It is suggested that the process by which data is recorded be improved. A specific person has to be responsible to check that all entries are complete after each shift. A little more effort can greatly increase the reliability of the maintenance data recorded on SAP. This will enable management to confidently use the data to make strategic decisions and hence improve HME availability.

The SAP data in its current state can thus not be used for accurate monitoring or strategic decision making.

## 4.6 Air Conditioning Units

**See Section D for the comprehensive report.**

### 4.6.1 Overview and Justification

During the summer months the temperatures for the area that Sishen is situated in regularly reach 40 degrees Celsius; conditions in the pit are even more extreme. Mining equipment can thus not be operated without air conditioning units (aircons). These air conditioning units make up a small part of the cost of HME, yet SAP data indicates that they are responsible for a considerable proportion of total downtime.

An initial investigation revealed that a new separate 24V air conditioning unit had just been installed on a 730. It was decided to ascertain how big losses due to air conditioning systems are, and whether the new air conditioning unit should be installed on more trucks, or different truck classes.

### 4.6.2 Key Findings and Relevance

It was found that problems with air conditioning make up approximately 2.5% of the total haul truck downtime. SAP data revealed that 730s and CATs are down for 12 and 14 hours per truck per annum respectively as shown in Figure 11:

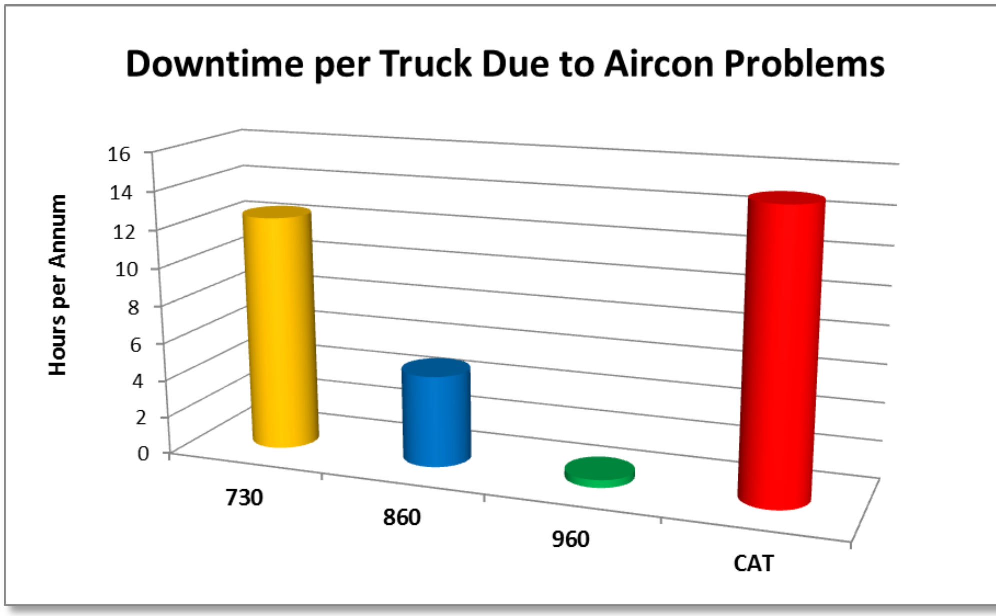
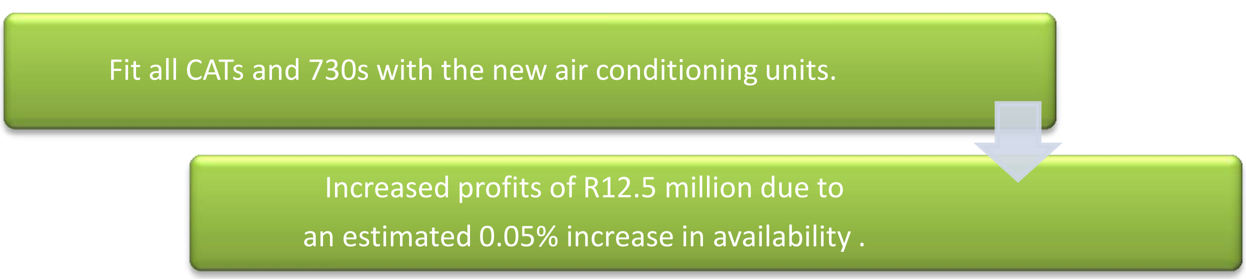



Figure 11: Annual downtimes due to air conditioning problems for different truck classes

The trial is nearing the end of its three month period with no breakdowns. A financial check (Section D:3.2) showed that the downtimes in Figure 11 needs to be reduced by only 3 hours for a new air conditioning unit to reach its breakeven point. As the trial is nearing the end of three months, it is expected that the new unit's annual downtime will be considerably less than 12 or 14 hours. Assuming the new unit causes three hours of downtime per annum and is replaced every year, an annual saving of R320,000 and R240,000 is expected for CATs and 730s respectively. This equates to approximately R12.5 million for all CATs and 730s. It is the equivalent of an 0.05% improvement in availability.




### 4.6.3 Recommendations

It is thus suggested that the new air conditioning units be fitted on all 730 and CAT trucks as soon as possible. Monitoring the new unit's performance over an extended period of time will reveal whether it is worth installing them on 860s as well.

## 4.7 Payloads

**See Section E for the comprehensive report.**

### 4.7.1 Overview and Justification

As discussed in Section 1.2 truck payloads has been identified as one of the three key factors crucial to efficient operations. An investigation was thus done on payloads to determine how Sishen is performing, and to identify opportunities for improvement.

### 4.7.2 Key Findings and Relevance

It was found that Sishen did a lot of work on payloads in the last year; this increased the average percentage of nominal payload to 96% for 2012 at the end of the available data range, end August, which is an improvement of 4% from 92% for 2011 and 2010. This is shown in Figure 12:

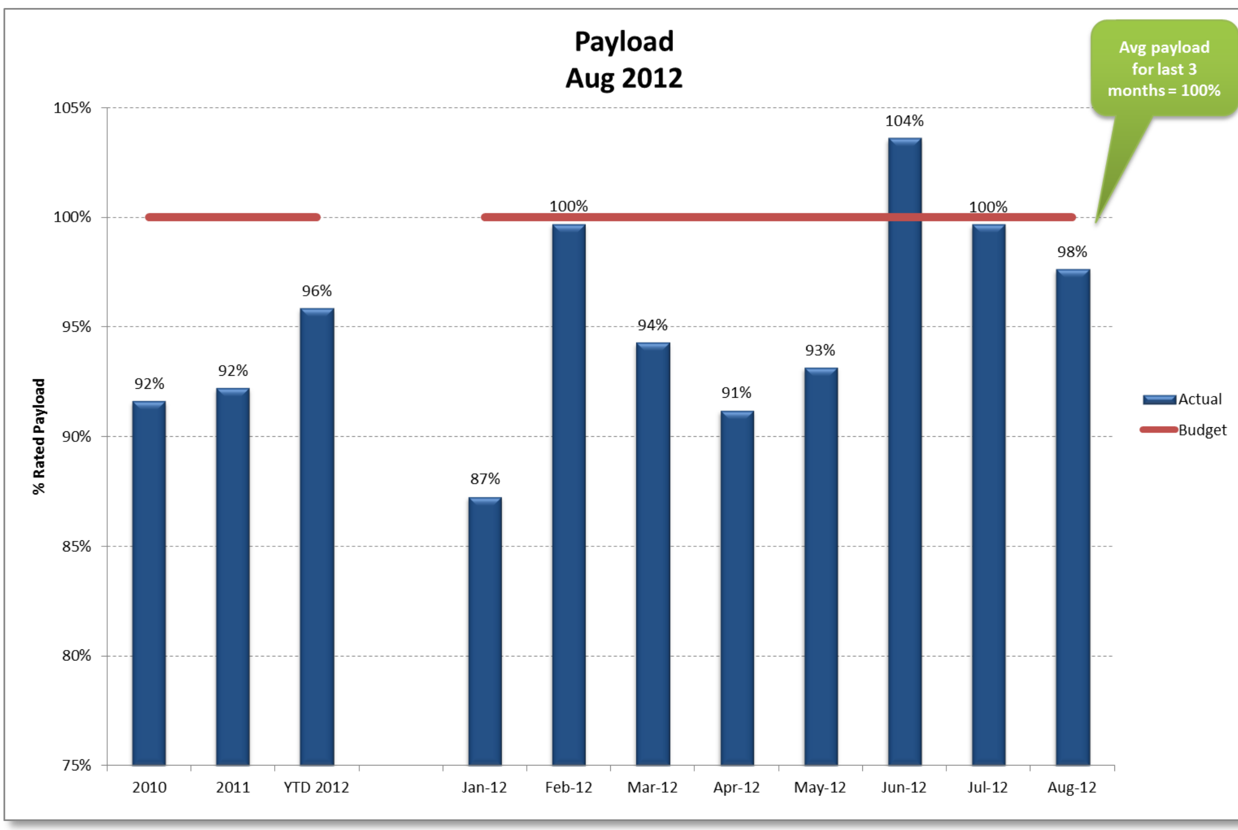



**Figure 12: Historic payload data for Sishen**

It should be noted that the average for the last three months is at 100%. This suggests that further improvements are not possible without consciously deciding to ignore the manufacturer's guidelines.

Develop sustainable methods to maintain payload levels at 100%.

Optimal OEE with regards to payloads.

### 4.7.3 Recommendations

Pursue sustainability: Sishen must put measures in place to ensure that the improved payload levels can be sustained over the long term. In order to achieve this sustainably shovel operators should be supported as much as possible. The PLMs are noted to be moderately unreliable and should be kept in good working condition as they assist shovel operators to load correctly. In addition to supporting shovel operators where possible incentives could also be implemented to motivate them to perform as well as they are physically able.

Pushing the envelope: Loading guidelines are based on the 10-10-20 load policy (5) & (6). If Sishen expects or plans to nominally overload trucks as done in June 2012 on Figure 12 an impact study should be done to determine the cost to machine life. The 10-10-20 rule states that a load may be up to 110% and up to 120% of the rated payload one time out of ten, but the nominal monthly load should not exceed the rated payload (Section E:2.1).

Where a shovel is under trucked partial passes should be considered. It has the potential to improve total tonnage by a considerable margin without greatly increasing cycle times for situations where shovels are under trucked. For partial passes to be successful shovel operators need to know how full a truck is. This further motivates having PLMs in good working condition.

## 4.8 Night Shift Maintenance

**See Section G for the comprehensive report.**

### 4.8.1 Overview and Justification

Sishen's maintenance department has started servicing the primary front end loaders and a part of the hauling fleet at night. This was done primarily to decrease the difference in availability for shovels during day and night shifts, to better align trucks and shovels availability. Whether or not more shovels should be serviced at night is currently being considered. It is thus important that the effect that servicing HME at night has on availability and use of availability be studied. This will allow management to asses whether or not to service more HME at night.

### 4.8.2 Key Findings and Relevance

By making use of dispatch data for the HME fleet it was found that the overall improvement of HME utilization or overall equipment efficiency (OEE) at Sishen was up 0.44% after implementing night shift services. This equates to approximately R150 million per annum. The improvements were mainly realised during the day shifts as shown in Figure 13:

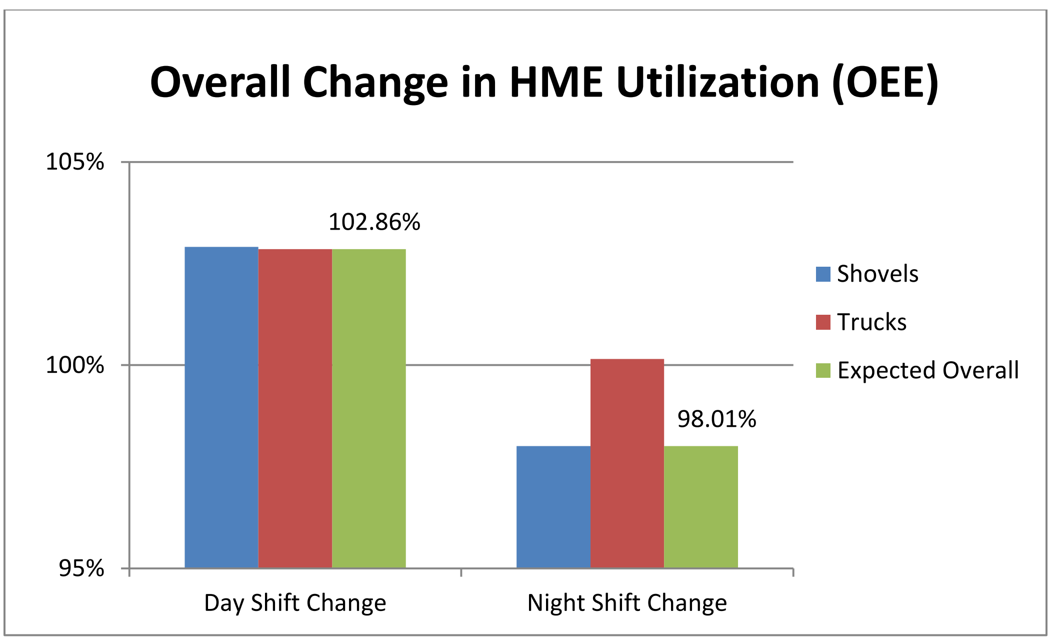



Figure 13: Expected change in overall HME utilization at Sishen as a result of the new maintenance plan



It was found that most of the improvements were due to a part of the haul truck fleet being serviced at night. Haul truck availability went up by 2.69% for night shifts and 4.91% for day shifts. An estimation of the situation, if front end loaders were not serviced at night, revealed that the 0.44% increase in overall HME utilization would have been higher at 0.79% (Section G:5). This is a 0.35% increase in OEE and equates to an additional R100 million per annum.

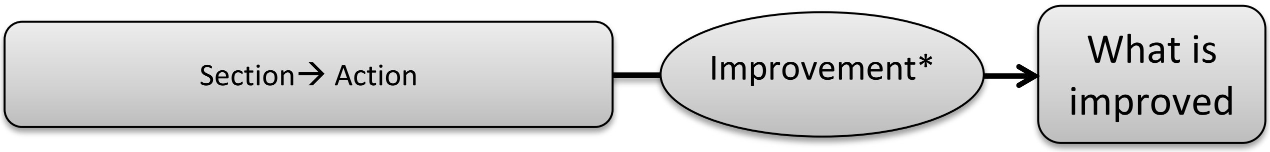
The improvement is due to the decrease in night shift HME utilization being negated whilst most of the improvements to the day shift utilization would be sustained.


### 4.8.3 Recommendations

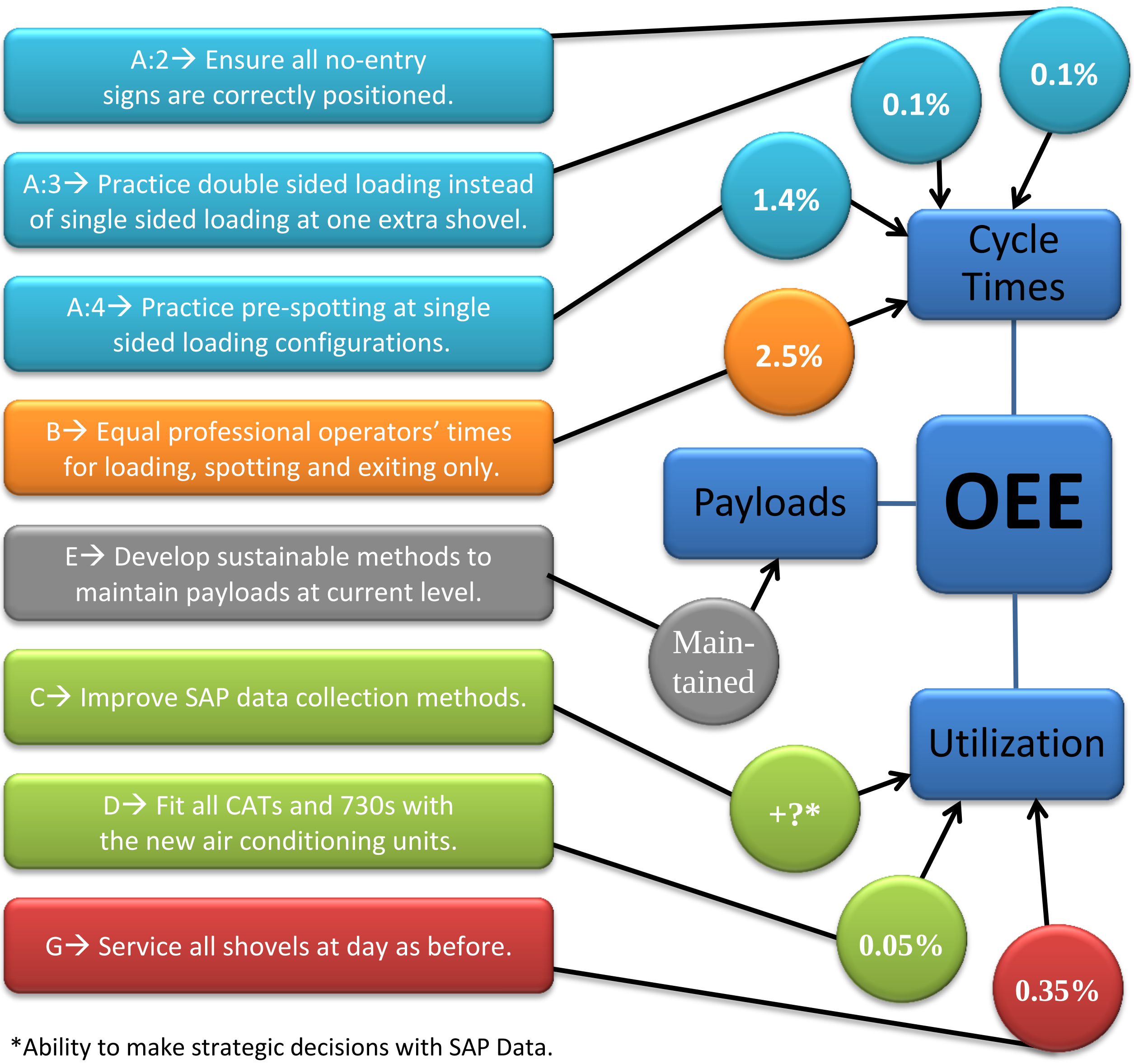
It is suggested that the decision to service front end loaders at night be reconsidered as well as any plans to service additional shovels at night. Servicing trucks at night seems to have had a positive effect on overall utilization and should be continued.

# 5 SUMMARY OF FINDINGS AND RECOMMENDATIONS

The investigations revealed that various small but significant improvements can be made to two of the three factors affecting overall utilization of HME capacity. Figure 14 illustrates how the findings fit together and what what effect they have on the three key factors determining HME efficiency or OEE:




*Recall that a 1% increase equates to approximately R250 million per annum as determined in Section F.




*Ability to make strategic decisions with SAP Data.

Figure 14: Summary of recommendations and expected effect on the utilization of overall HME capacity

The above findings led to a range of recommendations being made, the primary recommendations are shown in Table 5:

**Table 5: Summary of primary recommendations**

| Area | Recommendation |
|---|---|
| Holding Positions | Put control measures in place to stop negligence. |
| Double Sided Loading | Ensure it is implemented where possible. |
| Pre-Spotting | Conduct an in-depth risk analysis to determine whether it is feasible. |
| Benchmarking | Provide incentives to optimise local operator performance. |
| SAP Data | Improve data collection procedures. |
| Air Conditioning Units | Install new units on 730s and CATs as soon as possible. |
| Night Servicing HME | Stop servicing front end loaders at night, continue with the trucks. |
| Payloads | Ensure sustainability to keep payloads at current levels. |

# 6 ANALYSIS OF OPPORTUNITIES FOR IMPROVEMENT

## 6.1 Sustainable Changes and Operational Drift

The findings reveal opportunities for improvement that can be grouped into two categories:

- Procedural: A change in methods, procedures and policies.
- Operational: Continuous operational improvements adhering to existing methods and procedures.

The primary recommendations can be grouped as shown in Figure 15:

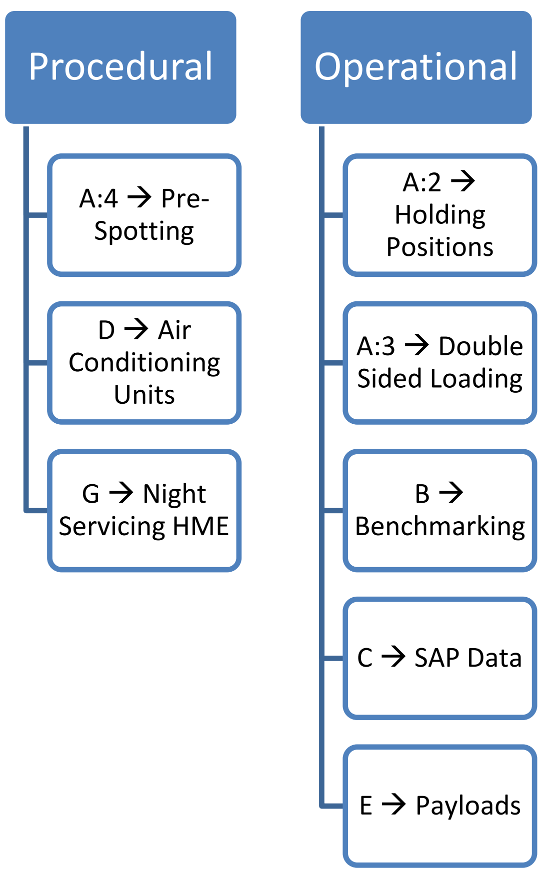



**Figure 15: Procedural and operational recommendations**

Procedural changes are likely to yield improvements that are more sustainable. If the pre-spotting procedure is implemented for example, operational drift is not likely to eventually corrode the benefits.

Operational changes however are those that one commonly focus on for a period of time and start doing well, but then when attention shifts away operational drift causes it to tend towards its prior state. An example of this could be holding positions; if emphasis is placed on correctly positioning stop signs it is likely to be done well for a month, yet starts to become neglected when the focus has shifted away again.

Operational drift is avoidable and can be controlled by resolutely monitoring the performance and motivating personnel to achieve the goals. Yet this process ties up resources even when done well.

## 6.2 The Kaizen Way: Sustainable and Continuous Improvement

Buzz words such as sustainability and continuous improvement or even "Kaizen" and "The Toyota Way" are well known, yet management and operational practices often neglect the philosophies behind them. There are two aspects of Kaizen or The Toyota Way that are especially beneficial to a complex multi faceted operation as found at Sishen:

- ✓ Continuous Improvement: One must always look to improve operations.
- ✓ Lasting Change: Improvements must have a lasting nature and be resistant to operational drift.

When the recommendations are considered in this light, it becomes clear that solutions must be sustainable. Consider three possible ways of dealing with holding positions as shown in Table 6:

**Table 6: Illustration of different approaches to dealing with opportunities for improvement**

| *Perspective* | *Sustainability* | *Cost* | *Description* |
|---|---|---|---|
| Short | Low | None | Management informs operations that stop-signs are not placed at the right positions and care must be taken to always position them at 50m. |
| Medium | Average | Medium | Management puts a "carrot-whip" system in place where stop signs are monitored and the responsible person rewarded/punished for performance. |
| Long | High | High | Management installs an electronic positioning system on haul trucks that notifies them when they are exactly 50m from a shovel. No-entry signs are only used to control light vehicles. |

Sustainable long term solutions often have a cost associated with them. Care must be taken not to avoid this cost at the cost of failing to secure a considerably more valuable improvement.

The recommendations concerning pre-spotting, air conditioning units and night shift servicing are sustainable by nature. It is with the other opportunities for improvement where care must be taken to formulate lasting improvements.

One method that can be used to bring about sustainable improvements is making use of incentives. Without making significant changes to a process many of the opportunities for improvement can be captured with a committed workforce. It is better to share a part of the extra profit with operators than to not capture it at all.

### 6.2.1 Getting Started with Kaizen

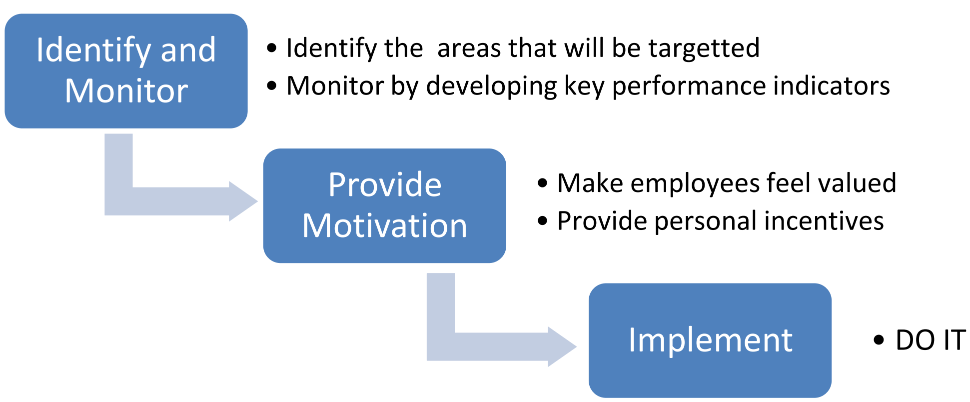
In order to initiate the Kaizen process management has to identify areas that will be focussed on and put resources towards it. In this case the areas that will be focussed on are:

- A:2 → Holding Positions
- A:3 → Double Sided Loading
- A:4 → Pre-Spotting
- B → Operator performance
- C → SAP Data
- E → Payloads

Developing Key Performance Indicators (KPIs) for these areas are necessary. This allows management and employees to start monitoring the performance of the sections relevant to them.

It must be noted that the attitudes of employees are crucial. Kaizen needs to become something all employees do because they want to, and because they know it is good for them and the company. It can not be something employees do because management dictates that it be done. In order to achieve this two elements will be helpful:

- ✓ Employees need to feel valued: Feedback must be given to suggestions as soon as possible with implementation taking place before enthusiasm is lost.
- ✓ Employees need incentives: Especially in the corporate mining environment loyalty alone will not drive employees to come up with good suggestions. Incentives that reward good suggestions will greatly increase the effort employees put into identifying opportunities for improvement.



## 6.3 Prioritisation of Recommendations

In order to correctly prioritise the recommendations the following factors must be considered:

- Magnitude of benefits
- Cost of implementation
- Time to implement
- Likelihood of success

By taking these factors into account, as they are discussed in the appendices, an outline of the suggested order of implementation can be devised. The researcher's recommendation is outlined below.

1) The recommendations that have a high likelihood of success and can be implemented at a low cost over a short period of time should be implemented first. They are:
    - ✓ A:2 → Holding Positions
    - ✓ C → SAP Data
    - ✓ D → Air Conditioning Units

2) The next set of recommendations to be implemented are those that require more resources or time to implement. They are:
    - A:3 → Double Sided Loading
    - G → Night Shift HME (Servicing shovels at day as before)

3) This leaves the two recommendations that require a lot of time and effort, yet promise large improvements. As implementing them will be a sequential time consuming process it is suggested that work on them be started as soon as the first three recommendations are implemented. They are:
    - ❖ A:4 → Pre-Spotting
    - ❖ B → Benchmarking (Improving operator performance)

# 7 CONCLUSIONS

The conclusions for each investigation can be found in the relevant appendices. Here follows some overall conclusions that tie the findings together.

## 7.1 Big Opportunities

Figure 16 does reveal two big opportunities for improvement that will be considerable in and of themselves. They are implementing pre-spotting and increasing operator performance, as found in Section A:4 and Section B.

### 7.1.1 Pre-Spotting

A 1.4% reduction in average cycle time, worth R350 million per annum, would be realised if pre-spotting was adopted. Company policy due to safety considerations currently stop pre-spotting at single sided loading configurations from being implemented**.** It is recommended that a proposal be made to adopt pre-spotting pending a thorough risk analysis.

### 7.1.2 Operator Performance

The data indicates that operators performance is the single area that provides the biggest opportunity for improvement at Sishen. This report suggests that management motivate HME operators and future operators by providing performance incentives.

Due to the importance and potential benefits of improving this area it must be emphasised that long term sustainable solutions must be sought. The primary suggestion is thus that an attractive remuneration and individual recognition scheme be put in place for HME operators. This would motivate current operators to perform better and lead to more job applications widening the selection pool hence enabling the selection of more talented and driven future operators.

Recall that the 2.5% or R600 million per annum is for loading, spotting and exiting only. As per Section B:2.4 primary delays are estimated to increase this figure to around 9% without secondary delays or cascading effects being taken into account. HME operators are in charge of multimillion rand production critical machinery; incompetence and a lack of motivation must not be suffered.

## 7.2 A Need for Continuous Sustainable Improvements

The various investigation have revealed several opportunities for improvement that can increase the overall utilization of HME capacity by a few percentage points. With the exception of operator benchmarking and pre-spotting, the values are individually relatively small as shown in Figure 16:

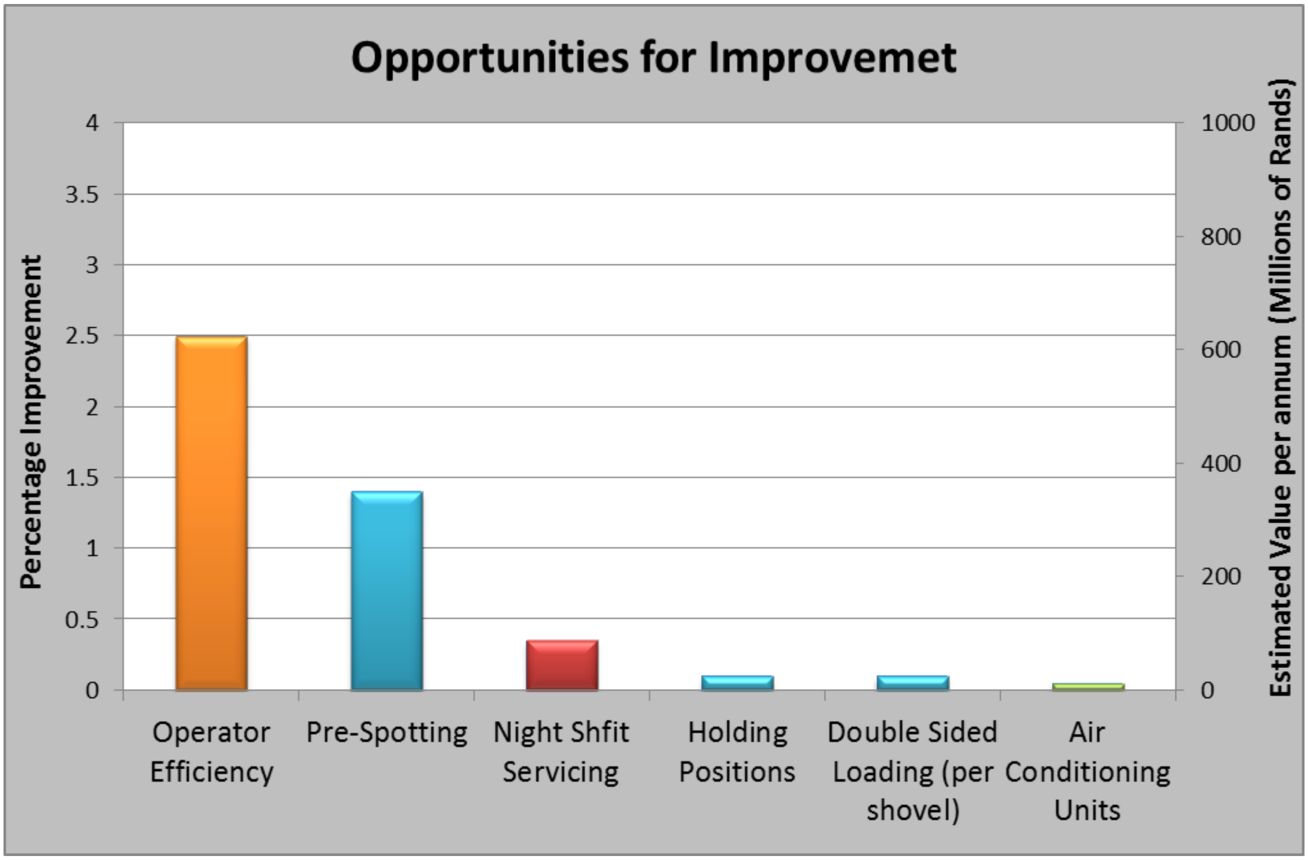



Figure 16: Opportunities for improvement

It must be noted that these smaller improvements can be relatively easily secured and make up a fair number when summed. Assuming two extra doubles sided loading positions are implemented the four smaller improvements as shown on Figure 16 above equate to approximately R200 million per annum.

As the opportunities for improvement are individually small a Kaizen type approach or mind set will be necessary where each opportunity is taken hold of and solved in a sustainable manner. Without this approach operational drift will corrode many of the improvements over time as they are on a number of different fronts.

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# 9 Reflective Summary

This project started with the aim of investigating HME efficiency at Sishen Mine. The initial scope included studies on:

- Calculations of the required fleet capacity
- Matching equipment with mining conditions and material
- Matching of loading and hauling equipment
- Alignment of maintenance strategy with production needs
- Operational system (Dispatch system) to manage maximum utilization
- Alignment between mine planning and dispatch (conflicting goals)
- Physical constraints impacting efficiencies
- Optimal utilization of HME

The project was intended for Sishen management personnel and would run from October 2012 until February 2013. The intended outcomes were the identification of issues impeding HME efficiencies and recommendations to mitigate them. It was expected that personnel and data on site would aid the investigation while time restrictions and operational considerations would hamper research and field studies.

As the investigations got underway it was decided to revise much of the original scope with the consent of the project sponsor. Changes were systematically introduced until the final scope was as follows:

- ✓ Holding Positions
- ✓ Double Sided Loading
- ✓ Pre-Spotting
- ✓ Benchmarking
- ✓ SAP Data
- ✓ Air Conditioning Units
- ✓ Night Servicing HME
- ✓ Payloads

The final investigations and field studies revealed opportunities for improvement quantified by a financial analysis. The main field studies were completed before the end of the Christmas break and the remaining investigations were finished by end January.

Revising the scope after initial investigation were done helped to make the study more relevant and yielded greater benefits to Sishen. This process was on-going with a new investigation being started mid

January due to great interest from management. Refining the scope was done by making observations and interviewing key management and operational personnel. Without their input the investigations would have been much less relevant. It was further found that by including management in the planning and investigation phase they were more willing to provide support during field studies and investigations. This was especially true for operational managers who approved memorandums motivating field studies that influenced HME operations.

The most significant challenges were with the collection and understanding of data. It was found that personnel often fail to understand the intricacies leaving the researcher to spend a lot of time puzzling it out. There was a specific case where an elaborate benchmarking investigation based on Dispatch data had to be thrown out due to the data not representing the information it was designed to.

A large part of the project centred around the interaction between trucks and shovels. This required a number of field studies where the researcher spent days in the pit observing operations. This developed a good understanding of the intricacies of extraction operations specifically, which enabled the researcher to better understand the overall integrated systems involving operations and maintenance. The time spent interviewing the expert American operations proved to be very valuable. These men have spent decades working with HME across the globe in all kinds environments and with various types of people. As most of the researcher's mining knowledge was obtained at Sishen, it was enlightening to learn more about mining in general and to study their opinions on what Sishen does well and what could be improved upon.

Some of the key lessons learned included the evolving scope phenomenon. When work is to be done in a certain area a detailed scope can often not be determined before initial investigations are done. It was further observed how management or operational personnel would go out of their way to make an investigation or field study work it they had a part in its formulation.

The main change that could be implemented for a future investigation of this type would be to leave the scope relatively open until initial investigations are underway. Even in a scenario where the scope is already well defined flexibility should be build into the methodology as initial investigations are likely to change one's understanding of the situation.

# APPENDIX A: Cycle Times

# Executive Summary

Three operational factors which directly affect cycle times was studied in this section, they are:

- Holding Positions: The point where a truck waits at a shovel to start its spotting procedures.
- Double Sided Loading: The loading configuration where a shovel loads trucks on both sides.
- Pre-Spotting: The part of the spotting procedure where a truck positions itself to reverse next to the shovel.

The effect that these factors were found to have at Sishen's operations are shown in Table A7:

**Table A7: Effect of measured factors on average cycle time**

| | *Description* | *Average Cycle Time Reduction* | *Annual Value* |
|---|---|---|---|
| **Holding Positions** | All "No-Entry" signs placed at the stipulated distance of 50m | 0.1% | R25 million |
| **Double Sided Loading** | Double Sided Loading used instead of Single Sided Loading | 1.7% | R425 million |
| **Pre-Spotting** | If Pre-Spotting was to be implemented at Single Sided Loading configurations | 1.4% | R350 million |

Some work has to be done to optimise the placing of no-entry signs at holding positions and further improvements can be made by implementing double sided loading more often. Yet double sided loading is unlikely to be implemented much more frequently than presently done and only saves time when a shovel has enough trucks. The gain of 0.1% (R25 million per annum) and a portion of the prospective 1.7% (R 425 million) should be pursued, yet the big opportunity lies in the 1.4% (R350 million) that could be saved by implementing pre-spotting. It is strongly recommended that a proposal be made to change this policy pending a thorough risk analysis.

## Holding Positions

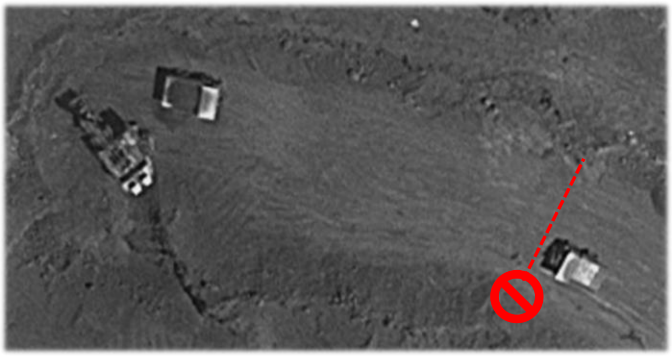


Figure A17: Holding Position at "no-entry" sign

The no-entry signs that determine where trucks wait as shown in Figure A17 were not thought to be ideally positioned. On a randomly selected day three loading areas observed were found to have no-entry signs out of position. The effect on overall operations was relatively low at a retardation of approximately 0.1% costing around R25 million per annum. This figure would be higher if drivers always obeyed no-entry signs; of the three misplaced signs only two were being obeyed.

It is suggested that control measures be tightened. As an alternative sustainable solution existing electronic positioning systems could be adapted to ensure trucks always hold at the correct distance. No-entry signs should still be used to control other traffic ensuring a safe loading area.

## Double Sided Loading

Double sided loading as illustrated in Figure A18 is thought to greatly decrease cycle times. It was found that this configuration is not often used at Sishen. This is due to a variety of factors ranging from mine planning to loading area set up. A study was done to determine the importance of double sided loading, it was found that a 1.7% reduction in average cycle times, worth R500 million per annum, could be obtained by exclusively practicing double sided loading instead of single sided loading with over trucked shovels.

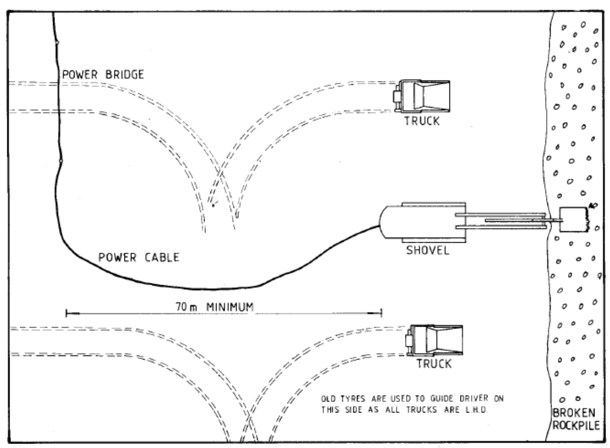



Figure A18: Illustration of a double sided loading configuration

Double sided loading should be implemented where possible. For shorter cycle times the time reduction would be much greater. Performing double sided loading with an optimal number of trucks at Bruce A would reduce the cycle time by approximately 5%. This benefit is negated if a shovel is over trucked.

**Pre-Spotting**

Pre-spotting is not practiced during single sided loading as shown in Figure A19 at Sishen. A 1.4% reduction in average cycle time, worth R350 million per annum, would be realised if this was adopted. Company policy due to safety considerations currently stop pre-spotting at single sided loading configurations from being implemented.

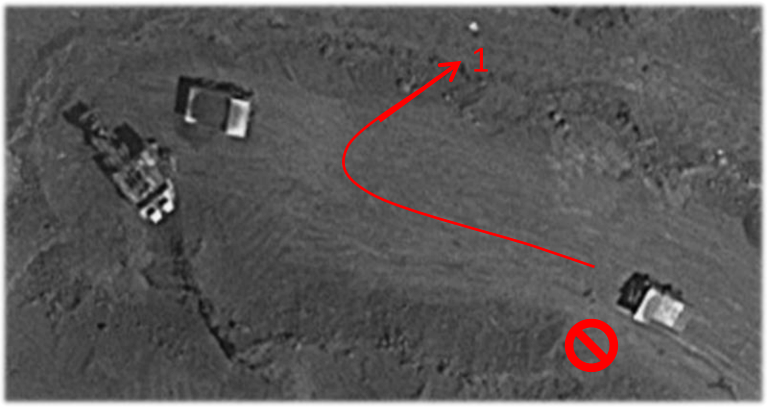


Figure A19: Pre-Spotting holding position

It is recommended that a proposal be made to change this policy pending a thorough risk analysis.

# Contents

## A:1 Introduction

When focussing on mining operations there are three factors that can be identified as being crucial to running an efficient operation:

- Availability and its use
- Payloads
- Cycle Times

These factors cover all the aspects that contribute to a successful operation, from equipment positioning, loading practices, dispatch efficiency, reliability or maintenance practices, and operator performance.

This section look at cycle times specifically. It will outline some definitions and local procedures, do a literature review, and go on to take a closer look at the following topics:

- ✓ Holding Positions
- ✓ Double Sided Loading
- ✓ Pre-Spotting

### A:1.1 Overview of Cycle Time

Various cyclic functions have cycles and can have certain cycle times that are of interest. This study is especially concerned with the cycle times associated with dump trucks. That refers to the time it takes a dump truck to cycle between loading and unloading points. The process is very similar across open pit operations. Depending on the focus of an analysis or observation a cycle might be broken up into different parts. At Sishen the Dispatch system receives event notifications(Appendix H:3.2.4) that are used to break a cycle up into different components as shown in Table A8:

Table A8: Event notifications and resulting truck statuses at Sishen

| Event | Truck Status |
|---|---|
| Assign Empty | Travelling Empty |
| Arrive | Queuing |
| Start Spotting | Spotting |
| Start Loading | Loading |
| Assign Full | Travelling Full |
| Arrive | Queuing |
| Start Spotting | Spotting |
| Dump | Dumping |

Such a cycle takes approximately half an hour on average according to the data shown below in Section A:1.3.

### A:1.2 Overview of Spotting Procedures

Each of the different truck statuses are influenced by various factors and may be broken up into sub section for further analyses. "Spotting" is examined closely in this study. Taking a closer look at spotting for single or double sided loading configurations reveals various components. These differ between:

- Single sided loading
- Double sided loading with a left handed approach
- Double sided loading with a 'blind' right handed approach

Before each spotting procedure is examined Figure A20 and Figure A21 will be looked at to illustrate the basic procedures involved with the different spotting approaches.

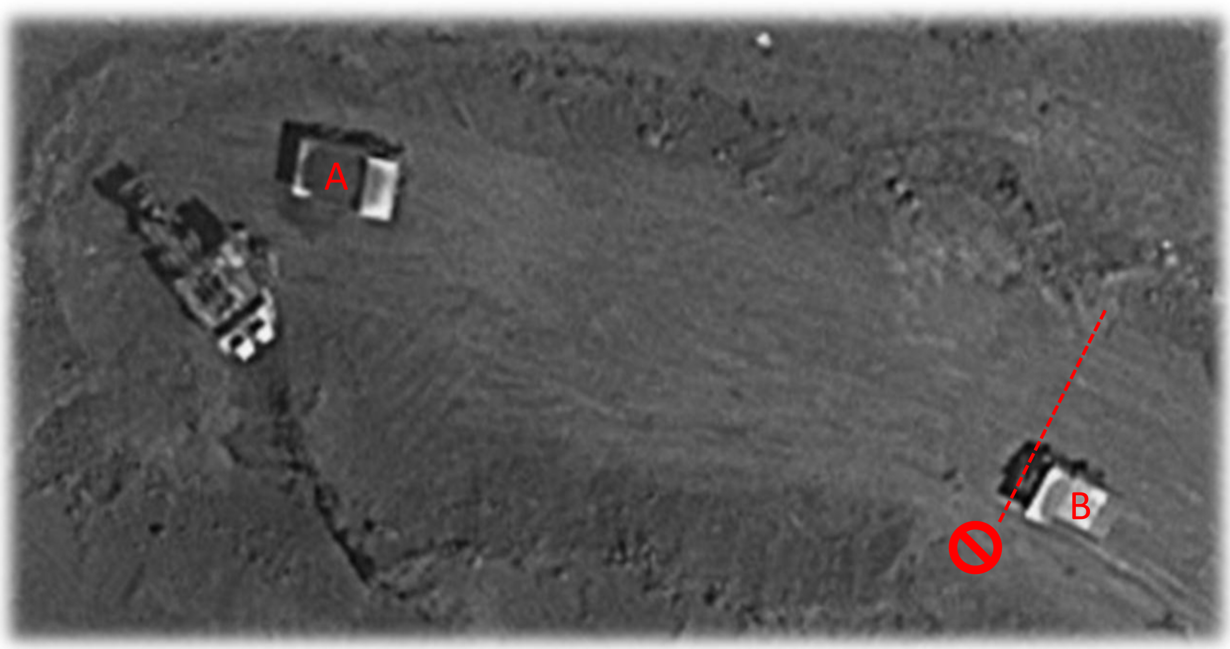



Figure A20: A basic single sided loading configuration

Figure A20 shows a basic single sided loading configuration. Truck B waits at the holding point which is set at 50m until truck A passes it before commencing with its spotting procedures. This configuration is only used when double sided loading is not possible, double sided loading is shown on Figure A21 below:

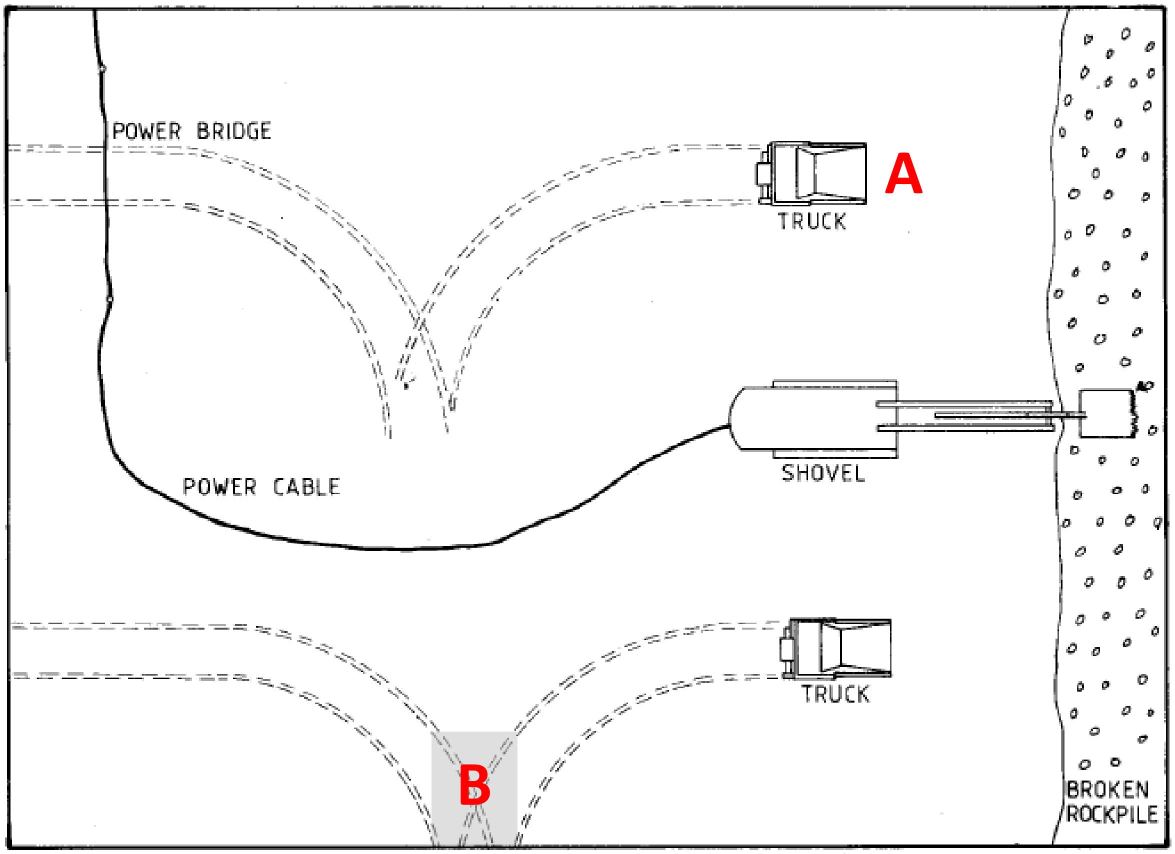



Figure A21: A basic double sided loading configuration

On the left side truck A moves into position whilst the shovel loads on the other side. Truck B however approaches from the blind side, and has to wait at point B until the shovel has finished loading on the other side and swings its arm into position before it can commence with its final spotting procedure. Figure A22 shows a shovel arm swung into position initiating and guiding the final spotting procedure from the blind side.

Figure A22: P&H 2300XPB swinging out its arm

“Final Spotting” or “Reversing In” is the part of the spotting procedure when the truck has turned around, and reverses into position ready for loading to commence. It is described in the official work instructions for Shovels, SHEQ-MINE-WI-068 revision 3, as follows:

> *15.5 Reversing in procedure.*
>
> *On the right hand side of the shovel the operator holds out a full bucket as marker at the correct distance for the haul truck to reverse. Remember, the bucket is only be held out for the period from the moment when the haul truck stands ready to reverse until it stands ready to be loaded under the bucket. The haul truck operator uses the bucket teeth as marker to reverse in line with it and square with the spit rods.*
>
> *On the left hand side of the shovel the haul truck operator reverses the haul truck on his own initiative, provided the shovel is busy loading a haul truck on the right hand side. The haul truck operator will determine a safe distance to reverse while the bucket of the shovel is above the bowl of the haul truck, or a full bucket of material could be held out on the left hand side of the shovel. The haul truck operator reverses the haul truck square to the spit rods while he positions the side of the haul truck bowl under the dumping arm.*

The procedure is different on the different sides of the shovel as all trucks are left hand operated. Visibility is thus better when approaching from the left side, but more obscure on the ‘blind’ right side.

More instructions can be found in the work instructions for Haul Trucks, SHEQ-MINE-WI-067 revision 8. It describes rules around a shovel as follows:

> *6.9 Rules at Shovels*
>
> *a) The drivers of haul trucks are responsible for turning and reversing safely at shovels. Turning before reversing into the loading position, haul truck drivers should make sure that the lane they are reversing into is safe and without stones that could damage the tyres.*
> *b) When loading could be done at both sides and the shovel operator does not give a clear indication on which side the next haul truck should be loaded and there is place on the left hand*

*side of the shovel, a haul truck arriving at the shovel should always reverse in at the left side of the shovel, except when there is an obstruction in the lane to reverse into, eg. equipment or stones.*

*c) When a haul truck is already standing to the left of the shovel, the next haul truck should go to the right of the shovel where he will be showed in by the shovel operator.*

*d) Drivers of haul trucks and other equipment should first complete their turn before they stop so when the vehicle starts to move again it can go either straight backwards or forward. This rule applies especially at shovels, but is just as valid at any other place in the pit.*

*e) Before the driver of a haul truck may turn to the right from a position where it was stationary, the driver should first make sure that it is safe to do so by walking onto the deck of the haul truck and ascertain if he would be able to do it safely.*

*f) Haul trucks should be loaded in the order that they arrive at the shovel and may not squeeze in before one another.*

*g) When more haul trucks are waiting at a shovel than those standing in the loading position, the other haul trucks should stop at a safe distance*

Keeping the above work instruction in mind, the spotting procedures for the various spotting approaches described at the start of this section are laid out in the following tables:

**Single Sided Loading**

The process for spotting at single sided loading configurations is shown in Table A9:

**Table A9: Spotting process during single sided loading after queuing**

| Current Position | Trigger | New Action | Description |
|---|---|---|---|
| Waiting at 50m (holding point) | Loaded truck passes | Pre-spotting | Moves towards shovel and turns around ready to start backing in |
| Ready to back in (same as position B, Figure A20) | Shovel arm in position (Figure A22) | Final Spotting | As soon as the shovel arm is swung out the truck reverses and positions itself under the bucket ready to be loaded |

This spotting approach is the most common one on the mine. Craig Barry, Production Manager at Loading and Hauling, estimates that loading on both sides of the shovel only occurs approximately 20% of the time (Section H:1.1.3, Q&A 2).

**Double Side Loading – Left Approach**

The process for spotting at double sided loading configurations on the left side of the shovel is shown in Table A10:

Table A10: Spotting process during double sided loading on the left side after queuing

| Current Position | Trigger | New Action | Description |
|---|---|---|---|
| Waiting at 50m (holding point) | Loaded truck passes | Spotting (Figure A21 truck A) | As soon as the loaded truck passes the truck moves towards the shovel, turns around and backs into position ready to be loaded |

This is the ideal spotting approach, the truck manoeuvres into position while the shovel is busy loading on the other side. No time is thus lost waiting for the truck.

**Double Side Loading – Right Approach**

The process for spotting at double sided loading configurations on the 'blind' right side of the shovel is shown in Table A11:

Table A11: Spotting process during double sided loading on the left side after queuing

| Current Position | Trigger | New Action | Description |
|---|---|---|---|
| Waiting at 50m (holding point) | Loaded truck passes | Pre-spotting | Moves towards shovel and turns around ready to start backing in |
| Ready to back in (same as position B, Figure A22) | Shovel arm in position (Figure A22) | Final Spotting | As soon as the shovel arm is swung out the truck reverses and positions itself under the bucket ready to be loaded |

Like with single sided loading the shovel has to wait for the truck to perform its final spotting procedures.

### A:1.3 Sishen Cycle Time Approximation

The average cycle time at Sishen is approximately 30 minutes (7). Data was extracted from dispatch on the 2nd of December 2012 to calculate the cycle times for that specific day. The cycle time and number of loads for each shovel is shown below, a weighted average is the calculated as shown in Table A12:

Table A12: Cycle Times for various shovels as extracted from the Dispatch system at Sishen on 2 December 2012

| Shovel | Cycle (min) | Loads | Cycle.Loads |
|---|---|---|---|
| S578-0100 | 48.2 | 4 | 193 |
| S592 | 63.0 | 6 | 378 |
| S582-0200 | 42.3 | 9 | 381 |
| S054-0300 | 47.8 | 16 | 765 |
| S562 | 30.4 | 23 | 698 |
| S560 | 26.6 | 35 | 932 |
| S570 | 36.1 | 41 | 1,480 |
| S582 | 42.8 | 44 | 1,883 |
| S566 | 31.3 | 53 | 1,658 |
| S564 | 27.0 | 54 | 1,460 |
| S563 | 43.2 | 57 | 2,460 |
| S582-0100 | 20.8 | 59 | 1,230 |
| S054-0200 | 48.0 | 66 | 3,167 |
| S561 | 34.6 | 70 | 2,419 |
| S584-0100 | 40.7 | 76 | 3,097 |
| S571 | 13.0 | 76 | 991 |
| S567 | 35.5 | 77 | 2,736 |
| S054-0400 | 42.4 | 97 | 4,114 |
| S565 | 15.9 | 109 | 1,733 |
| Total | | 972 | 31,774 |

| | |
|---|---|
| **Weighted Average =** | 32.7 minutes |

32.7 minutes equates to a cycle time of approximately 2,000 seconds. This figure can be used for basic calculations.

The average number of loads is approximately 50 per shovel on a shift.

## A:1.4 Literature Review

Whilst many variables differ from mine to mine most approaches and processes remain similar.

### *A:1.4.1 Factors Crucial to Efficient Operations*

One approach or philosophy that one would expect to remain constant is the three factors crucial to efficient operations mentioned at the start of this section: Payloads, Cycle Times, and Availability and its use. This is not always the case, as an illustration Krause (2) holds that the three main production factors are truck payloads, cycle times and operator efficiency. He illustrates their relation to "some of the other variables" with the "value rainbow" as shown in Figure A23:

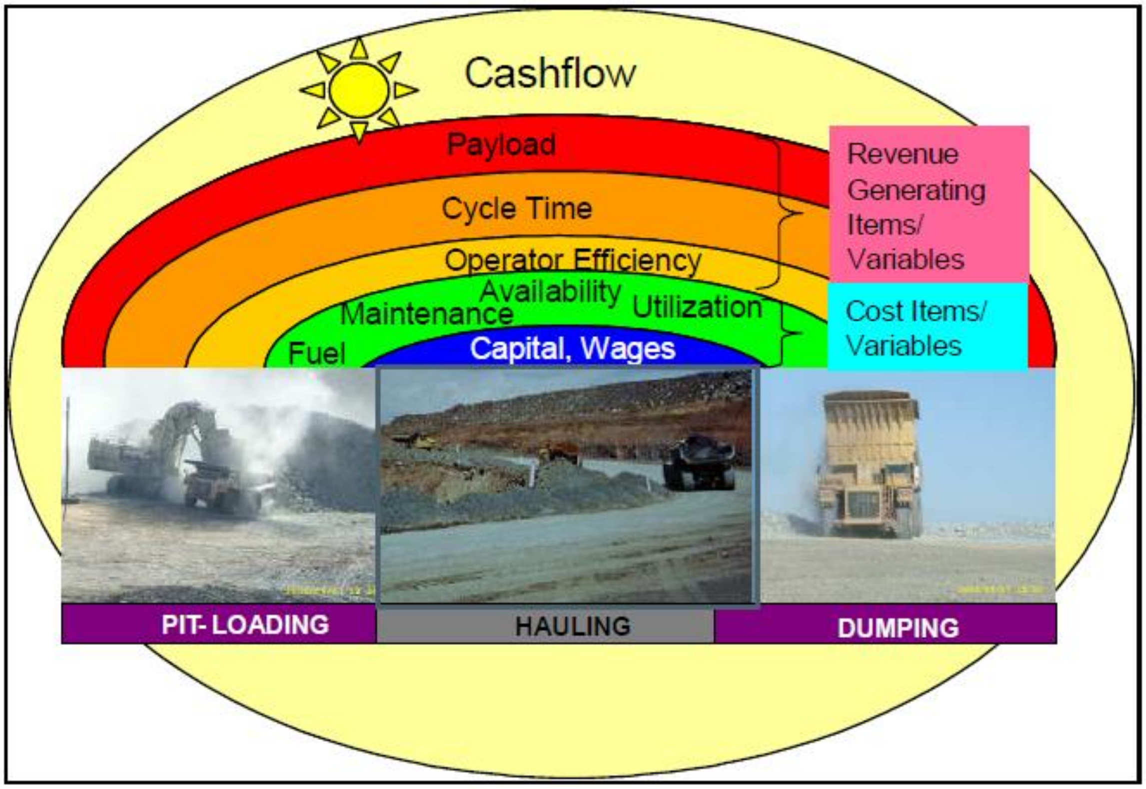



Figure A23: "The Value Rainbow" by Krause (2)

Krause uses the Value Rainbow to argue that, "*Mining operations generally focus only on the loading area but, the Value Rainbow shows that hauling and dumping are equally important in realizing cycle efficiency and most importantly cashflow*". It is certainly true that hauling and dumping are important components of "*cycle efficiency"* or cycle times, the way the value Rainbow highlights the dependency on cash flow is also helpful. Operator efficiency is an important aspect affecting operational efficiency, it is good that the Value Rainbow emphasises this, yet describing operator efficiency as one of the three main production factors may be less helpful. Operator efficiency affects Payloads and Cycle times in the same way that mine planning, equipment compatibility or blasting quality does. It is not one of the main KPIs but an important factor affecting various KPIs.

Availability or Utilization which the Value Rainbow does not list as one of the three "*Main Production Factors"* is similar to the two other main production factors in the sense that it also directly affects operational efficiency. "Availability and its Use" is furthermore also affected by various factors including technical expertise which is the equivalent of operator efficiency in the pit.

Contrary to some approaches it makes sense to have "Availability and its Use" as a main production factor instead of operator efficiency. Though various models may be used depending on who is looking at the system for what reason.

### A:1.4.2 *Cycle Time Breakdown*

Once again a hauling cycle can be broken up into many components depending on the need of the analyst. Krause (2) breaks a hauling cycle up into the same same segments as is done at Sishen (Section H:1.1.1). Both are shown in Table A13 below:

**Table A13: Krause's Cycle Time Breakdown compared with Researcher's Sishen Breakdown**

| Krause's Breakdown | Researcher's Sishen Breakdown |
|---|---|
| Travel empty time (can include bunching or waiting for slow haulers on ramps) | Travelling Empty |
| Waiting at shovel (or loader) | Queuing |
| Truck spotting at shovel or loader (loading unit) | Spotting |
| Loading time | Loading |
| Travel full time (can include bunching or waiting for slow haulers on ramps) | Travelling Full |
| Waiting at destination | Queuing |
| Spotting at destination (plant tipping bin, stockpile or dump site) | Spotting |
| Dumping time | Dumping |

These breakdowns of cycle times are identical. This is due to the fact that both studies were concerned with HME optimization. When examples of cycle time breakdowns are sought of similar operation with a focus on different analyses different breakdowns are obtained. This is illustrated below in Figure A24 with Li's "Event Sequence for Truck Haulage Model" (8). A closer observation will reveal that all the component shown in Table A13 are present, in addition to this there are more points included by Li for his analysis.

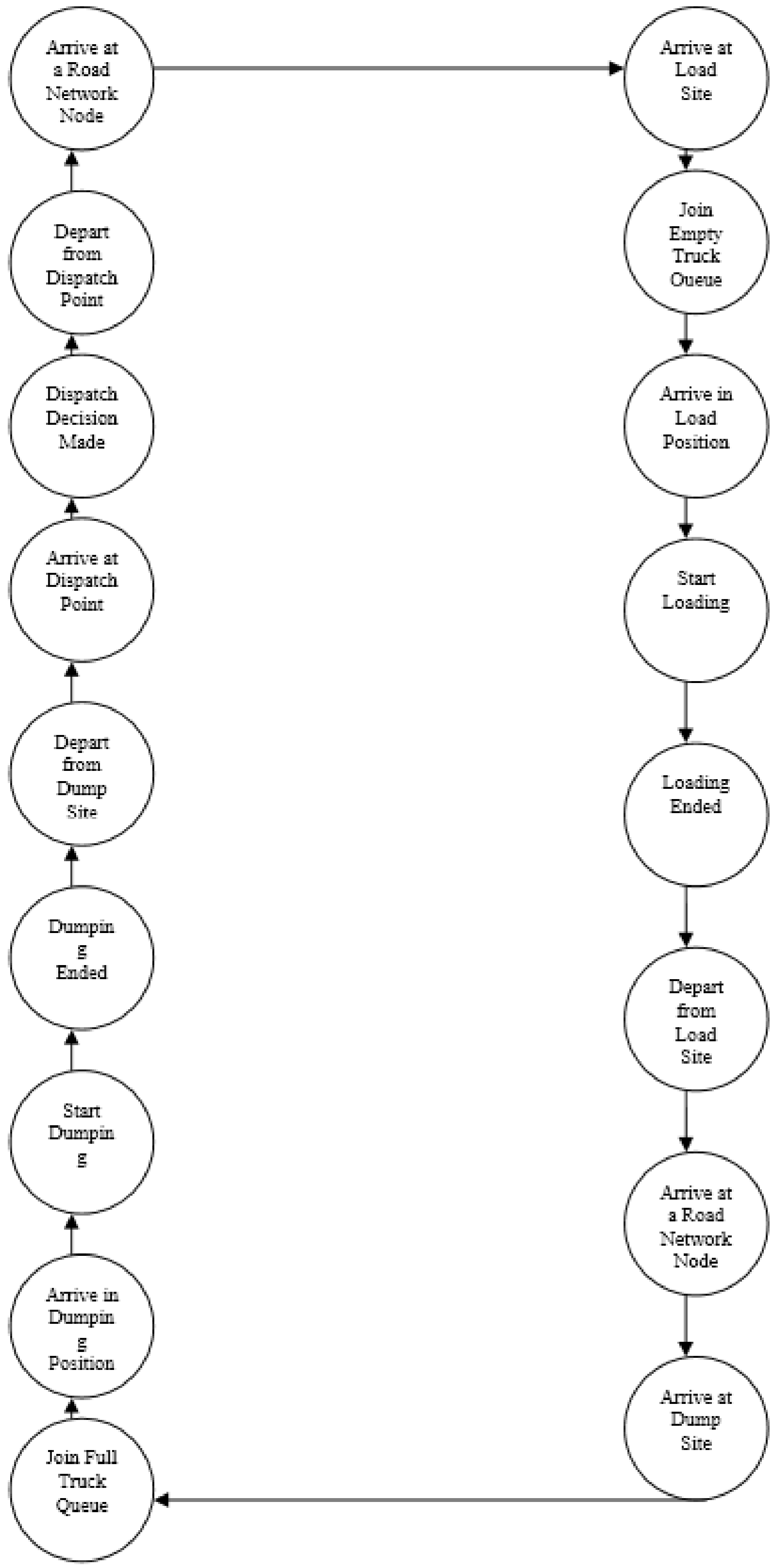



**Figure A24: Li's Cycle Time Breakdown**

### A:1.4.3 Spotting Procedures

As an example of standard operating procedures the North American Construction Group's "Standard Operating Procedure" for "Backing Haulers to Loading Equipment, Dozers, etc." can be looked at. In section 4.6 it states that (9):

> Ensure visual and/or verbal contact with loading equipment/dozer operator and receive proper signal **EACH TIME** before you back to loading equipment/dozer. Never back to blind side of shovel/excavator unless the bucket is stopped and staged in the loading position as a spot marker. Self spotting is permitted on the good side of shovels providing ground and visibility conditions are safe. Line up with the shovel's cones and ensure the counterweight is perpendicular to the track frame prior to reversing.

These guidelines are integrated into Sishen's operating instructions as described above in Section A:1.2. No significant deviations in operating procedures were discovered, work can however be done to determine how closely these procedures are adhered to.

### A:1.4.4 Cycle Times

Benchmarking or comparing gross cycle times will not reveal any useful information. This is due to the wide range of often uncontrollable differences in operating condition.

## A:2 Holding Positions

### A:2.1 Overview

When a truck arrives at a shovel it waits at a holding position marked by a no-entry sign before commencing with its spotting procedures. Cycle times are increased due to the "no-entry signs" not being moved as the shovel moves, or simply not placed at their ideal locations. This increases the spotting time which is one of the primary components contributing to cycle times. The no-entry signs are meant to be 50m from the shovel. Any extra distance causes unnecessary delays as the next truck has a longer distance to cover whilst spotting and has to wait for the loaded truck to get past it before commencing with its spotting manoeuvres. This does not apply where shovels is able to load on both sides. Craig Barry, Production Manager at Loading and Hauling, estimates double sided loading only occurs around 20% of the time due to a range of limitations at Sishen (Section H:1.1.3, Q&A 2).

### A:2.2 Methodology

A field study was conducted. All the no-entry sign positions at shovels were systematically recorded. The impact on cycle time of any poorly placed no-entry signs were studied. This study was aimed at revealing the amount of time unnecessarily added to the cycle time. Figure A25 illustrates the extra distance a truck has to travel if the holding point is not set at the correct position:

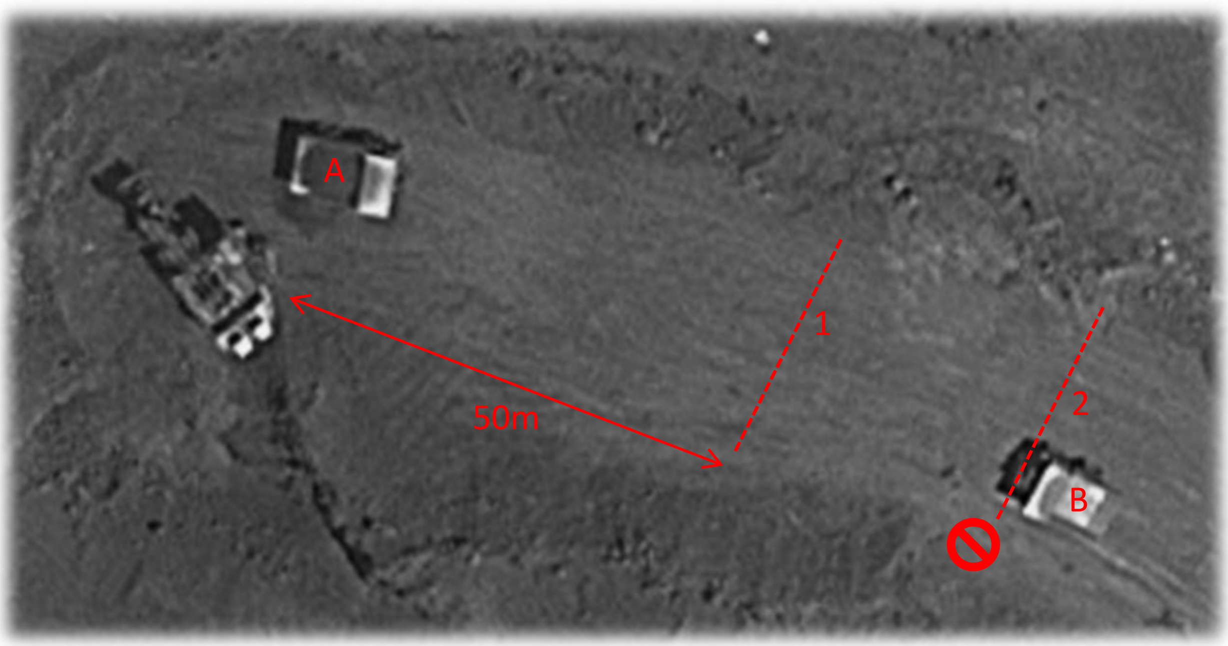



**Figure A25: Satellite Imagery of Operations at Sishen, date undisclosed (10)**

Extra time = Time for truck A to get from position 1 to position 2 whilst exiting the loading area +

Time for truck B to get from position 2 to position 1 whilst entering the loading area

Note: Considering that a haul truck has to turn around, and back up next to the shovel in the 50m space the speeds were expected to be low and varying, the situation was further complicated by the often poor surface of the manoeuvring space. It was thus assumed that the time taken to get to position 1 from position 2 is a fair estimate of the extra time.

#### *A:2.2.1 Procedures*

The following procedures were followed to ascertain the positioning of the no-entry signs and measure the impact of badly placed signs, it was repeated at each shovel location:

1) **Initial Observations**: A bakkie was used to travel to each shovel, once the vehicle was parked in a safe location an estimate of the distance from the shovel to the no-entry sign was made. If the no-entry sign was positioned roughly 50m to the shovel the shovel number was recorded and no further work was done.
2) **Setting the Marker**: For cases where the no-entry sign was visibly more that 50m from the shovel delays were recorded. To record the extra time as explained in the previous section it was necessary to locate the 50m mark. This was done by physically measuring 50m from the back of the shovel. The rest of the distance to the no-entry sign was recorded. As per safety procedures the shovel could only be approached whilst the bucked was down, where necessary this required a radio call to the operator when no trucks were waiting.
3) **Time Measurements - In**: Once the marker was placed a vantage point was sought that allowed the researcher to see when a truck passes the marker and the no-entry sign. A stopwatch was started when the truck of interest started moving from the no-entry point and stopped when it passed the 50m mark. This time was recorded.
4) **Variables**: Whether the truck started from a standing or rolling start was also recorded, special cases where the truck started early or stopped past the no-entry point was also recorded.
5) **Time Measurements – Out**: Once the truck had been loaded, started moving and passed the 50m mark the stopwatch was started again and stopped once the truck passed the no-entry sign. This time was also recorded.
6) Steps 3-5 was repeated as necessary and possible to obtain sufficient data.

### *A:2.2.2 Data Analysis*

On the 26th and 29th of November 2012 the researcher manually visited most of the shovels in the pit. The recorded distances of no-entry signs were are shown in Table A14:

**Table A14: Distance of no-entry signs from shovels**

| Shovel Code | Description | Distance | Comments |
|---|---|---|---|
| S560 | P&H 2300XPB (Rope) | 80m | |
| S561 | P&H 2300XPB (Rope) | - | Not Set Up |
| S562 | P&H 2300XPB (Rope) | ≈50* | ≈50 |
| S563 | P&H 2300XPB (Rope) | ≈50* | |
| S564 | P&H 2300XPB (Rope) | 110m | |
| S565 | P&H 2300XPB (Rope) | - | Not Set Up |
| S566 | P&H 2300XPB (Rope) | - | Not Set Up |
| S567 | P&H 2300XPB (Rope) | ≈50* | |
| S570 | Kom WA 1200 (Front) | ≈50* | |
| S571 | Kom WA 1200 (Front) | 60m | |
| S580 | Kom WA 1200 (Front) | ≈50* | |
| S581 | Kom WA 1200 (Front) | - | Not enough space for sign; next to road |
| S054 | LIEBHER 996 | - | Down |
| S054 | LIEBHER 996 | ≈50* | |
| S054 | LIEBHER 996 | ≈150* | Queue ignoring sign |
| S584 | LE TRON 2350 (Front) | ≈50* | |

* The approximately symbol (≈) indicates that the distance was estimated only. Due to the pressure on production it was deemed inappropriate and unnecessary to take measurements that would be close to 50m or could not be timed for other reasons.

Only three shovels had no-entry signs that were significantly out of position, they are:

- A P&H 2300XPB rope shovel, S560, with holding position at 80m.
- A P&H 2300XPB rope shovel, S564, with holding position at 110m.
- A LIEBHER 996 with holding position at approximately 150m.

The impact on cycle time at the LIEBHER was insignificant as the trucks ignored the sign and queued at approximately 50m.

At the P&H 2300XPB's a few spotting times were recorded on the 26th. Both shovels went of-line after a while though. The next opportunity was only on the 29th, by this time the sign at S564 had been moved to 50m and S560 had dug around the side and was approximately 50m from the no-entry sign.

**Shovel S564**

The few data point that were collected for shovel S564 with its no-entry sign at 110m are shown in Table A15:

Table A15: Extra time due to misplaced no-entry sign

| Start | Truck Class | Distance | Extra on Entry* | Extra on Exit* | Total Extra | Comments |
|---|---|---|---|---|---|---|
| Standing | 860E | 110m | 18 seconds | 21 seconds | 39 seconds | |
| Standing | 860E | ≈50m | None** | 11 seconds | - | Truck 559 |
| Standing | 860E | 110m | 19 seconds | 17 seconds | 36 seconds | |

*See methodology for explanation.

**This truck drove past the no-entry sign and waited at approximately 50m from the shovel.

When trucks obey the no-entry sign at just over 100m approximately 30 seconds can be added to a their cycle time.

Truck 559 saved 15-20 seconds by passing the on-entry sign at 110m and waiting at 50m, another 10 seconds are saved by exiting faster. Whilst the no-entry sign might have been out of position in this case, it is dangerous to have drivers become used to disobeying rules.

It must be noted that the number of data points are weak, results are thus only indicative and must be further investigated if accuracy is required. More data points could not be acquired as the no-entry sign was shifted.



**Shovel S560**

More data point were collected for shovel S560 with its no-entry sign at 80m, they are shown in Table A16:

Table A16: Extra time due to misplaced no-entry sign

| Start | Truck Class | Distance | Extra on Entry* | Extra on Exit* | Total Extra | Comments |
|---|---|---|---|---|---|---|
| Standing | 730 | 65* | 8 | 10 | 18 | |
| Standing | 730 | 65* | 7 | 10 | 17 | |
| Standing | 730 | 60* | 5 | 8 | 13 | |
| Standing | 730 | 70* | 8 | - | - | |

*The trucks did not obey the no-entry sign, they went past it and waited closer.

At this shovel the waiting trucks stopped past the no-entry sign and often started moving before the exiting truck passed completely.

Still, under these conditions approximately 15 seconds are added by trucks spotting from around 65m instead of 50m.

An additional observation that was made is that the shovel was not stationary, in this case it moved around by as much as 20m. This is not considered normal operating behaviour.

Again it must be noted that the number of data points are weak, results are thus only indicative and must be further investigated if accuracy is required. More data points could not be acquired as the shovel went of line, and was set up differently when the pit was again visited.

**Significance**

Accurately determining what effect these delays have on the mine as a whole would be a complicated endeavour, yet a few simple calculations can give a fair indication. The effect of the recorded extra or unnecessary cycle times will be expressed in terms of:

- ✓ Effect on individual shovel
- ✓ Effect on overall operation
- ✓ Effect of having trucks spot from 110m and 65m on average cycle time

Taking data of cycle times from around the same time periods as found in Section A:1.3 allows the effect on each shovel ton be calculated as shown in Table A17:

**Table A17: Effect of extra spotting time on individual shovels**

| Shovel | Average Cycle Time | Measured Extra Time | Unnecessary Extra Time |
|---|---|---|---|
| S560 | 1596 seconds | 15 seconds | 0.9% |
| S564 | 1621 seconds | 35 seconds | 2.2% |

A 1% and 2% delay on shovel S560 and S564 respectively is quite significant. Yet considering the misplaced signs were only affecting two shovels the effect on the mine as a whole would be substantially less. A crude approximation is made by comparing the total extra time from the above delays to the total cycle time for all trucks across the mine as shown in Section A:1.3 for 2 December. This is shown in Table A18:

**Table A18: Effect of delays measured delays on whole system**

| (seconds) | Total Time | Extra from S560 | Extra from S564 | Total Extra | Effect on Total |
|---|---|---|---|---|---|
| Details | 31,774 X 60 | 15 X 35 | 35 X 54 | 900 + 2100 | 3,000 ÷ 1,906,469 |
| Total | 1,906,469 | 525 | 1,890 | 2,415 | **0.13%** |

This shows that a couple of misplaced no-entry signs can retard overall efficiency by approximately 0.1%.

A third way of looking at the significance of misplacing no-entry signs is to approximate what effect placing a single sign at 65m or 110m has on the average cycle time and overall operation. This is shown in Table A19:

**Table A19: Effect of misplacing a sign at 110m or 65m on the specific shovel and overall operation**

| (seconds) | Extra Time | Average Cycle Time | Delay on Average Cycle | Delay on Entire Operation** |
|---|---|---|---|---|
| 65m | 15 | 2,000* | 0.8% | 0.04% |
| 110m | 35 | 2,000* | 1.8% | 0.09% |

*As found in Section A:1.3

**Total time of 1,906,469 as above with average number of cycle approximated to 51 (972÷19).

### A:2.3 Results Summary

Out of 16 of the large shovels examined only three were found to have a no-entry sign positioned significantly further than specified by company work instructions. This was as follows:

- 150m for one of the Liebher 996 shovels
- 110m for shovel S564, a P&H 2300XPB
- 80m for shovel S560, a P&H 2300XPB

Due to changing conditions only a limited number of time delays could be recorded, for the shovels above they were as follows:

- Liebher 996 with no-entry sign at 150m: **None**, trucks **ignored the sign** and parked at roughly 50m
- P&H 2300XPB designation S564 with no-entry sign **at 110m**: Approximately **35 seconds** extra time
- P&H 2300XPB designation S560 with no-entry sign at 80m: Trucks ignored the sign and held at approximately **65m**, extra time was approximately **15 seconds**

The effect of the misplaced no-entry signs were found to be:

- A 1% and 2% delay on shovel S560 and S564 respectively
- A 0.1% retardation on overall operations

It was observed that badly placed signs were ignored at two of the three locations, at the third, S564, the 110m sign was obeyed, but not always.

### A:2.4 Discussion

**Findings**

It was found that most no-entry signs are at the correct position. Of 16 shovel loading areas examined only three were found to have no-entry signs incorrectly positioned. Instead of being at 50m these signs were at 65m, 110m and 150m. As sings that are badly placed are often ignored, in this case the 65m sign was mostly ignored and the 150 sign was completely ignored the impact on operations tends to be reduced. For trucks holding at the 65m sign 15 seconds per cycle was lost whilst trucks holding at the 110m sign added approximately 35 seconds to the cycle time. This roughly equates to a 1% increase in cycle time with the 65m sign and a 2% increase at the 110m sign. Overall operations are retarded by approximately 0.1%; this is a relatively small loss, but one that can be negated with minimal effort. According to Section F this would be approximately R25 million per annum to Sishen.

**Accuracy**

It is noted that the accuracy of these findings, especially the interpolation regarding overall impact is rudimentary. This is due to various differences in operating condition and pit lay out from time to time, determining an exact figure would be expensive. The figures are still fair approximations, and useful for getting an idea of how big relevant inefficiencies are.

**Recommendations**

The fact that some trucks stop past the no-entry signs where they are not optimally placed requires the importance or relevance of the no-entry sign serving as the official holding point to be questioned. This is further supported by the fact that the shovels do move around in certain conditions, it was observed to be by as much as 20m. There are solutions that would get rid of the additional cycle time caused by bad positioning of the signs or safety risks associated with moving shovels. One such a solution would be to make use of existing positioning devices on trucks and shovels to place virtual holding positions. A display in the truck can indicate how far a truck is from a shovel allowing the operator to hold at the ideal location. Any safety risks due to malfunction are neglectable as operators will primarily rely on visuals, only using the distance for fine tuning. Due to safety considerations the no-entry points could still be used to control other traffic and personnel, just not be used as holding point for haul trucks. At the very least shovel operators should be managed in such a way that they place the no-entry signs at the correct position during the shift change. Foremen are to oversee this as is currently being done to a certain degree.

### A:2.5 Conclusion

It was found that while some no-entry signs are badly positioned the effect on overall operations are minimal due to drivers often ignoring badly placed signs. Whilst the retardation on the overall operation is low at approximately 0.1%, worth R25 million per annum, it is unnecessary and can be easily mitigated. As a suggestion for a sustainable solution no-entry signs could be used only for traffic control and safety considerations with electronic positioning systems defining the exact holding point for haul trucks relative to shovels. At the moment the losses occur due to shovel operators failing to position the signs during shift changes and foremen not successfully addressing the problem.

## A:3 Double Sided Loading

### A:3.1 Overview

Loading on both sides of a shovel decreases cycle times as one truck can get into position whilst the other is loading instead of holding at the no-entry sign. Craig Barry, Production Manager at Loading and Hauling, estimates that loading on both sides of the shovel occurs approximately 20% of the time (Section H:1.1.3, Q&A 2). Figure A26 shows how a typical double loading site could be set up. It shows that a good amount of space is needed, if this space is not available only one truck would be able to get into position at a time. In order to gauge the importance of implementing double sided loading the cycle time difference between double and single sided loading will be determined.

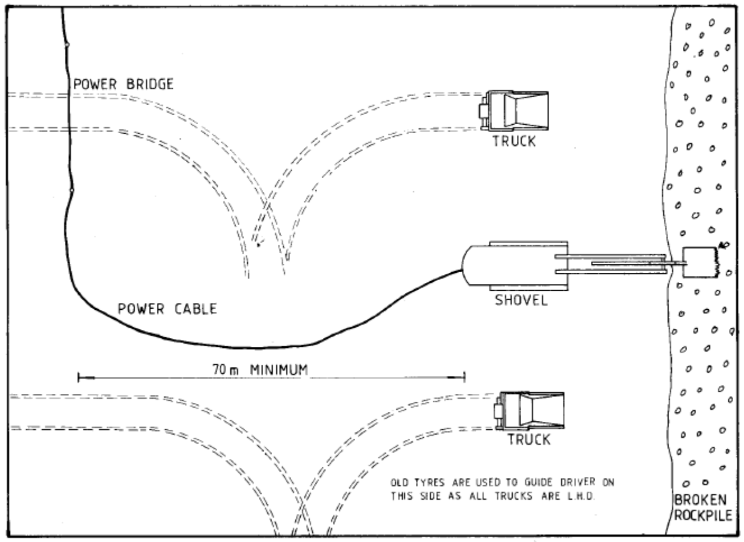



**Figure A26: Illustration of double sided loading, the 70m holding distance has been changed to 50m at Sishen. Sourced from (43)**

### A:3.2 Methodology A – Frequency of Double Sided Loading

The proportion of loading instances where shovels are loading on both sides will be investigated.

#### *A:3.2.1 Procedures*

During the holding position observations as noted in Section A:2.2.1 it was noted whether shovels were loading on one or both sides.

#### *A:3.2.2 Data Analysis*

During these observation on the 26th and 29th of November 2012 no instances of double sided loading were recorded.

*Double sided loading was seen at other times, the exact fraction of the time it is implemented is thus not known, but Craig Barry's estimate of 20% seems high.

### A:3.3 Methodology B – Benefits of Double Sided Loading

The difference in cycle times between double sided loading and single sided loading will be measured. As an indication of the difference in cycle times due to the different configurations the time the shovel waits for the next truck under over trucked conditions will be used. This is the time from the moment the loaded trucks leaves until the next truck is ready to be loaded. It is the same as last bucket of current truck to first bucket of next truck ("last bucket to first bucket").

#### *A:3.3.1 Procedures I – Double sided loading*

Measurements were taken on the 6th of December at the Bruce A loading area for benchmarking purposes. These measurements contain the needed data to determine an average loading time at double sided loading configurations. See Section A:2.2.1 for a breakdown of the methodology.

#### *A:3.3.2 Data Analysis*

The time for "last bucket to first bucket" at double sided loading is the sum of the time it takes the shovel to spin round and grab a bucket full of material, and the time it takes the truck to get into position once the bucket is ready. The recorded times are shown in Figure A27:

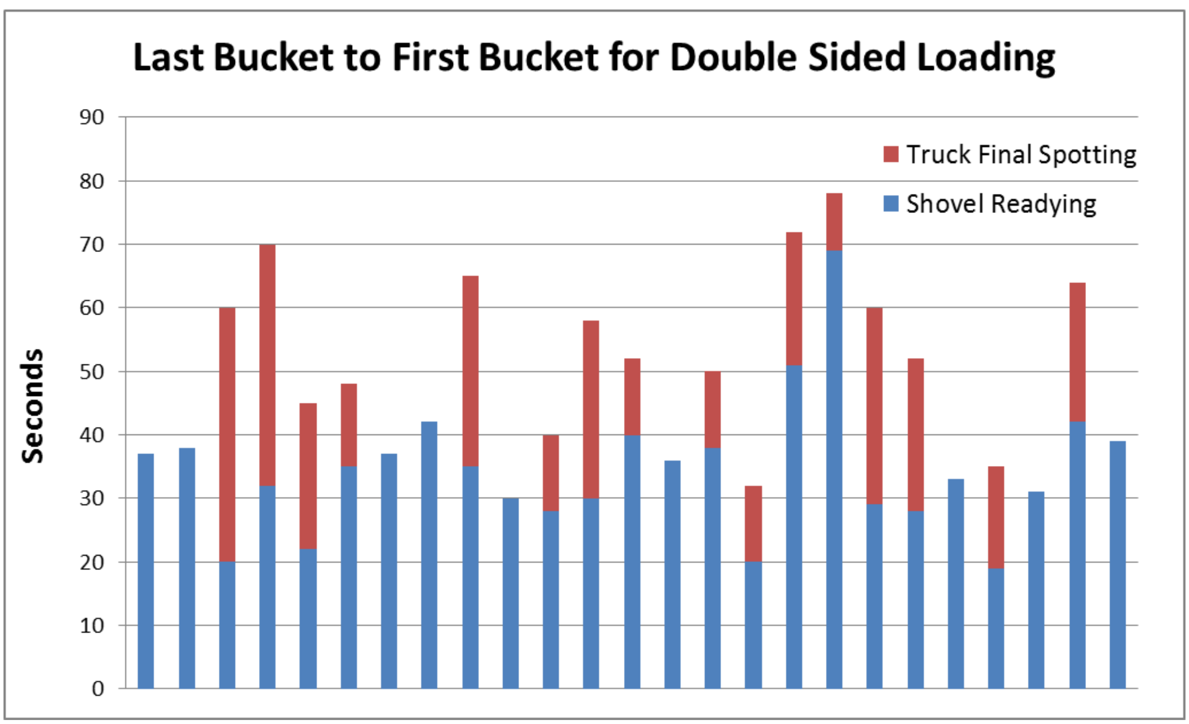



Figure A27: "Last Bucket to First Bucket" for Double Sided Loading

The average time from the above data is 48 seconds. This is for the sum of both sides, the instances with no “Truck Final Spotting” times are for loading on the left side where the truck is in position.

### A:3.3.3 Procedures II – Single sided loading

Measurements were taken on the 5th of December at Shovel S564’s loading area for benchmarking purposes. These measurements contain the needed data to determine an average loading time at single sided loading configurations. See Section B:2.2.1 for a breakdown of the methodology.

### A:3.3.4 Data Analysis

The time for “last bucket to first bucket” at single sided loading is the sum of the time it takes the loaded truck to ‘exit’, and the time it takes the next truck to spot. The recorded times are shown in Figure A28:

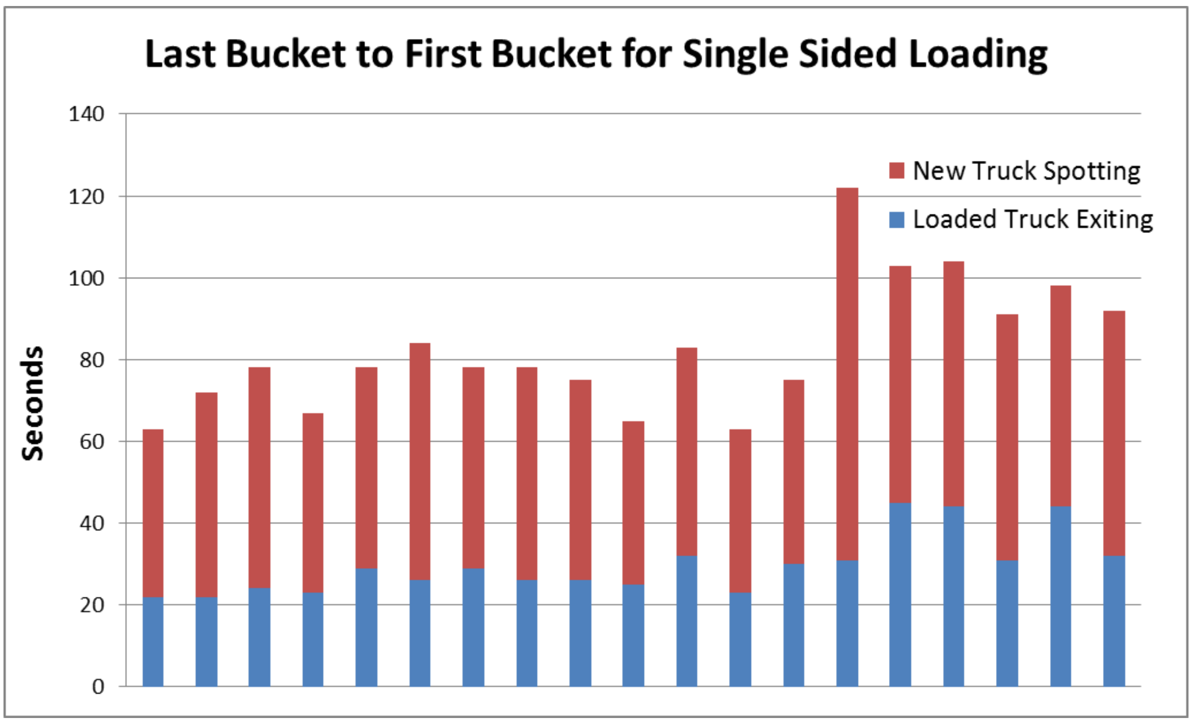



Figure A28: "Last Bucket to First Bucket" for Single Sided Loading

The average time from the above data is 82 seconds.

## A:3.4 Results Summary

During the round of observation no instances of double sided loading was observed, double sided loading was however seen at other times. This suggest that double sided loading probably takes places less than 20% of the time as estimated by Craig Barry.

The average "last bucket to First bucket" time was 48 and 82 seconds for double sided and single sided loading respectively. This is a difference of 34 seconds which equates to 1.7% of the average cycle time of 2,000 seconds as found in Section A:1.3. 1.7% is worth approximately R425 million per annum to Sishen.

### A:3.5 Discussion

This study found that double sided loading does not occur as often as thought. The reasons for the lack of double sided loading were not studied. It was found that 34 seconds or 1.7% of average cycle time is saved by double sided loading. This was done by finding the time difference between double and single sided loading for "last bucket to first bucket". This is a fair approximation assuming a shovel is over trucked, when there is a lack of truck no difference will exist between single and double sided loading.

### A:3.6 Conclusion

The benefits of double sided loading were found to be less than expected. The approximately 1.7% reduction in cycle time is significant, but is only realised when the shovel is over trucked. Where possible double sided loading should be implemented. This is not always possible or easy. It must be noted that with the average number of loads at 50 per shift spending 25 minutes per shift setting up negates the benefits.

## A:4 Pre-Spotting

### A:4.1 Overview

During the spotting process as explained in Section A:1.2 the next truck has to wait at 50m for the previous truck to exit before he can start his spotting procedure. If the next truck was to pre spot whilst the current truck is loading he would not have to wait for the previous truck to travel 50m before spotting, and would only have a small distance to spot. This “Pre-Spotting” is not done due to safety considerations. It is further more not a decision made by operation, but company policy according to Craig Barry as recorded in an interview (Section H:1.1.5).

This section will investigate the cost to cycle time imposed by this safety precaution. If the time is found to be significant the risk can be thoroughly analysed and a suggestion made to alter the work instructions.

Pre-spotting will see truck B hold at point 1 instead of at the no-entry sign as shown in Figure A29:

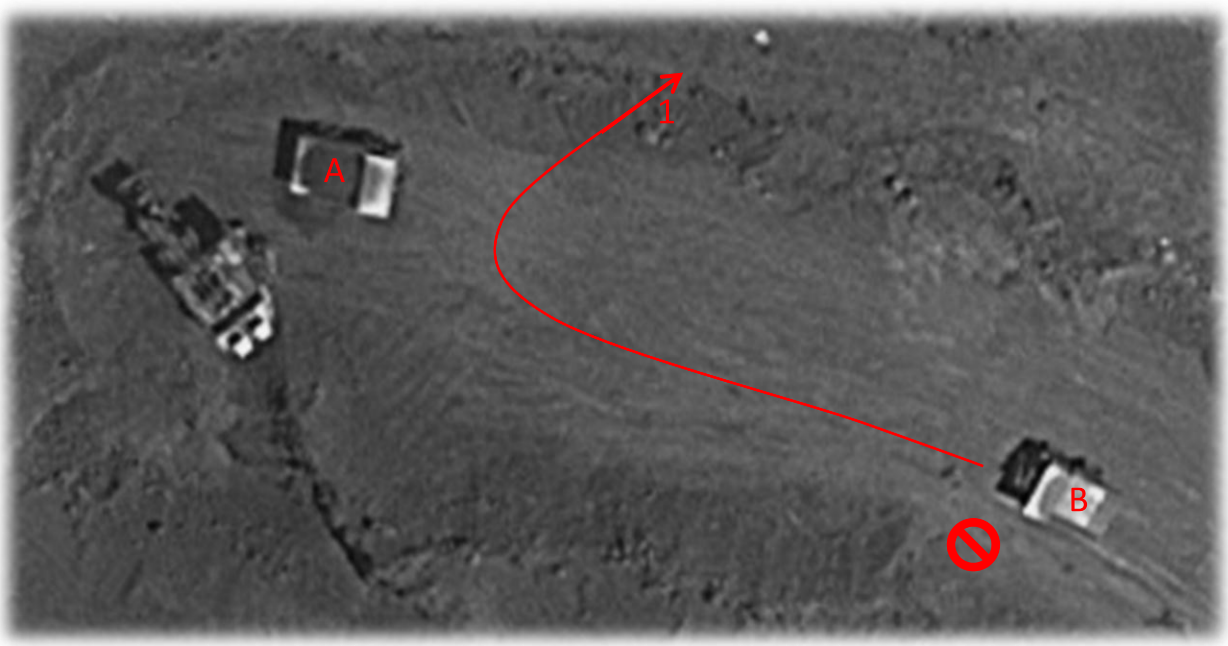



Figure A29: Prospected Pre -potting Manoeuvre

The time saved will be the sum of the time for truck B to get to point 1 and the time for truck A to get from point 1 to the no-entry sign.

### A:4.2 Methodology

A field study will be conducted to determine the above mentioned times. This will be combined with the benchmarking exercises and holding position studies. See Section A:2.2.1 and Section B:2.2.1 for the methodologies.

#### A:4.2.1 Procedures

The unique measurements that were required for this study was the pre-spotting time and the "past pre-spotting position" time on the exit. The data was recorded during the benchmarking and holding position studies and extracted for this analysis.

#### A:4.2.2 Data Analysis

The time that will be saved is the sum of the pre-spotting time and the time it takes the exiting truck to move from the point where it is past pre spotted truck to the 50m mark. The times as recorded are for Komatsu 860E's only and is shown in Figure A30:

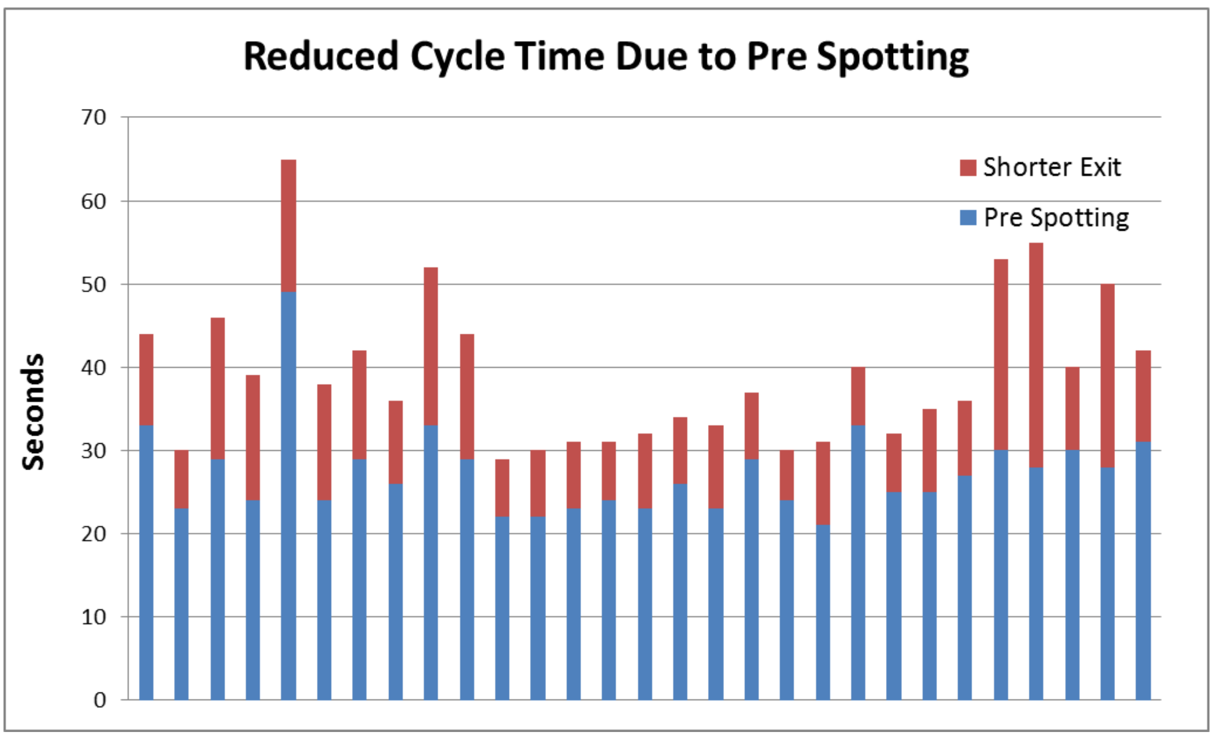



Figure A30: Time that can be saved by practicing pre-spotting

The average time calculated from the data above is 39 seconds. Before assuming that 39 seconds can be saved it has to be made certain that there is still enough time left for the shovel to prepare its next bucket. The time for this preparation was recorded during the benchmarking exercise in section V and is shown in Figure A31. These times are for a double sided loading configuration, it is assumed that it will not be longer for single sided loading.

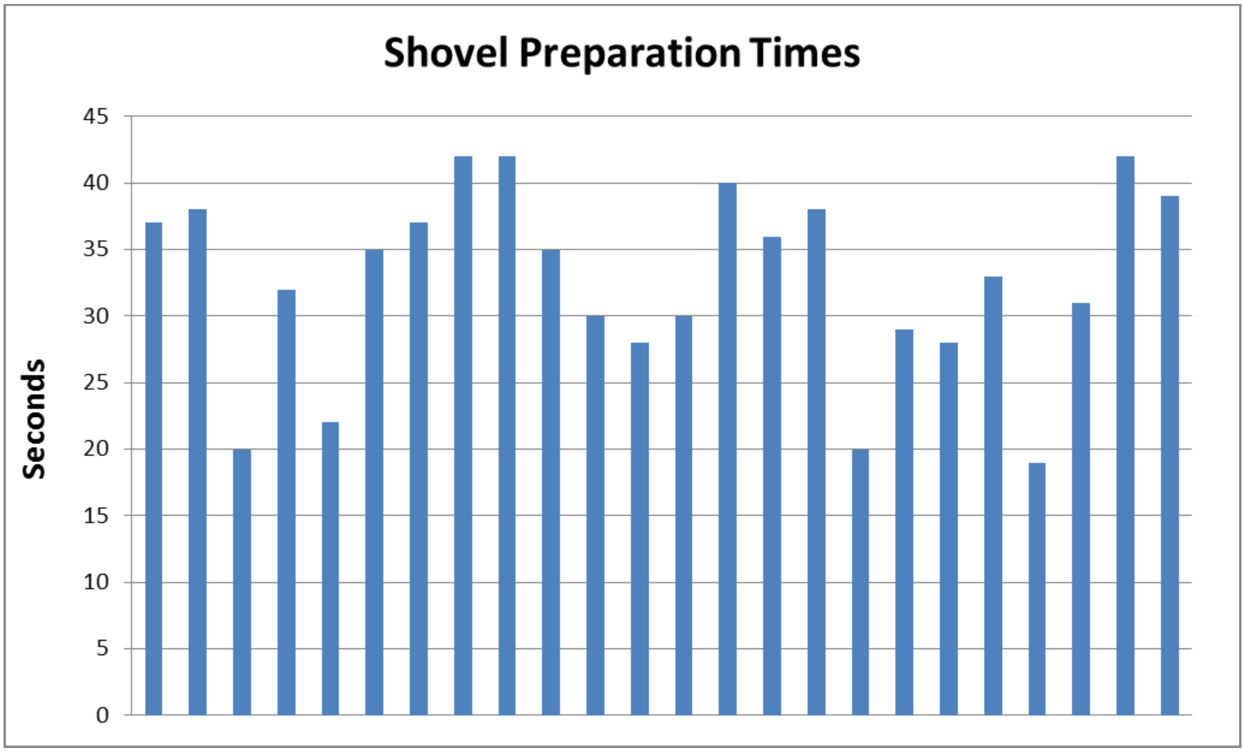



Figure A31: Shovel Preparation Time

The average time from the data shown above is 33 seconds. This time has to be less than the time it takes a loaded truck to pass the pre spotted truck, the shovel has to be in position before final spotting can begin. The same set of data that was used to determine that 39 seconds can be saved is used, it is shown in Figure A32:

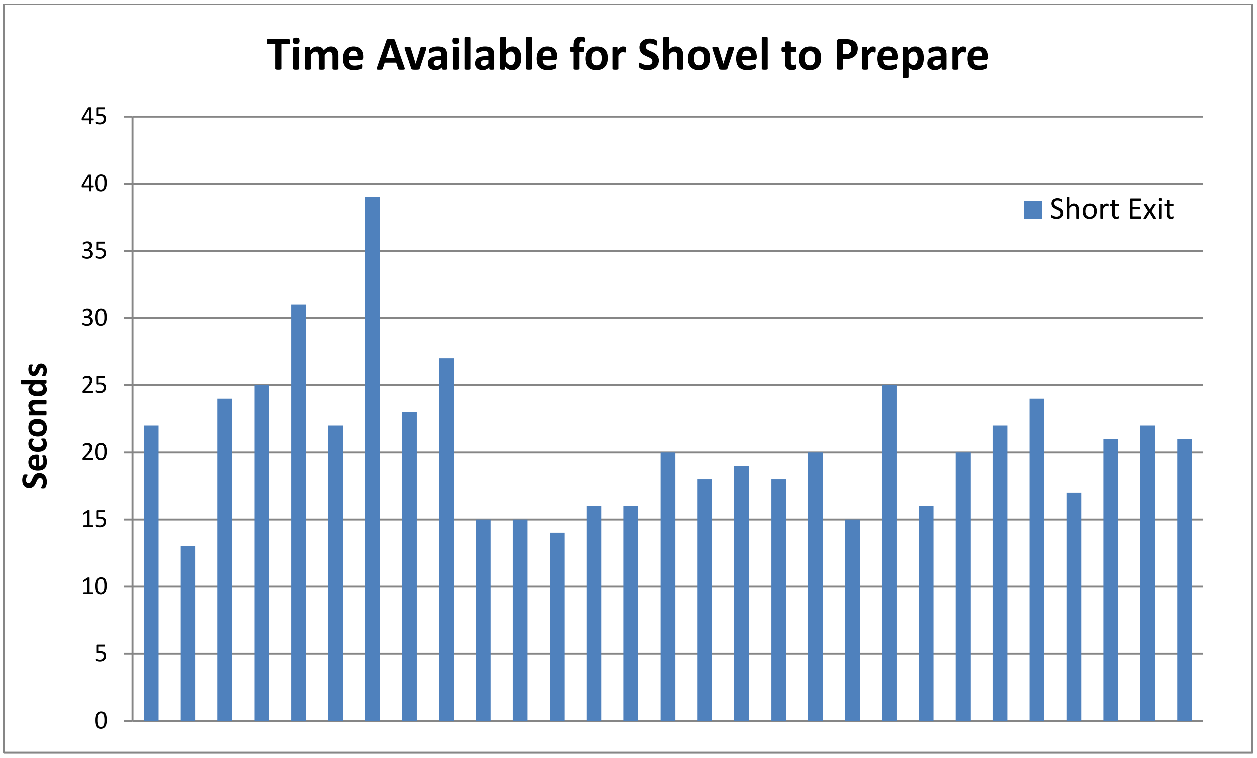



Figure A32: Time available for the shovel to prepare

The average of the data shown above is 21 seconds. The check does thus not hold as 33 seconds is needed to prepare but only 21 is available. Twelve seconds is lost leaving the total gain at 27 seconds (39-12).

### A:4.3 Results Summary

It was found that 27 seconds can be saved per cycle if pre-spotting is done. Spotting takes 39 seconds shorter but the truck has to now wait for 12 seconds for the shovel to be in position before final spotting can commence. The 27 seconds equates to 1.4% of the average cycle time of 2,000 seconds as found in Section A:1.3. This will result in Sishen making an additional profit of approximately R350 million according to Section F.

### A:4.4 Discussion

Practicing pre-spotting at single sided loading configurations will realise a greater reduction in cycle time than obtained from double sided loading and can be implemented at all loading sites. This is not being done at present, though some more experienced drivers admit that they do it from time to time suggesting feasibility. The hazards do not seem to be more that those of double sided loading, again this sentiment was shared with the researcher by drivers when discussed.

### A:4.5 Conclusion

Pre-spotting is not practiced at single sided loading configurations at Sishen; a significant amount of time can be saved by implementing it. More time than saved by setting up a few additional double sided loading configurations. Company policy due to safety considerations currently stop pre-spotting at single sided loading configurations from being implemented. It is strongly recommended that a proposal be made to change this policy pending a thorough risk analysis.

## A:5 Summary

Three operational factors which directly affect cycle times was studied in this section, they are:

- Holding Positions: The point where a truck waits at a shovel to start its spotting procedures.
- Double Sided Loading: The loading configuration where a shovel loads trucks on both sides.
- Pre-Spotting: The part of the spotting procedure where a truck positions itself to reverse next to the shovel.

Table A20 shows the effects that these various factors have on an average cycle time at Sishen:

**Table A20: Effect on average cycle time**

| | *Description* | *Average Cycle Time Reduction* | *Annual Value* |
|---|---|---|---|
| **Holding Positions** | All "No-Entry" signs placed at the stipulated distance of 50m | 0.1% | R25 million |
| **Double Sided Loading** | Double Sided Loading used instead of Single Sided Loading | 1.7% | R425 million |
| **Pre-Spotting** | If Pre-Spotting was to be implemented at Single Sided Loading configurations | 1.4% | R350 million |

## A:6 Conclusion

Some work has to be done to optimise the placing of no-entry signs at holding positions and further improvements can be made by implementing double sided loading more often. Yet double sided loading is unlikely to be implemented much more frequently than presently done and only saves time when a shovel has enough trucks. The gain of 0.1% (R25 million per annum) and a portion of the prospective 1.7% (R 425 million) should be pursued, yet the big opportunity lies in the 1.4% (R350 million) that could be saved by implementing pre-spotting. It is strongly recommended that a proposal be made to change this policy pending a thorough risk analysis.

# APPENDIX B: Operator Benchmarking

# Executive Summary

Operators have a big influence on how efficient the overall utilization of HME is. The presence of four contracted American expert operators at Sishen provided the ideal opportunity to benchmark Sishen's employee proficiency against industry leaders. A few processes were selected that could be easily and accurately measured and would provide a good gauge of the operators' proficiency. These were:

- Final spotting times (trucks) – The time it takes to reverse into position next to a shovel.
- Exit times (trucks) – The time it takes to exit the loading area (50m) after being loaded.
- Loading time (shovels) – The time it takes to load a truck.

It was found that the expert operators outperformed the local operators in each of these processes, the amount of time by which the expert operators outperform local operators and the value that this holds to Sishen is shown in Table B21:

**Table B21: Time by which the expert operators outperformed local operators and the value this holds for Sishen**

| (Expert Operators) | *Time saved* | *Percentage of Locals' time* | *Reduction in Average Cycle Time* | *Annual Value* |
|---|---|---|---|---|
| **Final spotting time** | 10 seconds | - | 0.5% | R125 million |
| **Exit times** | 8 seconds | - | 0.4% | R100 million |
| **Loading time** | 31 seconds | 82% | 1.6% | R400 million |
| ***Total*** | *49 seconds* | - | *2.5%* | *R625 million* |

The net effect can be underestimated as only a few segments of the complete cycle was measured, in addition to this first degree delays such as failing to see a waiting truck or spilling rocks on the manoeuvring area was not considered. It is estimated that these first degree delays push the 2.5% up to around 9% or R2 billion per annum. This figure is only a rough estimate based on a few measurements and extrapolations. If second degree delays such as the maintenance consequences of bad driving techniques or delays due to wrong digging angles are considered the figure would most likely be even higher.

The physical measurements prove that local operators do not posses the same skill as the expert operators. Simply training drivers more rigorously will not solve the problem however, observed delays and inconsistent performances suggest that the local work ethic has to be improved as well.

It is suggested that management put structures in place that are able to monitor and motivate each individual's performance. This is to be done in parallel with effective operator training and selection processes.

# Contents

## B:1 Overview

Efficient use of HME is an important factor determining how effective the overall utilization of equipment is. Having operators who are more efficient at controlling machinery can have a big effect on cycle times. Some of the key areas that can be measured are spotting times and loading times. There are currently four contracted American expert operators (EOs) on the mine. This presents a good opportunity to benchmark Sishen's employee proficiency against industry leaders.

The most accurate performance indicator is physically measuring spotting times and loading times according to Kotze (11) and Barry (12). The researcher's observations in the pit support this view; operators were observed to be inconsistent with the application of their status buttons, recorded spotting times and loading times were thus thought to be unreliable.

The data from dispatch would however still have been studied as it was thought that it might supplement some of the field measurements, at the conclusion of this study it was found that the expert operators were logged in on other operators' profiles. The analysis was thus meaningless and hence omitted from this study.

## B:2 Methodology

A field study was conducted. This was to be supplemented with data from the dispatch system. The field study measured various spotting time components and loading times, the data from dispatch would provide further statistical data on loading rates.

### B:2.1 Spotting Times

In order to measure the difference in spotting times and related manoeuvring times between local drivers and the expert operators physical measurements were taken by the researcher in the field. This involved organising a situation where various times could be compared and going into the pit using a stopwatch to collect data.

### B:2.1.1 *Procedure*

1) **Logistics:** A memorandum motivating the field study and its requirements was written to Craig Barry. This was approved with the study to be undertaken on the 6th of December 2012. On 6 December the shift Foreman made the necessary arrangements after liaising with the researcher. The memorandum can be found in Section H:2.2.
2) **Site Selection:** Bruce A was selected as the site for the field study as it was high priority and would have a continuous flow of trucks. The Le Tourneau would be loading there.
3) **Operator Arrangements**: As per the memorandum one of the expert operators was put on a truck and fixed to the shovel loading at Bruce A.
4) **Observer Positioning**: A bakkie was used to travel to the shovel, the vehicle was parked in a safe location which provided a good view of the shovel and the surrounding area at Bruce.
5) **Shovel Change:** The Le Tourneau arrived on site, started preparing its loading area, and left Bruce A again. This was due to a rope shovel, P&H 2300XPB designation S565, which was positioned in the area and down for maintenance being put back into service. The rope shovel was provided with a shovel operator after approximately 30 minutes and was ready to start loading in another 30 minutes.
6) **Truck Classes:** The Shovel was supplied with a mixture of 860Es and 730s, as explained in the memorandum, trucks of the same class were required for realistic comparisons to be made. The shift foreman was contacted and arranged with dispatch to send only 860Es to Bruce A.
7) **Double Sided Loading:** At 11am after 17 positioning times for 860Es was recorded the shovel started loading on both sides. This initiated new loading procedures and a new set of data that could not be compared to the single sided loading manoeuvring times.
8) **Data Collection:** Separate data had to be collected for loading on the left side and the 'blind' right side of the shovel. Measurements were taken on each side of the shovel for "Final Spotting Time" and "Exit Time".
    - Final Spotting Time – The time was started as soon as the shovel was waiting for the truck and stopped once the truck was in position.
    - Exit Time – A mark was selected to approximate when the truck was clear of the loading area, the time was started when the shovel gave a hoot to indicate it was done loading, and stopped when the truck reached the selected 'clear' mark.
9) **Duration**: Step 7 continued until the shovel went down for unscheduled maintenance at 4pm. At this stage step 8 had yielded 41 usable data points.

### B:2.1.2 Results and Discussion

Two relevant performance indicators were targeted and could be extracted from the data. This was the "Final Spotting Time" and "Exit Time" of trucks.

**Final Spotting Time**

Final spotting time refers to the last part of the spotting procedure where the truck backs up under the waiting shovel arm as shown in Figure B33. On the left side of the shovel there should not be any final spotting times as the truck is supposed to move into position whilst the shovel loads the truck on the other side. This is shown as position A on the Figure B34. On the right side, which is referred to as the 'blind side' as all trucks are left hand operated, the truck has to wait for the shovel to swing out its arm before backing up into position from point B in Figure B34.

Figure B33: P&H 2300XPB swinging out its arm

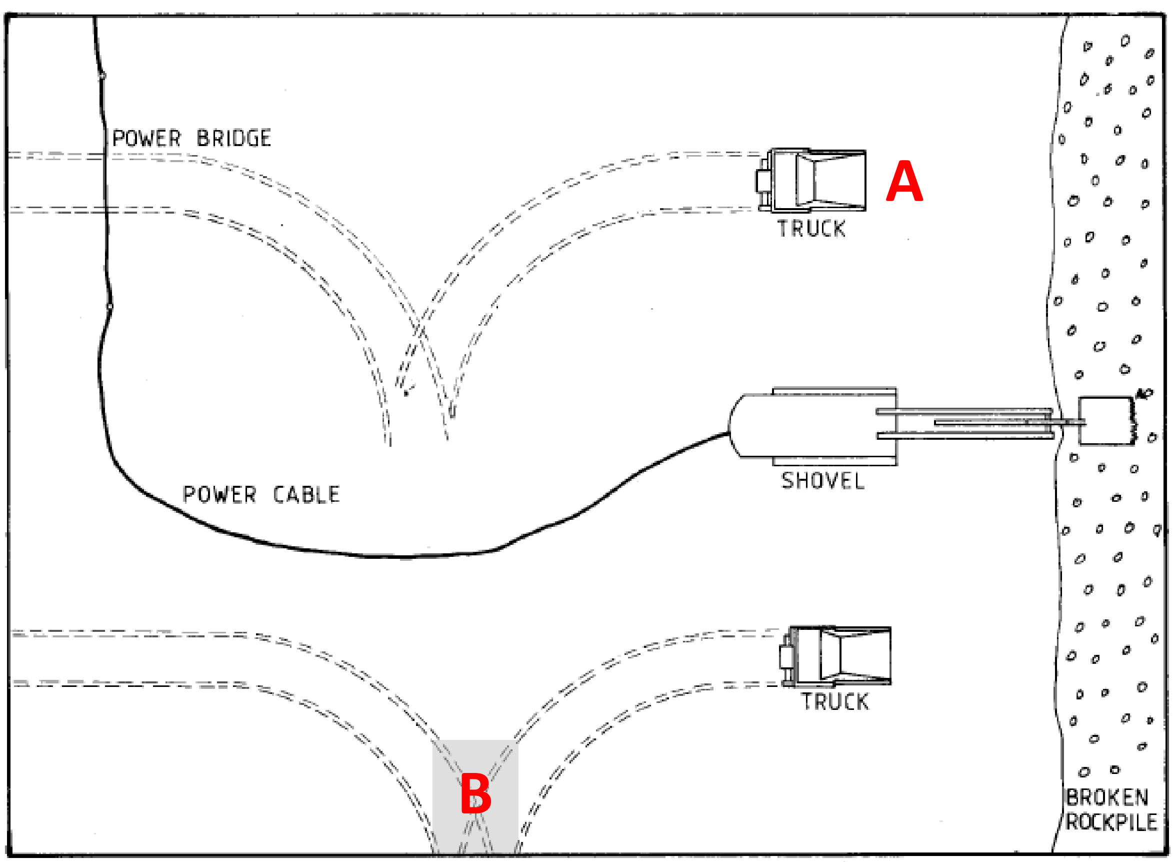



Figure B34: Illustration of double sided loading, showing pre-spotting positions. Sourced from (43).

Any times recorded on the left side is thus an unnecessary addition to cycle time and adds to the waiting times of all the trucks present. The time taken on the right is also a direct component of cycle time and directly adds to the waiting time of all the trucks currently at the shovel. The "Final Spotting Time" was thus seen as the key performance indicator as it retards the current truck, the shovel and all waiting trucks. This is the case for single or double sided loading shovel configurations. The field study revealed the following final spotting times shown in Table B22.

**Table B22: Summary of Final Spotting Times for Benchmarking Exercise Results, truck 34 was operated by an expert operator.**

| Truck # | Side | Time per Instance (sec) | Average (sec) | No Waiting on left |
|---|---|---|---|---|
| 11 | Left | 0+0+9+0 | 2.3 | 3 out of 4 |
| 13 | Left | 12+0+0 | 4 | 2 out of 3 |
| 14 | Left | 23 | 23 | 0 out of 1 |
| *34* | *Left* | *0+0+0+0+0* | *0* | *5 out of 5* |
| 40 | Left | 28+21+31 | 26.7 | 0 out of 3 |
| | ***Ave. Left*** | ***8*** | | |
| 11 | Right | 12 | 12 | |
| 13 | Right | 12+22 | 17 | |
| 14 | Right | 30+26+24+22+12 | 22.8 | |
| *34* | *Right* | *12+9+8+16* | *11.3* | |
| 40 | Right | 40+13 | 26.5 | |
| | ***Ave. Right*** | ***18*** | | |

The expert operator (EO) was operating truck number 34. When comparing the performance to the local operators Figure B35 is obtained. This shows that approximately 10 seconds is lost on average on either side of the shovel just during the final spotting manoeuvre. It was also observed that the expert operator was able to be in position 5 out of 5 times for loading

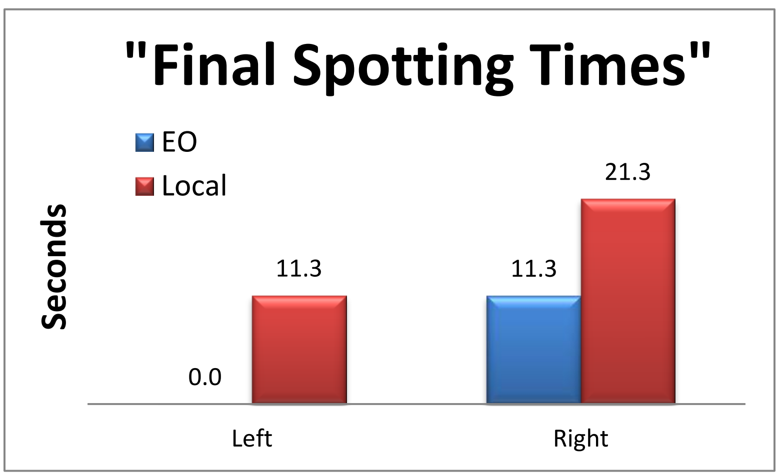



**Figure B35: Difference between expert and local operators final spotting times**

on the left side; the cumulative local score was 5 out of 11. Either the local operators are not aware of the procedures or they are not driven enough to perform efficiently. In either case better operator performance with no additional cost to equipment would reduce the average cycle time by 10 seconds.

One way to approximate the effect that these delays have on production would be to determine the extra number of loads that could be done if they were negated. At Bruce A where this field study was conducted a 109 loads were recorded on a sample shift on 2 December as in Section A:3.1. This means that 1,090 seconds would be lost due to bad pre-spotting. Assuming a continuous supply of trucks as was common at Bruce A and an average loading time of approximately 4 minutes 4.5 extra loads could be done on a shift. This is a 4% increase. It must be noted that Bruce A was the busiest loading area in the mine, the affect at other sites would not be as great.

As seen in Section A:1.3 the average number of loads for a shovel is around 50 per shift. For an under trucked shovel the effect would be 10 seconds per cycle, if the cycle is of average length (2,000 seconds as shown in Section A:1.3) the delay would only be 0.5% which equates to 0.25 loads per shift. It is thus relatively small. If the same shovel was over trucked the effect would be similar to that described above for Bruce A.

It can thus be estimated that the loss of production just from inefficient final spotting times are between 0.5% and 4% depending on how well trucked a shovel is. It must be noted that most shovels do single sided loading. Final spotting is a component of single sided loading, the entire single sided loading process takes much longer. It is thus reasonable to assume that even more time would be saved with proficient drivers at single sided loading configurations.

**Exit Times**

“Exit Time” looks at how long the truck takes to clear the loading area. At double sided loading configurations it is of little concern, especially if the shovel is over trucked. If a truck takes slightly longer it will simply queue for a slightly shorter time. The effects are far more pronounced at single sided loading configurations. Here the next truck (B) has to wait for the current truck (A) to exit before it can initiate its spotting procedures. This is shown on Figure B36 below:

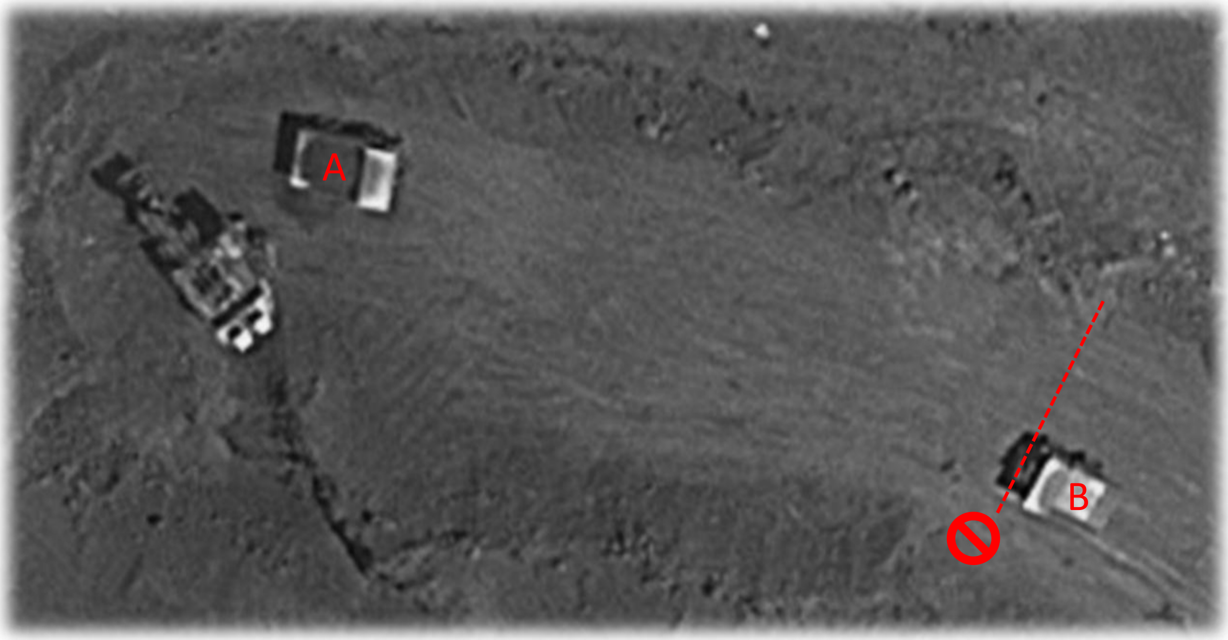



Figure B36: If truck A delays its departure, truck B is also delayed.

During this field study the shovel was loading on both sides. A marker was selected at approximately 50m (the distance a truck waits at for single sided loading) to determine whether any time could be saved in this area. The recorded times for the expert operator and local operators are shown in Table B23 below:

Table B23: Summary of Exit Times for Benchmarking Exercise Results, truck 34 was operated by an expert operator.

| Truck # | Side | Time per Instance (sec) | Average (sec) |
|---|---|---|---|
| 8 | Left | 30 | 30 |
| 11 | Left | 33+44+25 | 34 |
| 13 | Left | 28+28+33 | 29.7 |
| 14 | Left | 32+27 | 29.5 |
| *34* | *Left* | *23+23+17+22+21* | *21.2* |
| 40 | Left | 32+40+20+41+30 | 32.6 |
| | ***Ave. Left*** | ***29*** | |
| 11 | Right | 24+25 | 24.5 |
| 13 | Right | 24+26 | 25 |
| 14 | Right | 23+21+25+18+28+20 | 22.5 |
| *34* | *Right* | *15+20+17+17* | *17.3* |
| 40 | Right | 34+21+25 | 26.7 |
| | ***Ave. Right*** | ***23*** | |

The expert operator was operating truck number 34. When comparing his performance to the local operators Figure B37 is obtained. This shows the expert operator outperforming the local average, taking only 67% and 71% of the time to exit the loading area. Figure B38 illustrates how the expert operator consistently outperforms local operators. Whilst local drivers achieve similar times on occasion, the consistency of the expert operator sets him apart.

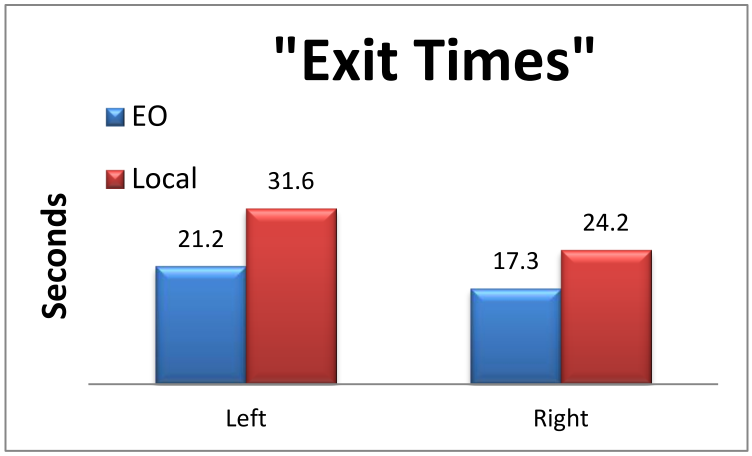



Figure B37: Difference between expert and local operators' exit times

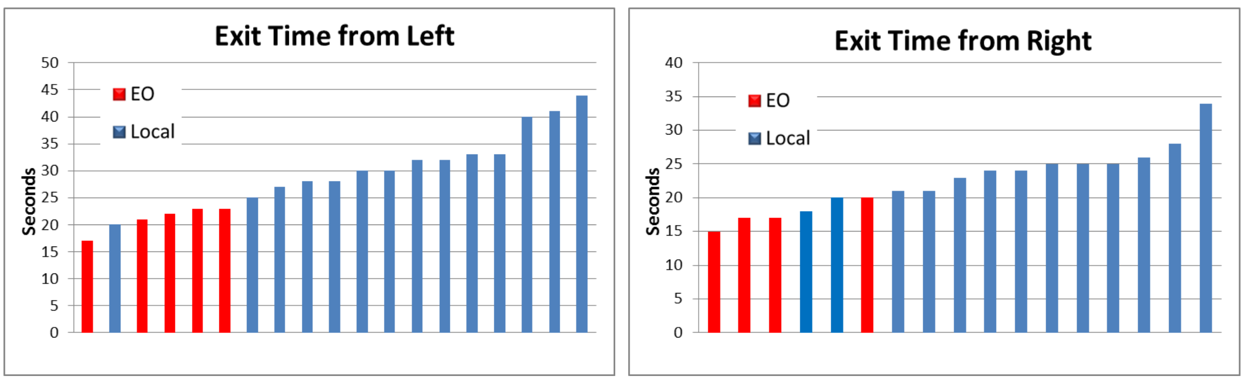



Figure B38: Exit times form left and right comparing expert operators and local drivers

As noted with final spotting times an additional 6-10 seconds (approximately 8 seconds) can be saved per cycle with no cost to machinery if local drivers operate their machinery more efficiently. Again it must be assumed that local operators are not motivated enough to perform to their full potential. This is supported by the fact that they do on occasion register similar times to the expert operator. It is probable that local operators do not posses the same skill and finesse as the expert operators, still the first consideration should be motivating them to consistently perform as well as they are able to.

8 seconds per cycle equates to 0.4% of cycle time for an average cycle of 2,000 seconds.

### B:2.1.3 Summary of Results

Benchmarking "final spotting time" and "exit time" revealed the following figures:

- **Final Spotting Time**: Local operators are approximately 10 seconds slower on average on either side of the shovel.
- **Exit Times**: Local operators are approximately 8 seconds slower on average.

It was noted that local operators do at times register similar times than the expert operator. They do however not have the same consistency.

At an under trucked shovel with an average cycle time 0.9% (0.5+0.4) is added to the cycle time just by inefficient final spotting and exiting manoeuvres. This effect will be more pronounced when the shovel is over trucked.

### B:2.1.4 Conclusion

Local truck operators do not perform as well as industry leaders. Approximately 1% is added to an average cycle time just by having slow final spotting and exiting times. When other facets of the entire cycle such as travelling, stopping and going, spotting at dump sites and dumping is considered the 1% will be significantly higher. This calls for better training and incentives or selection procedures to enable and motivate local operators to perform better.

## B:2.2 Loading Times

In order to measure the difference in loading times between local drivers and the expert operators physical measurements were taken by the researcher in the field. This involved going into the pit and using a stopwatch to collect data. A P&H 2300 XPB, shovel S564 was loading an old dump site. The material at the old dumpsite is consistent. This means that there were no significant variances at different times in a shift, or even between different shifts.

### B:2.2.1 Procedure

1) **Shovel Selection**: A P&H 2300 XPB, shovel S564 was selected for the benchmarking exercise. This was due to the fact that it is loading an old dump site where material loading is consistent.
2) **Operators Arrangements**: An arrangement was made to have one of the expert operators operate the shovel from 8am until 12pm and a local operator who is thought to have a typical performance from 12pm until 8pm.

3) **Observer Positioning**: A bakkie was used to travel to the shovel, the vehicle was parked in a safe location at 9am.

4) **Loading Time Measurements**: A stopwatch was started as soon as the shovel signalled that the truck was in position with its hooter. The stopwatch was stopped as soon as the shovel gave a hoot to signal that loading is complete.

5) **Operator change and maintenance**: Whilst the arranged operator change took place a mechanical fault was found with the shovel's tracks. They had to be fixed to prevent serious failure. The maintenance crew left at 3:45pm and the first bucket by the local operator was recorded at 5pm.

6) Repeat step 4. The last measurement was taken at 7pm. Various other occurrences were recorded.

### *B:2.2.2 Results and Discussion*

The loading times recorded for "Frank", who is one of the expert operators, and a local operator is shown on Figure B39:

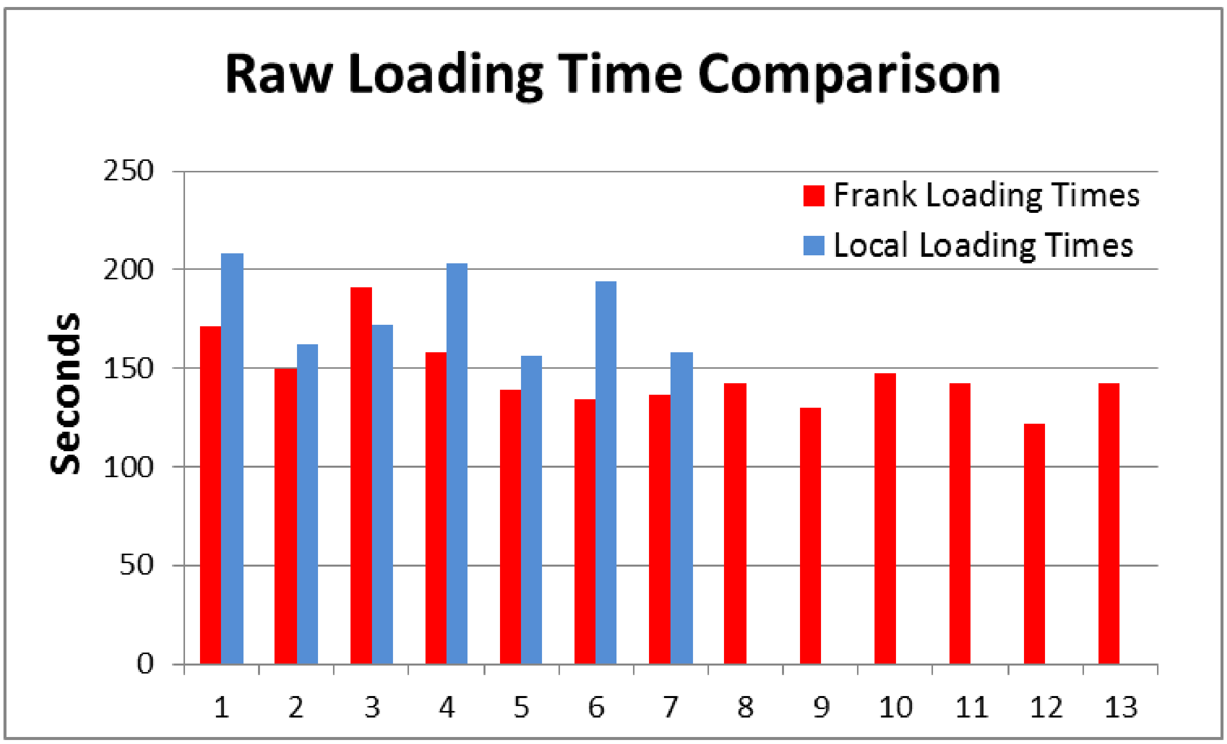



Figure B39: Comparison of loading times between an expert operator and local operator.

The averages are 174 and 142 seconds for the local and expert operator respectively. The expert operator thus outperforms the local operator by 31 seconds or 18%. A part of the inefficiencies arise from not digging full buckets, the local operator averaged six scoops whilst the expert operator averaged five scoops. Comparing the number of scoops assumes similar payloads. Due to the position of the observer and the condition of the on board scales exact payloads could not be recorded. The fluctuating scales did however seem higher for the expert operator. The provisional payload notes are shown in Figure B40:

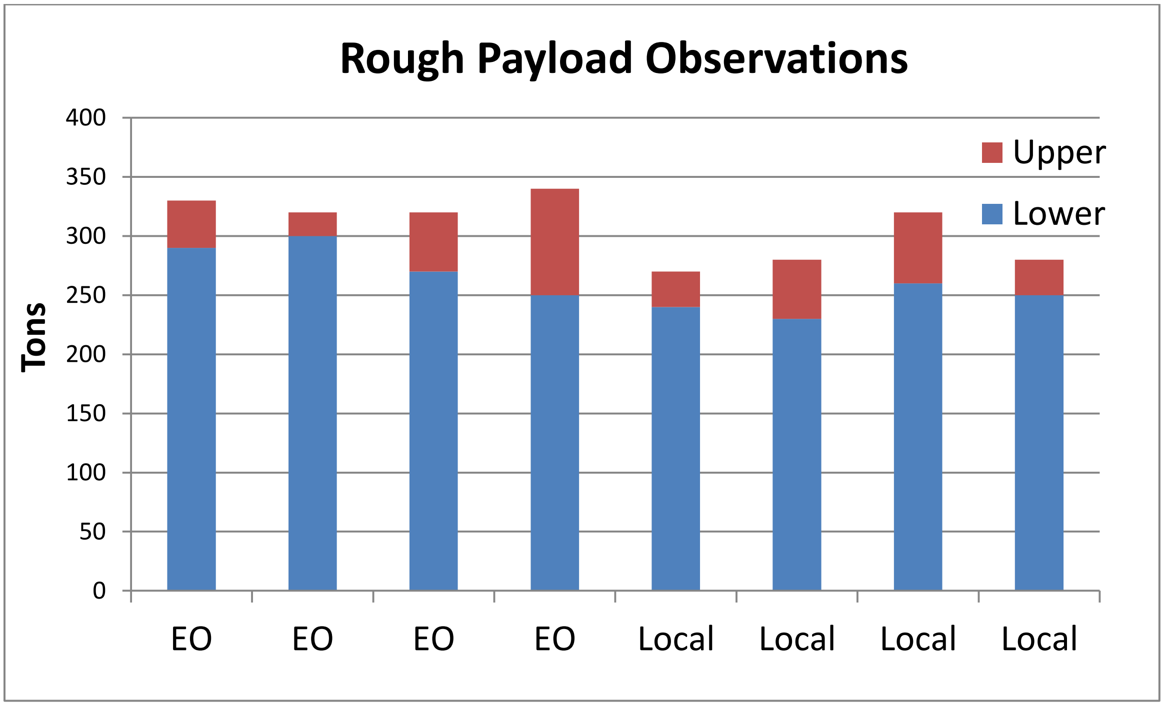



Figure B40: Rough payload observations during benchmarking

This data is not accurate, it does however consistently show that the expert operator (EO) tended to load more than the local operator. Lighter payloads were thus not the reason for the expert operator's swifter loading times.

Sishen's average cycle time of 2,000 seconds would be reduced by 1.6% with the 31 seconds by which the expert operator outperforms the local operator.

It must be noted that this was under easy loading conditions. This reduced the gap between operators of different skill levels. The biggest factor was that the operators were loading with a slow analogue shovel. As discussed with the foreman (Section H:1.1.6) S564 is the only analogue rope shovel left and is much slower than other shovels. A more skilled operator will outperform other operators even further on a quicker shovel. Other factors that reduced the possible gap were:

- ✓ The shovel was under trucked
- ✓ It was loading a stockpile with consistent material

Even though the expert operator outperformed the local operator by 20% under easy loading conditions many incidents involving the local operator were ignored. They could not be numerically calculated with a small data pool but negatively affect cycle times and overall utilization. Whilst the expert operator had no incidents or delays the local operator had the following issues:

- Failed to see trucks, lost 108 seconds.
- Failed to see truck, truck hooted.
- Had to call a grader to clean loading area.
- Scales indicate under loading, the accuracy was uncertain, but it was visually confirmed.
- Asked truck to re-spot, lost 38 seconds.

These issues were all observed during only seven loading cycles.

Assuming that the above is typical and incorporating delays into the local operator's loading time adds 21 seconds to the local operators loading time. When this is taken into account the expert operator only takes 73% as long to load a truck. That is 52 seconds less or a reduction in average cycle time of 2.6%. Bad loading practices, spilling rocks specifically, resulted in the local operator having to call in a grader to clear the loading area. This takes close to 10 minutes, considering only 7 loading cycles were done another minute can be conservatively added to the local operators loading time. When this is taken into account the expert operator only takes 55% as long to load a truck. That is approximately 110 seconds less or a reduction in average cycle time of 5.5%. This information is summarised in Table B24:

**Table B24: Comparison of expert operators and local operators**

| (Loading Times) | Loading Time | % of Expert Operator's Time | Extra Cycle Time |
|---|---|---|---|
| Expert Operator Gross | 142 seconds | 100% | - |
| Expert Operator + All Delays | 142 seconds | 100% | - |
| Local Operator Gross | 174 seconds | 123% | 1.6% |
| Local Operator + Loading Delays | 195 seconds | 137% | 2.6% |
| Local Operator + All Delays | 255 seconds | 180% | 5.5% |

### B:2.2.3 Summary of Results

Figure B41 illustrates how the expert operator and Local operator compare. The numerical data can be found in Table B24.

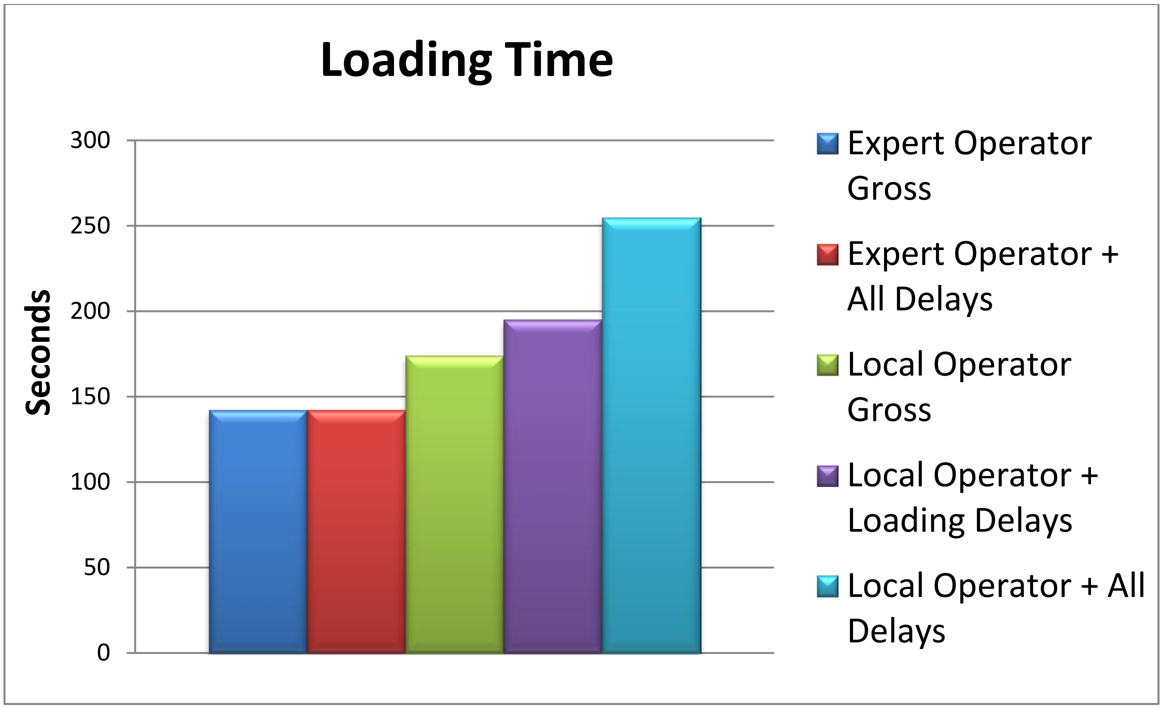



**Figure B41: Loading time benchmarking**

It was found that the expert operator only takes 82% of a local operator's gross time to load a truck. This saves approximately 30 seconds per cycle. When delays are taken into account the local operator performs much worse. If the delays are taken to be typical the expert operator loads close to twice as fast as a local operator which saves more than 5% on an average cycle. The expert operators were also observed to load better payloads.

### B:2.2.4 Conclusion

Local truck operators do not perform as well as industry leaders. Approximately 1.6% is added to an average cycle time by slow gross loading times alone. When other factors and delays are considered the 1.6% can be higher than 5%.

The expert operators do physically load faster. They take approximately 80% of the time it takes a local operator to load a truck, yet the big inefficiencies with local operators lie in delays. Some of these delays are due to a lack of concentration (taking 108 seconds to realise a truck is waiting) whilst others are due to bad loading practices (spilling rock). It is imperative that better training and incentives or selection procedures are put in place to enable and motivate local operators to perform better.

### B:2.3 Results Summary

On final spotting time and exit time alone the expert operator saved 18 seconds per cycle on average when compared to a local operator. Gross loading time was 31 seconds faster on a shovel. When some of the other delays were taken into account on the shovel the cycle time of the expert operator was 5.5% faster compared to 1.6%. It is fair to assume that other factors in the truck cycle time will see the 0.9% jump up as well. Noting the value of a 1% reduction in cycle time as determined in Section F Table B25 lists all the measured additional time to a cycle of average length compared to the expert operators and its value to Sishen:

**Table B25: Additional average cycle time compared to expert operators**

| Task | Extra Cycle Time | Annual Value |
|---|---|---|
| Truck Final Spotting | 0.5% | R125 million |
| Truck Exiting | 0.4% | R100 million |
| Shovel Loading Gross | 1.6% | R400 million |
| ***Truck Net Loss Estimate*** | ***3.2%**** | ***R800 million*** |
| ***Shovel Loading Net Loss Estimate*** | ***5.5%**** | ***R1,375 million*** |

*Estimate based on measured delays due to operator as shown Section B:2.2.2.

**Estimate based on the proportion the shovel's gross and net loss differs.

The delays considered are not comprehensive. Even the shovel and truck net loss estimates do not consider second degree delays such as the maintenance consequences of bad driving techniques or delays due to wrong digging angles.

### B:2.4 Discussion

When the directly measured delays are summed it is found that having skilled operators on shovels and trucks will decrease average cycle times by 2.5% (0.5%+0.4%+1.6%) which is worth around R600 million per annum. This value can be very misleading as first degree delays such as failing to see a waiting truck or spilling rocks on the manoeuvring area is not considered. It is estimated that these first degree delays push the 2.5% up to around 9% (5.5%+3.2%) or R2 billion. This figure is only a rough estimate and the linearity of financial estimation may not hold under large percentage increases. If second degree delays such as the maintenance consequences of bad driving techniques or delays due to wrong digging angles are considered the figure would most likely be even higher.

Based on the observations it would be conservative to estimate that expert operators outperform local drivers by 10% when physical loading speed, first and second degree delays and other cascading affects are taken into account. It would be very difficult and expensive to determine an accurate percentage when all physical, primary and secondary delays are taken into account, what is however apparent is that local drivers do not perform as well as they could.

It has been observed with shovel and truck operators the local operators do not posses the same level of operational expertise as the expert operators. Delays and inconsistent performance measurements suggest that the physical skill is only a part of the problem, determination and commitment seems to be lower as well. This suggest that there is no simple action that can be taken to improve the situation, a comprehensive plan needs to be put in place that motivates personnel. This needs to be done parallel to improved training and selection processes.

### B:2.5 Conclusion

Local operators are outperformed by the expert  operators on site. This is due to both slower physical operating speeds and lower levels of motivation. Physical losses on average cycle times are 2.5% for the measured component with first degree delays pushing this figure up to an estimated 9%. This still excludes second degree losses. These figures indicate that operator performance is an area where improvements are possible that can significantly increase the overall utilization of HME at Sishen.

The physical measurements prove that local operators do not posses the same skill as industry leaders. Simply training drivers more rigorously will not solve the problem however, observed delays and inconsistent performances suggest that the local work ethic has to be improved as well.

As seen by the estimated R2 billion that physical and primary delays from truck and shovel operators cost Sishen operator efficiency is a key component of efficient HME utilization. It is suggested that management put structures in place that are able to monitor and motivate individual performances. This is to be done in parallel with effective training and selection processes.

# APPENDIX C: SAP Data Collection

# Executive Summary

The data recorded on SAP for maintenance purposes was studied. It was found that the reliability of this data is an issue impeding its use for strategic decision making.

Figure C42 shows the proportion of the data that is useable after incorrect and incomplete data entries are filtered out as well as the proportion of data that can be used when incorrect and incomplete data is analysed and remedied:

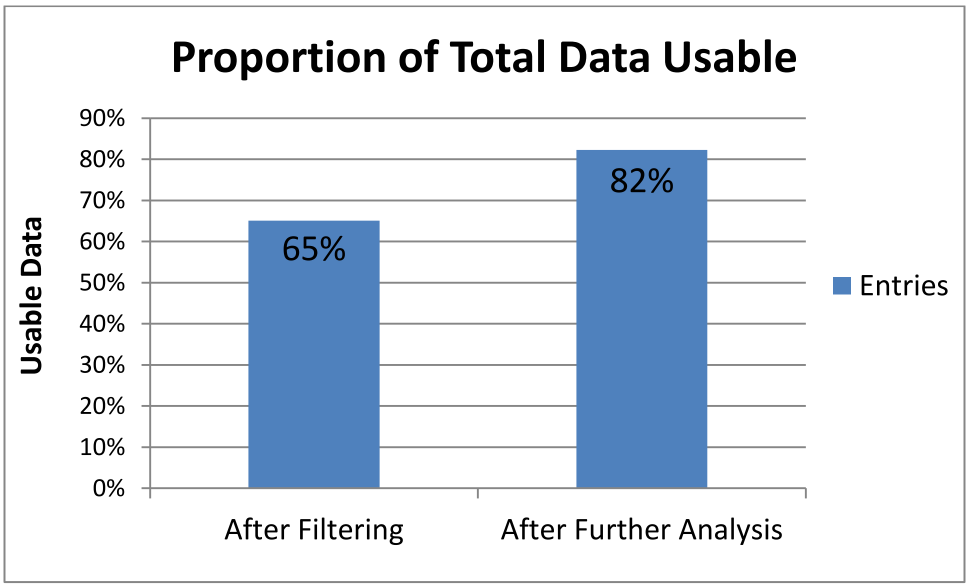



Figure C42: Number of entries and recorded times on SAP that are correct

Only 65% of entries were correct, the complex process of analysing and correcting the incorrect entries allowed 82% of entries to be used. This represents 17% of the total recorded time. Management is unlikely to have the time to go through the incorrect entries. They will thus only be able to make decision based on 65% of the total number of entries. The information can thus not be used for accurate monitoring or strategic decision making.

It is suggested that the process by which data is recorded be improved. A specific person has to be responsible to check that all entries are complete after each shift. A little more effort can greatly increase the reliability of the maintenance data recorded on SAP. This will enable management to confidently use the data to make strategic decisions.

# Contents

## C:1 SAP at Sishen

The maintenance department at Sishen uses a system locally referred to as "SAP". SAP is the world leader in enterprise software and software-related services in terms of revenue. They are headquartered in Germany (13). The use of SAP in the area of breakdown data collection for the purpose of data analyses will be studied, henceforth this report will refer to that use and function with "SAP".

Data was obtained from SAP for the period 1 October 2011 to 31 September 2012 to perform an analysis. It was found that the consistency and completeness of the data was not sufficient to yield reliable results. This was only for haul truck, not shovels. This is done as the Section Engineering Manager: Mining Maintenance Primary describes the trucks as their bottle neck. Any findings or improvement to the system can be implemented at other sections if they are found to work effectively.

### C:2.1 Overview

#### *C:2.1.1 Breakdowns*

When primary equipment breaks down it is recorded on SAP. Dispatch logs a time and description. The problem code or classification, notes and end time are finally recorded by the technician or person called out to fix the machinery. The job card or notes taken by the person fixing the machinery is entered into SAP by a clerk.

#### *C:2.1.2 Mistakes and Incomplete Entries*

The student and a senior planner identified the follow problems with the analysed data which consisted out of 27,332 entries

- Massive hours – some entries had inflated hour counts (such as 3 months), yet when checked against dispatch the truck were operational during the period.
- No hours – some entries had zero hours, due to not being closed of.
- Small hours – some entries had unrealistically low hours.
- No category – many entries had not been put in a category.
- No operator – many entries were put under the category, "no operator", yet they had various problems, and in other cases no problem.

A rough estimate showed at least a 3rd of the entries were compromised. This renders the data unreliable.

### *C:2.1.3 Uses of Data*

As outlined in the interview with a senior planner Section H:1.1.2 one of the primary uses of the data is for analytical purposes. It can be used to access information such as; what causes most of the down times or how different factors are trending. This information can be used to concentrate efforts and plan maintenance, yet such decision making can not be made on unreliable data.

## C:2.2 SAP Data Analyses

The data was studied to determine how reliable it is. The following issues were identified with the data covering the period from 1 October 2011 to 31 September 2012:

### *C:2.2.1 Massive hours*

Thirty seven of the entries showed times in access of 500 hours. This accounts for 83% of the total recorded time. Figure C43 shows what effect simply ignoring these suspicious entries has on the data:

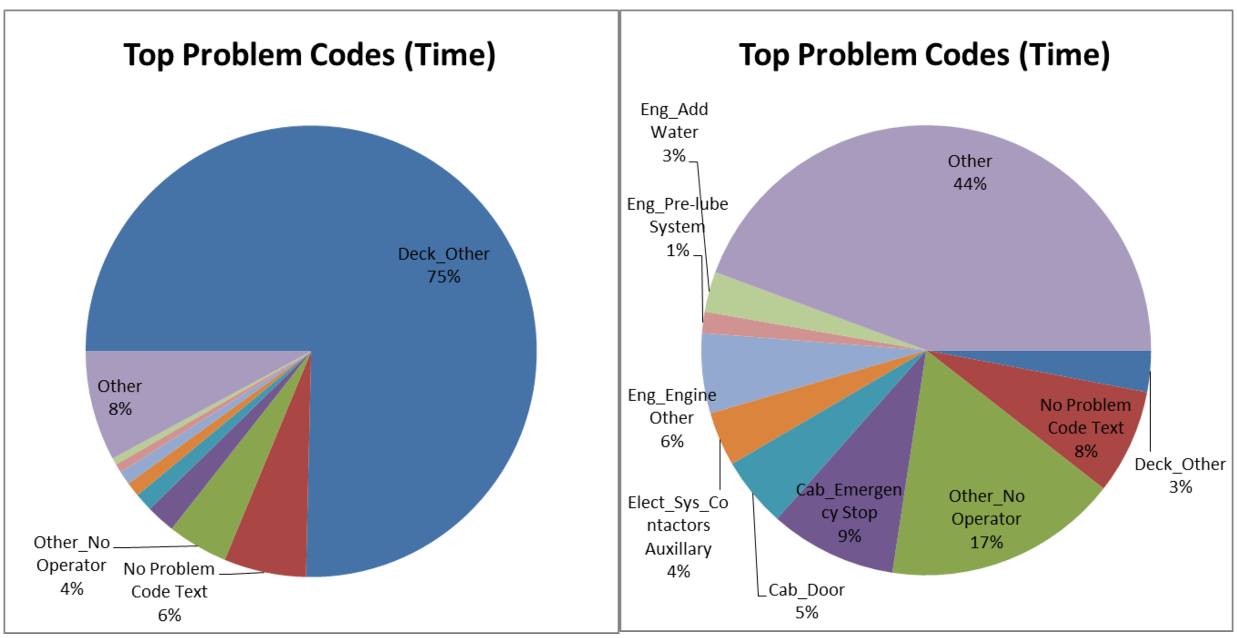



Figure C43: Ignoring the entries with unrealistically large times changes the downtime proportions to the right hand pie chart

Note how "Dech_Other" overshadowed the data, yet removing the 37 out of 27,332 false large entries ,which makes up 83% of the total time, gives a more realistic picture. Knowing how accurate this assumption is will be hard to determine.

### *C:2.2.2 No hours and unrealistically low hours*

Two thousand two hundred and seven entries showed no time. This is due to them having no closing date. A further 2,621 entries showed 10 minutes or less, which is deemed unrealistically low and thus compromised. The 10 minute mark was chosen by the senior planner as a realistic cut-off time for the purpose of this analysis. Omitting these 4,828 entries has no effect on time and the effect shown in Figure C44 on the number of reported breakdowns:

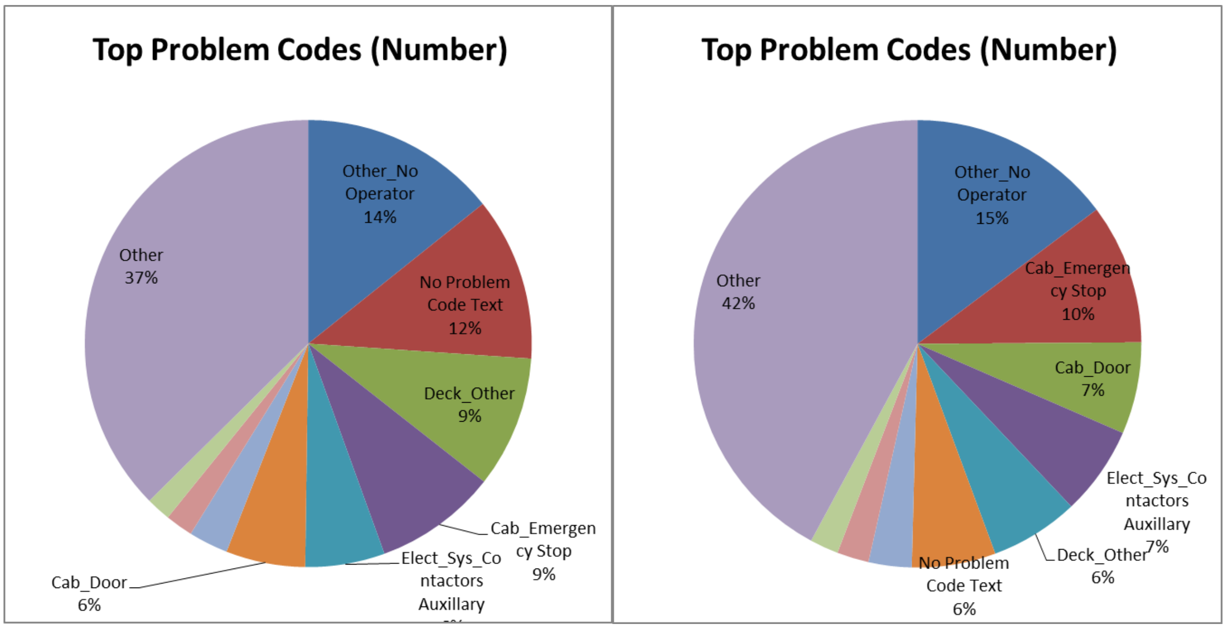



Figure C44: The changes in number of entries if zero time entries are ignored

Only a small change is observed with "Other_No Operator" going from 14% to 15%, "Cab_Emergency Stop" going from 9% to 10%, "Cab_Door" going from 6% to 7% and "Deck_Other" going from 9% to 6%. The latter is the only significant change aside from "No Problem Code Text" which went from 12% to 6%. This is illustrated in Figure C45:

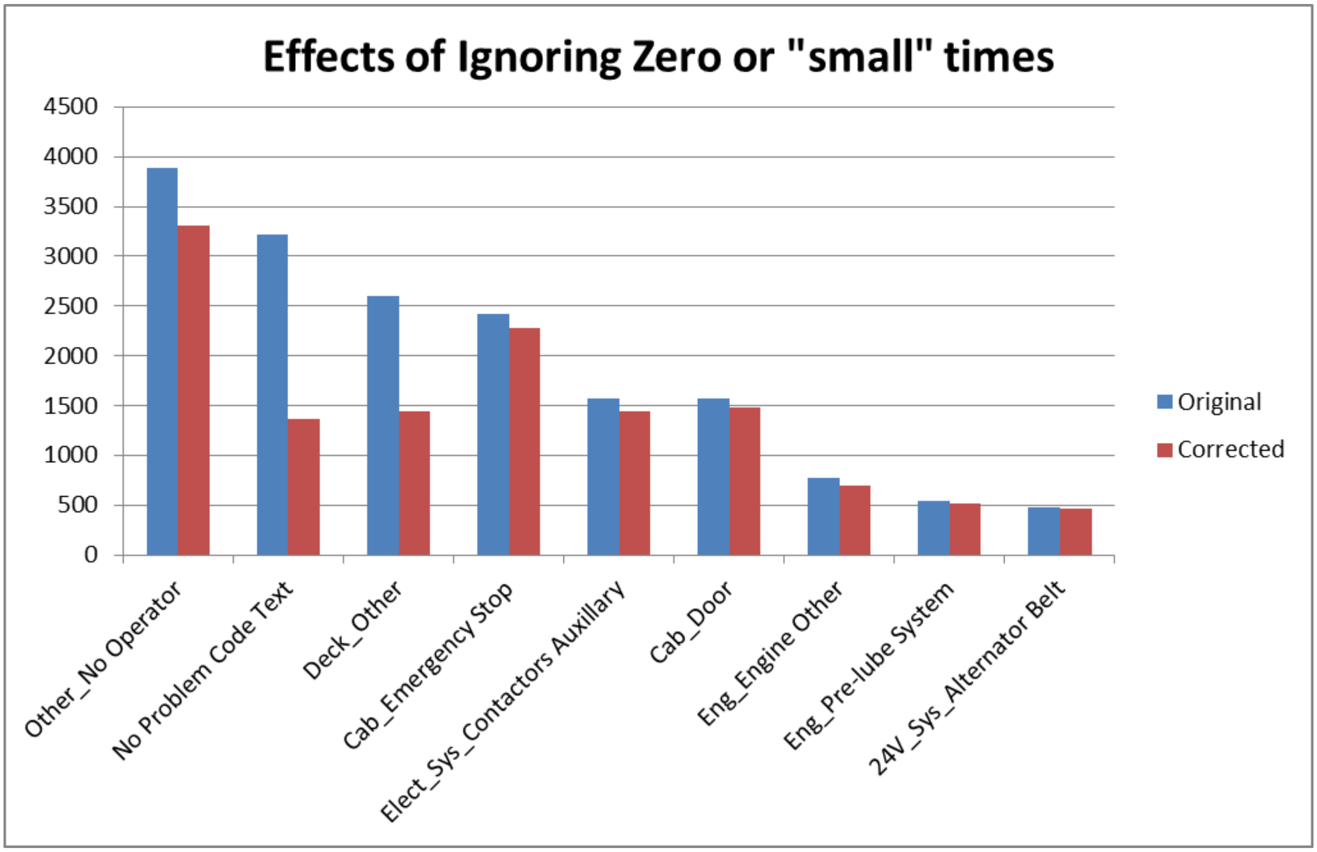



**Figure C45: Changes for different categories when zero time entries are ignored**

Aside form “No Problem Code Text” and “Deck_Other” the changes are small and similar. It is thus safe to assume that zero time mistakes are not category specific.

### *C:2.2.3 No Category and No Operator*

Some entries had empty fields whilst others had “Other_No Operator”, both represented various occurrences. Attempting to analyse the data as in Section C:2.2.5 can identity some of the categories (approximately 4,000 out of the 7,134), yet this is time consuming and will not be done by a manager trying to analyse the data. Figure C46 shows the effect of ignoring these 3,222 empty fields and 3,912 “Other_No Operator” fields (after ignoring the massive hour entries):

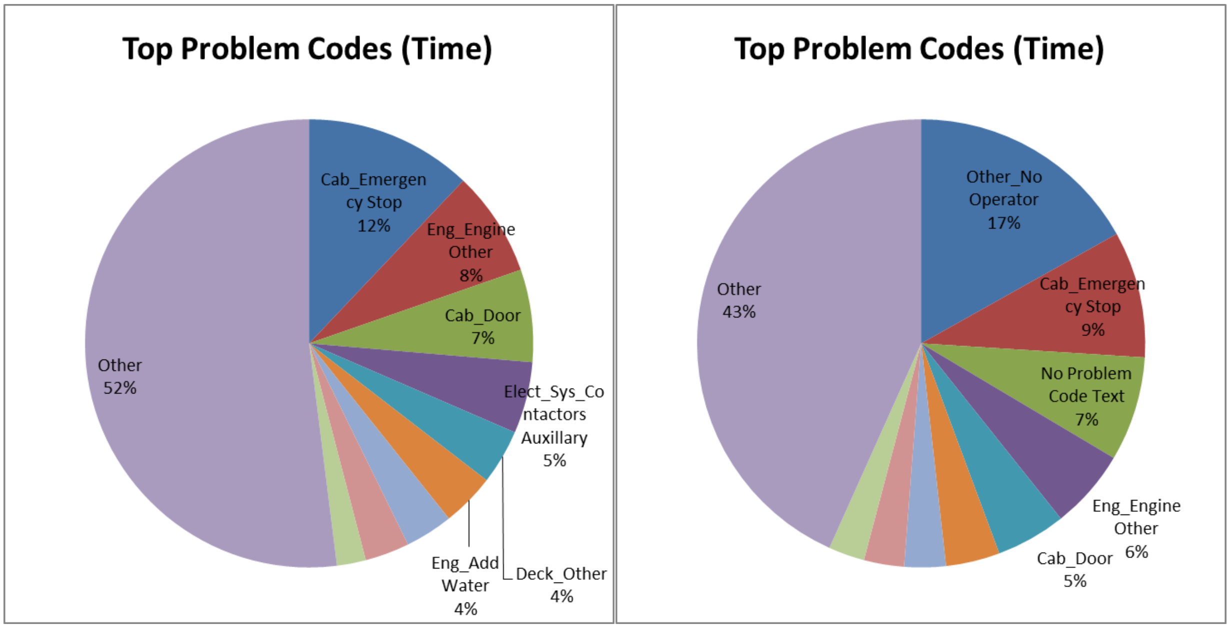



Figure C46: The changes in number of entries if undefined entries are ignored

All absolute values remain the same aside from "Other_No Operator" and "No Problem Code Text" which disappears. It is thus safe to assume that the error is not category specific.

### *C:2.2.4 Simultaneous filtering*

Applying all these filters or changes simultaneously results in the proportions shown in Figure C47:

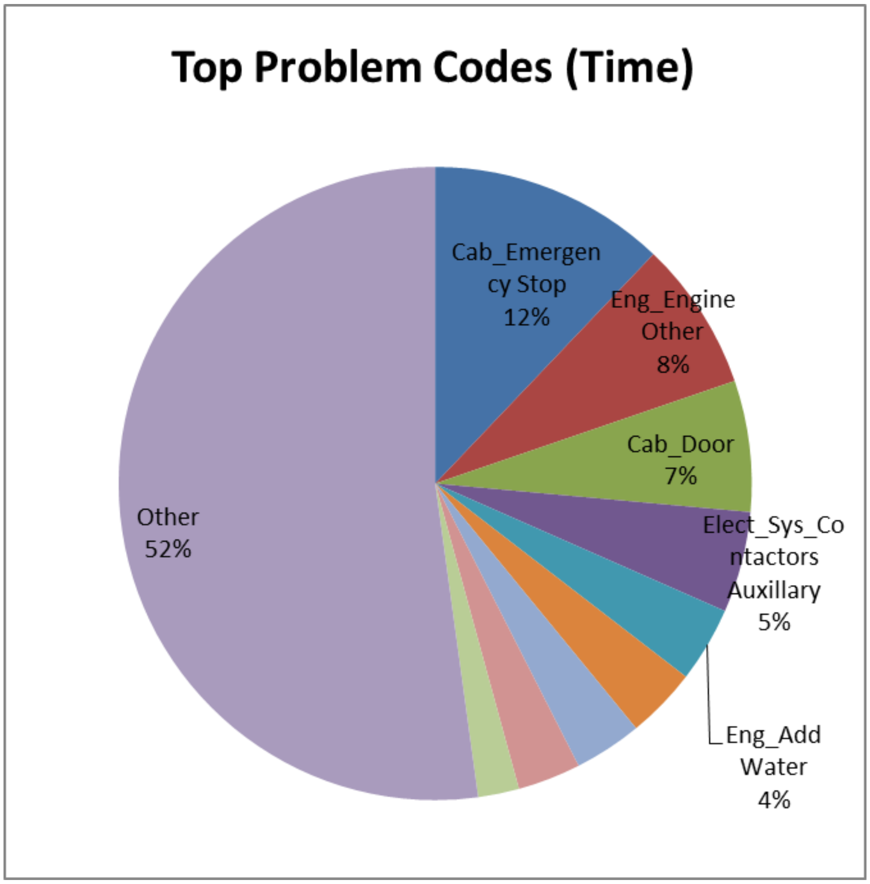



**Figure C47: Problem code proportions after all filtering is done**

This accounts for 17,785 out of the original 27,332 entries or 25,198 out of the original 198,757 hours. That is 65% the original number of entries and 13% of the original time.

### *C:2.2.5 Undefined Entries*

The remaining 7,314 undefined entries were systematically sorted into categories. This was done by searching for key words in the descriptive columns and matching entries with relevant categories. The steps followed are shown in Table C26:

Table C26: Steps followed to categorise undefined entries.

| Step | Action | Zone Searched | Search Keywords | New Definition | Instances |
|---|---|---|---|---|---|
| 1 | Find and enter definition in “Problem Code Text” | “Short Description of Notification” and “Item Text” | “Aircon” (confirm relevance) | “Cab_Air Conditioner” | 289 |
| 2 | Find and enter definition in “Problem Code Text” | “Short Description of Notification” and “Item Text” | "Radio" (confirm relevance) | "Cab_Radio Two-way" | 99 |
| 3 | Replace remaining empty “Problem Code Text” | - | - | "Other_NoProblemCodeTextandNOTIME" | 1475 |
| 4 | Find and enter definition in “Problem Code Text” | “Short Description of Notification” and “Item Text” | "Alternator" (confirm relevance) | "24V_Sys_Alternator" | 8 |
| 5 | Find and enter definition in “Problem Code Text” | “Short Description of Notification” and “Item Text” | “geen”, “verkeer”, “fout” or “afgeboek” (confirm relevance) | "Other_VerkeerdAfgeboek" | 848 |
| 6 | Find and enter definition in “Problem Code Text” | “Short Description of Notification” and “Item Text” | “diesel” (confirm relevance) | "DTank_Diesel Tank" | 118 |
| 7 | Find and enter definition in “Problem Code Text” | “Short Description of Notification” and “Item Text” | “skiet” (confirm relevance) | "Other_Uitgejaagvirskiet" | 33 |
| 8 | Find and enter definition in “Problem Code Text” | “Short Description of Notification” and “Item Text” | “self” (confirm relevance) | "Other_SelfFix-NoProblem?" | 476 |
| 9 | Find and enter definition in “Problem Code Text” | “Short Description of Notification” and “Item Text” | “tyre monitor” or “tyre” (confirm relevance) | "Other_Tyre and Monitor" | 953 |

| | | | | | |
|---|---|---|---|---|---|
| 10 | Mark unknowns | - | - | “Other_ No Operator Various” | 2744 |

Figure C48 shows the problem code proportions following the steps in Table C26:

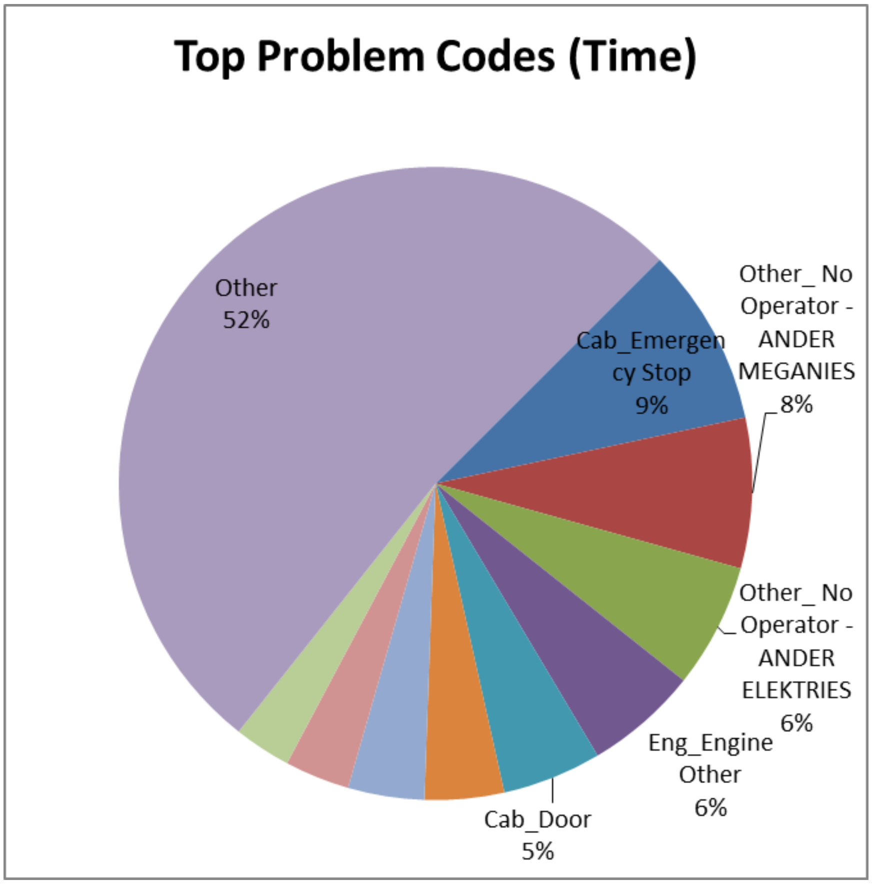



Figure C48: Problem code proportions after analysing unknowns

This accounts for 22,486 out of the original 27,332 entries or 33,346 out of the original 198,757 hours. That is 82% the original number of entries and 17% of the original time. It thus makes use of another 17% of the total entries and increases the time represented by 32% (25,198 to 33,346).

When these results are compared to the simply filtered result of Section C:2.2.4 the differences shown in Figure C49 and Figure C50 are observed:

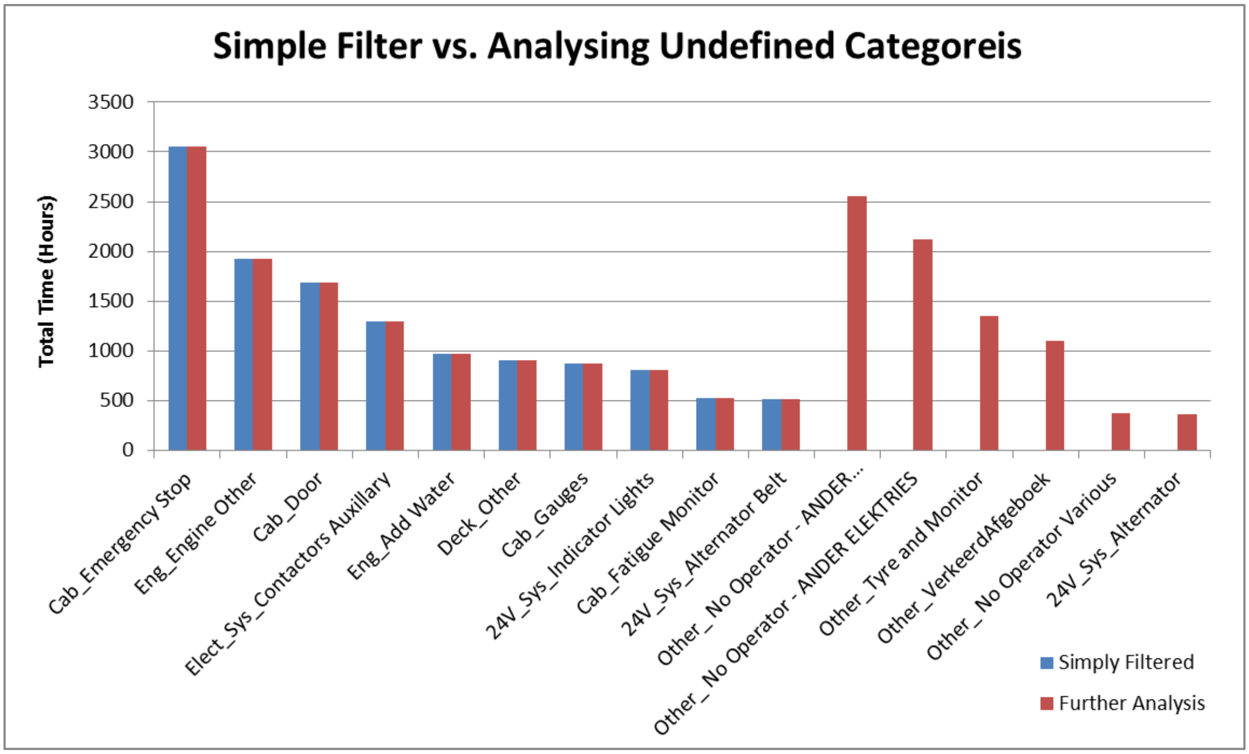



Figure C49: The difference in downtimes between applying a simple filter and analysing incorrect entries

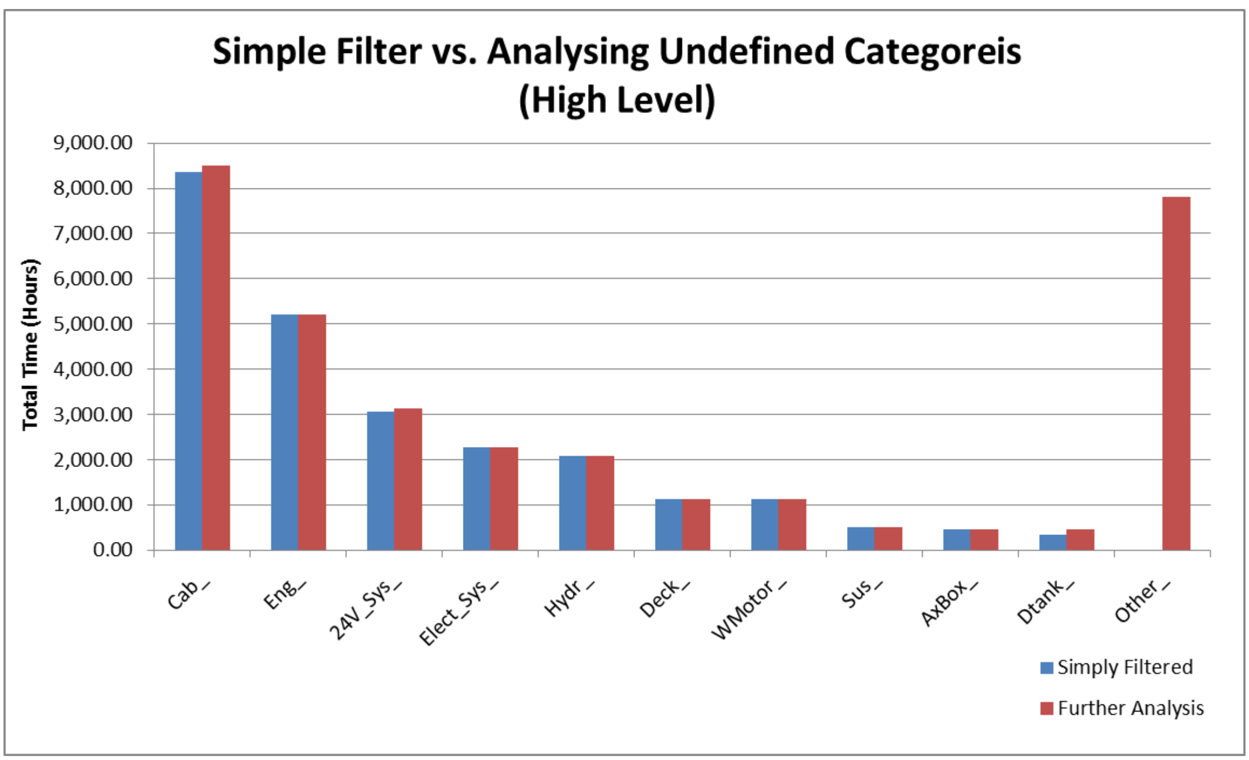



Figure C50: The difference in downtimes between applying a simple filter and analysing incorrect entries for main categories

It is clear that simply using the filtered data ignores a substantial section of the data and will lead to wrong decisions. As an illustration of this it can be seen on Figure C49 that "Other_Tyre and Monitor" is the forth most time expensive category, and needs more attention than "Alternator Belt" for instance.

It must also be noted that this further analysis does not provide much useful information, aside from illustrating that there is a big unknown. It can thus not be seen as a solution.

In addition to the above mentioned there are 4,828 entries missing, 2,207 showing no time and 2,621 deemed to shown unrealistically low times. If these entries were entered correctly they are likely to make a considerable difference to the result as well.

## C:3 Findings

The data was found to be incomplete and incorrect. Figure C51 shows the number of entries that had specific problems:

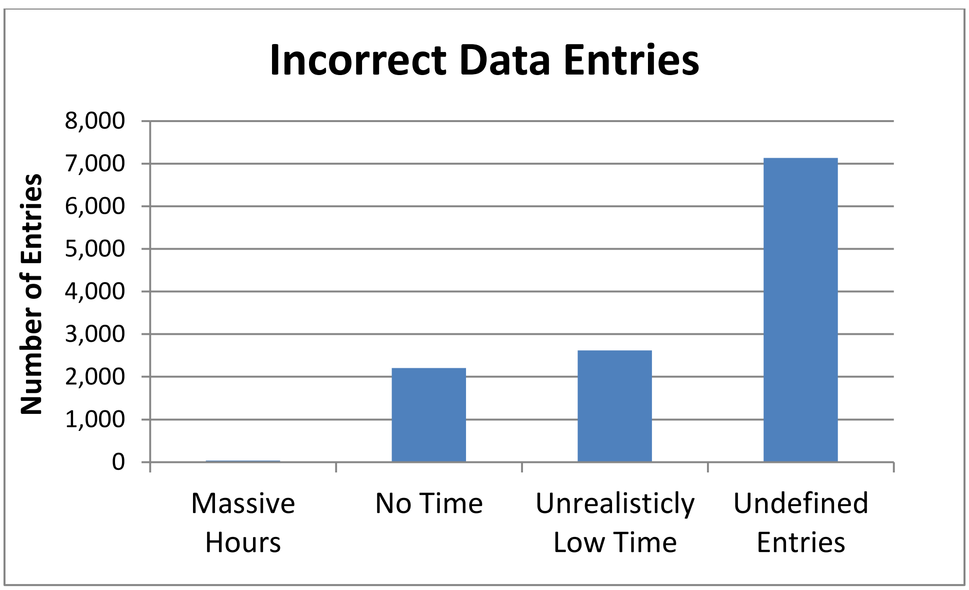



Figure C51: Number of incorrect data entries per type of mistake

The data thus needed to be filtered to get usable information. Yet this filtering process left to many unknown entries and times. An analysis was needed to correct and identify the incorrect and unknown entries to make a larger portion of the data available for analysis. Figure C52 shows the number of entries and portion of total entry time that was usable after filtering and further analyses:

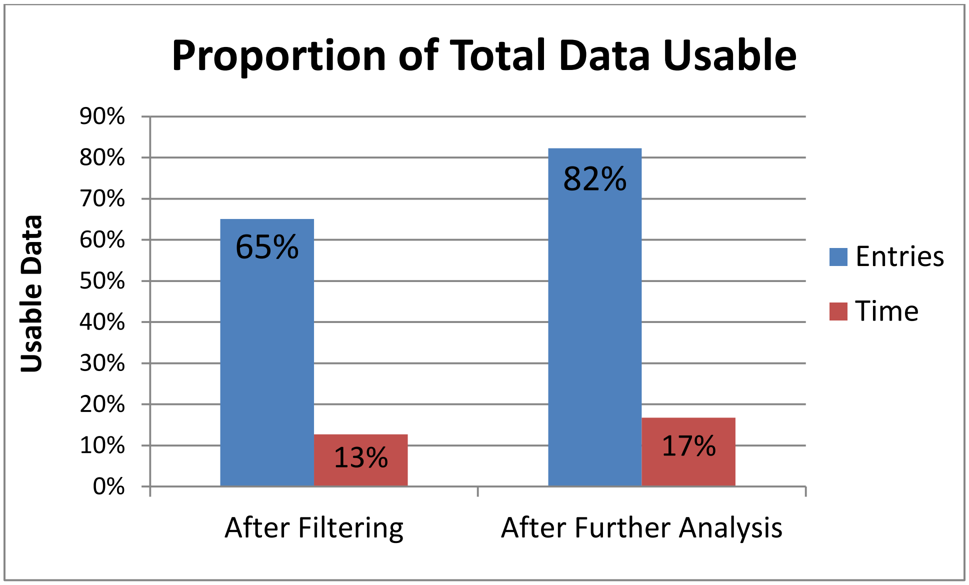



Figure C52: Proportions of data usable after filtering and analysing undefined entries

The data shows that filtering is needed before any analysis can be done with the data, yet only 65% of entries can then be used. An extensive analysis enables a further 17% of the data to be used. This process is time consuming and still leaves 18% of the data entries unusable.

## C:3 Discussion

The SAP system used by maintenance aims to record all the break downs. This creates an opportunity for precise analysis, trend tracking and strategic planning. Yet the system is not reliable enough to be confidently used in this manner. A comment made by a senior planner during an interview recorded in Section H:1.1.2 seems to be accurate; 80% of the work is being done but shows little benefit, the last bit of effort is needed to get the system operating reliably and yielding results that management can use with confidence to form maintenance plans and adjust for observed trends.

In order to implement this somebody must take responsibility, ensuring data is entered correctly, and following up on mistakes. The year analysed had 27,332 entries, it equates to 77 entries per day. Checking up to a 100 entries a day is a manageable undertaking, the challenge will be in following up on mistakes. As discussed the year analysed had 7,314 entries which were incorrect, the average is 20 per day. It can be assumed that once mistakes are followed up on they will decrease as knowledge of the expectation spreads.

This calls for a person to spend 10-30 minutes each day checking the previous day's mistakes, and then an hour or two correcting them. Once people start entering data correctly, something that takes little extra time, the mistakes become fewer and fewer.

## C:5 Proposal

### C:5.1 Memorandum

A proposal was made to give the above mentioned task to a person for a trial period. This was to be for trucks only. The workload would be less than mentioned above due to the decreased number of trucks operating after the strike. The memorandum of the proposal that was made with the backing of the SEM : Mining Maintenance Primary as well as that of the senior planner can be found in Section H:2.1.

### C:5.2 Non-Acceptance of Proposal

The proposed trial was not implemented.

The department heads were not happy with the idea despite the SEM and the senior planner's support. Since the 2013 budget plans to appoint more clerks the decision was made to take no action at this stage.

## C:6 Recommendation and Conclusion

It is strongly recommended that the process whereby data is entered into SAP be revised. At present only 65% of the data is correct resulting in low reliability: management can thus not use the information to make strategic decisions.

Most of the required work is already done, yet the resulting data is unreliable. A little more effort is required to unlock the full potential of a system that can greatly aid strategic planning and monitoring.

# APPENDIX D: Air Conditioning Units

# Executive Summary

It was found that problems with air conditioning make up approximately 2.5% of the total haul truck downtime. SAP data revealed that 730s and CATs are down for 12 and 14 hours per truck per annum respectively as shown in Figure D53:

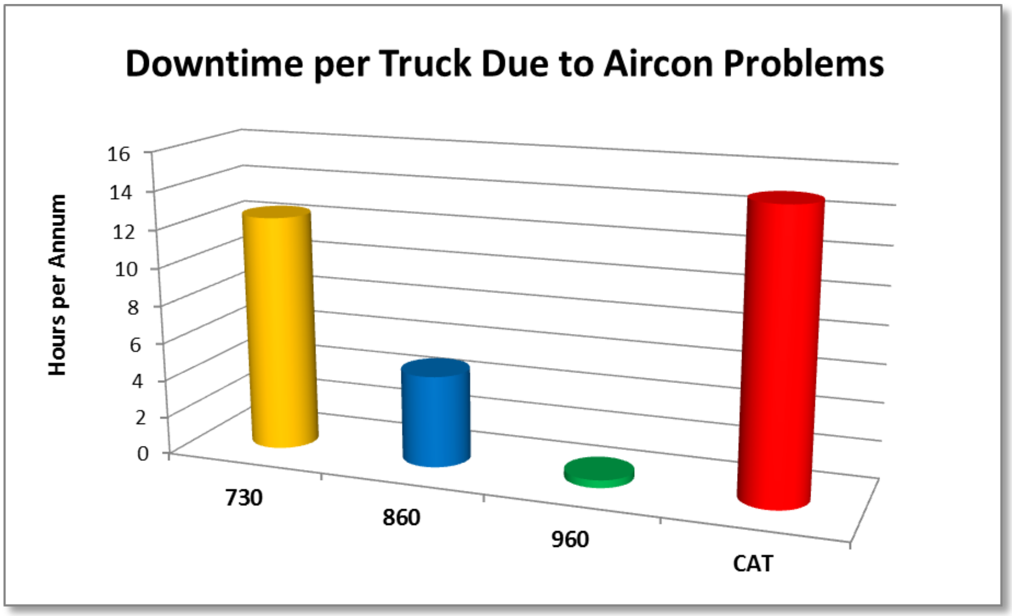



Figure D53: Annual downtimes due to air conditioning problems for different truck classes

A new separate 24V air conditioning unit is currently being trialled on a 730. The trial is nearing the end of its three month period with no breakdowns. A financial check showed that the downtimes in Figure D53 need to be reduced by only 3 hours for a new air conditioning unit to reach its breakeven point. As the trial is nearing the end of three months it is expected that the new unit's annual downtime will be considerably less than 12 or 14 hours.

Assuming the new unit causes three hours of downtime per annum and is replaced every year an annual saving of R12.5 million is expected.

It is thus suggested that the new air conditioning units be fitted on all 730 and CAT trucks as soon as possible. Monitoring the new unit's performance over an extended period of time will reveal whether it is worth installing them on 860s as well.

# Contents

## D:1 Introduction

During the summer months the temperatures for the area that Sishen is situated in regularly reach 40 degrees, conditions in the pit are even more extreme. Mining equipment can thus not be operated without air conditioning units (aircons).

During the study of maintenance data on the SAP system (Appendix C) it was found that approximately 2.5% of unplanned haul truck down time is caused by problems with air conditioning. As this percentage is relatively high for a component that makes up a small part of a heavy machine a further investigation was warranted.

## D:2 Investigation

### D:2.1 SAP Data

An investigation was conducted to determine whether the high frequency of aircon failures was consistent for all truck classes. By making use of maintenance data from Appendix C it was found that this is not the case. Figure D54 shows the average number of hours each truck class was booked down for aircon failures:

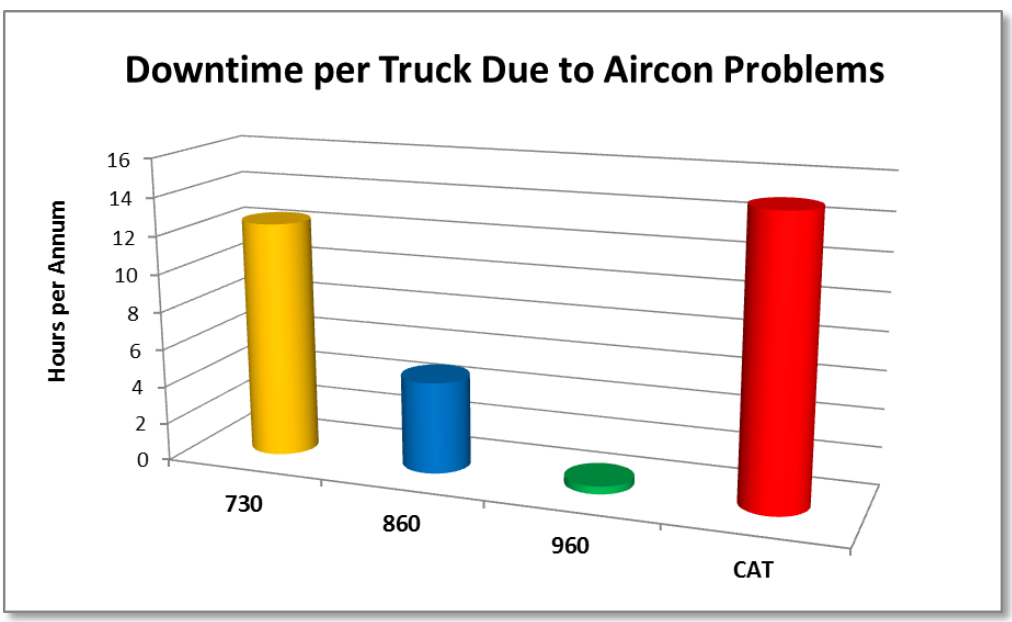



Figure D54: Annual aircon downtimes for different truck classes

Older trucks were found to have significantly more aircon problems than new trucks. The Komatsu 930Es had almost no downtime due to aircon failures, the older 860Es had around 4 hours of downtime per truck per year while the still older 730Es and CATs had well over 10 hours.

### D:2.2 Interviews

As aircon related downtimes were disproportionately high for 730s and CATs specifically the relevant management personnel were contacted. Deon Palm, General Engineering Supervisor – Trucks A, and Gielie Loots, Section Engineering Manager – Mining Maintenance Primary, was contacted. They revealed that they were aware of the problem, and that a new test unit had already been installed on a 730, designation f514-0557. This trial would run from the start of November through to the end of January.

## D:3 Trial Unit

### D:3.1 Operation Advantages

The trial unit is a separate 24V air conditioning system. This means that it can be easily installed on any dump truck. Some of the advantages on top of the suspected superior reliability include:

- ✓ Reduced idling times: The new 24V unit can run while the truck is turned of. As all trucks have separate battery packs this can be done without draining the batteries needed to start the truck. Trucks are often idling while they wait so that the drivers can remain cool. This puts a lot of wear on the system as extended idling causes issues such as incorrect oil pressures.
- ✓ Ability to carry spares: The units are relatively small and cheap, extras can thus be kept on hand ultimately reducing downtimes.
- ✓ Quick to replace: The units are built in such a way that they can be changed quickly. This is due to design consideration such as not needing to replace gas when changes are made.

### D:3.2 Financial Check

The cost of the trial unit was approximately R70,000, further units are expected to cost less when bulk orders are placed. According to Table D27 a loss of around R40,000 is estimated for each hour a truck is booked off unexpectedly:

Table D27: Rough calculation of the cost of downtime for a haul truck (source: operations)

| Critical assumption : Trucks is the bottleneck | |
|---|---|
| | |
| Truck tempo | 300 |
| Stripping Ratio | 0.25 |
| DMS yield | 83.20% |
| MA | 87.50% |
| UMA | 78% |
| Marginal Income | 600 |
| | |
| Ready Truck Hrs | 16.38 |
| Truck Prod / day | 4914 |
| Truck Ore Prod / day | 1,228 |
| Truck Ore Product tons / day | 1,022 |
| Income per Truck / day | R613,267 |
| | |
| **Income per Truck / hour** | **R37,440** |

Table D27 shows that two hours of downtime needs to be saved to pay for the new unit. This means that if a new unit is installed each year and a 730 goes down for aircon 10 hours minus the installation time instead of 12 hours the breakeven point would have been reached. Assuming it takes an hour to install the new unit nine hours of downtime marks the breakeven point.

If downtime is reduced by 25% (3/12) it would make the operation profitable.

The expected annual saving can be determined and is shown in Table D28 with the following conservative assumptions:

- New Unit Cost is R80,000 and replaced every year taking one hour.
- Truck Downtime Costs R40,000 per hour
- New Unit causes three hours of downtime per annum

Table D28: Expected annual savings

| | CATs | 730s |
|---|---|---|
| Number* | 8 | 43 |
| Annual Average Aircon Downtime** | 14 hours | 12 hours |
| Saved Annual Downtime | 10 hours | 8 hours |
| Annual Production Saving per Truck | R400,000 | R320,000 |
| Cost of New Unit | R80,000 | R80,000 |
| Net Annual Saving per Truck | R320,000 | R240,000 |
| Net Annual Saving for Truck Class | R2.56 million | R10.32 million |
| **Total Annual Saving** | **Approximately R12.5 million** | |

*Sourced from F:3.2

**Sourced form D:2.1

## D:4 Trial Status

At the time that this section was written, 9 January 2013, the new air conditioning unit had been operating for over two months without an incident. The truck operators have not reported any displeasure with the new unit's performance. Management plans to asses the situation after three months before placing bulk orders.

Due to the extent of the savings it is recommended that installation be done as quickly as possible.

## D:5 Summary

It was found that the downtime due to airon problems make up 2.5% of total downtimes for haul trucks. A 730 and a CAT loses 12 and 14 hours per truck on average each year. The 860s lose around four hours per truck per annum whilst the 960s have nearly no aircon related downtime.

Management is busy testing a new air conditioning unit, the test is nearly the end of its three month period: No incidents have been reported with the new unit at this stage.

If the downtime per truck is reduced by three hours the project would reach its break even point. This is very likely as current annual downtimes are above 12 and 14 hours for 730s and CATs and the new unit has already been operating for close to three months with no downtime.

It is estimated that the annual saving would be approximately R12.5 million.

## D:6 Conclusion

The decision to reduce haul truck downtimes due to air conditioning units that is currently in its trial phase will most likely result in a significant decrease in overall downtime. The new units should be installed as soon as possible on 730s and CATs due to the considerable expected savings. Monitoring the long term performance of the new units will reveal whether they should also be installed on the 860s.

# APPENDIX E: Payloads

# Executive Summary

Truck Payloads has been identified as one of the three key factors crucial to efficient operations. This section investigated the status quo at Sishen with the aim of identifying areas where improvements would add value. It was found that Sishen did a lot of work on payloads in the last year; this increased the average percentage of nominal payload to 96% for 2012 at the end of the available data range, end August, which is an improvement of 4% from 92% for 2011 and 2010. This is shown in Figure 12:

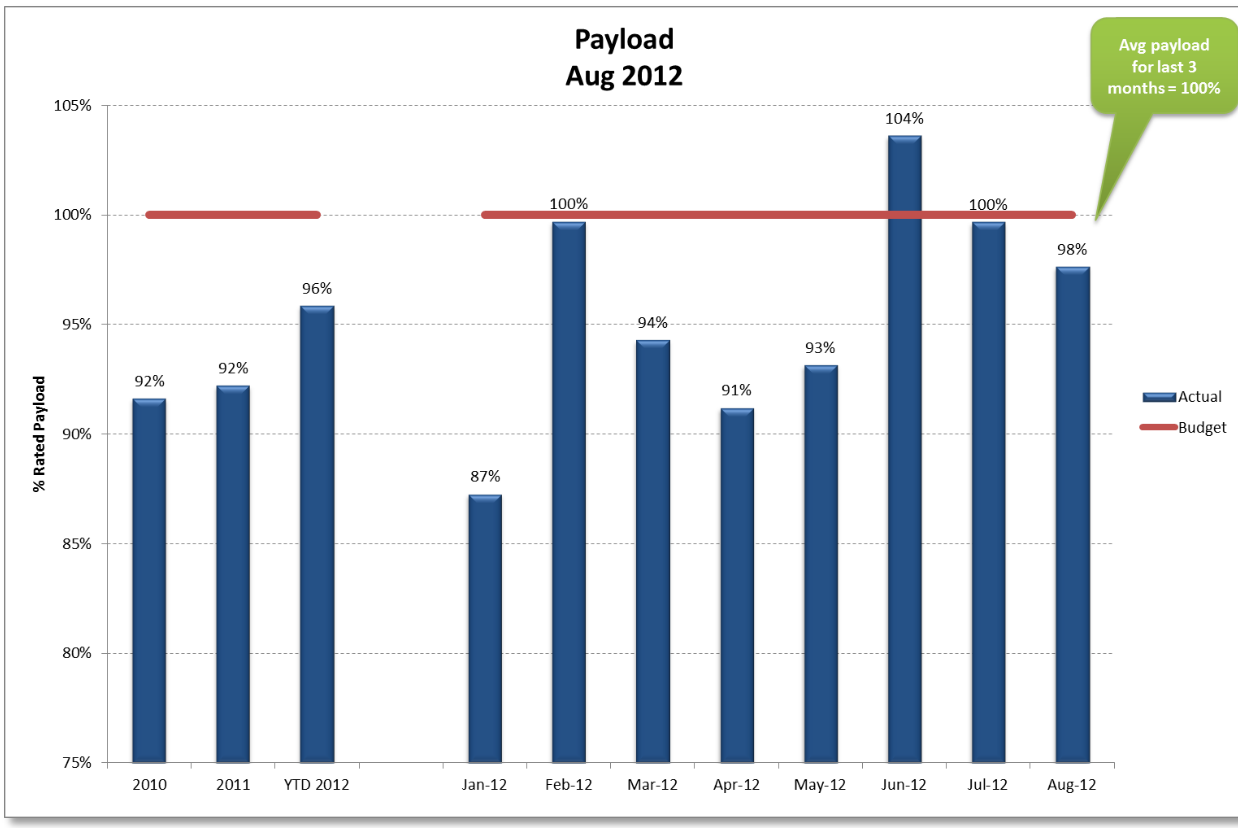



**Figure E55: Historic payload data for Sishen**

This means that further improvements are not possible without consciously deciding to ignore the manufacturer's guidelines. Before such a decision is made an in depth study should be undertaken to determine the negative effects of nominally overloading trucks even if the specified limit of 120% of the nominal payload is not exceeded.

Management should focus on ensuring that the payloads remain at 100% of nominal. In order to achieve this sustainably shovel operators should be supported as much as possible. The PLMs are to be kept in good working condition as they assist shovel operators to load correctly.

Partial passes should be considered. It has the potential to improve total tonnage by a considerable margin for situations where shovels are under trucked. For partial passes to be successful shovel operators need to know how full a truck is. This further motivates having PLMs in working condition.

# Contents

# E:1 Introduction

## E:1.1 Relevance

Payloads directly affect the overall utilization of HME capacity in mining operations. It is one of the three key factors crucial to efficient operations as noted in Section A:1 and can also be found at the top of the "The Value Rainbow" in Figure A23 as described by Krause (2) and discussed in Section A:1.4.1. It is thus important to monitor and optimise payloads.

## E:2.1 Challenges

When material is loaded and hauled with various trucks and loaders it is reasonable to assume that inefficiencies will arise. These inefficiencies result from under loading trucks or doing partially filled passes with the loader. This is unavoidable as the loading capacity of all trucks are not multiples of all the loaders' bucket volumes. Even in an ideal 'multiple' case the loader does not load an exact amount with each pass, yet it could be argued that the deviations are within limits for the truck.

A second consideration that has to be made is compatibility in the sense of, "what shovel can load what truck". In an ideal system every shovel will be able to efficiently load every truck. This ideal system is very flexible. Flexibility is useful when planning the operations or coping with defect machinery. Once certain shovels can only load certain trucks the system becomes more complex, less flexible and ultimately less efficient.

# E:2 Literature Review

Before the status quo at Sishen is examined a brief look at the literature is necessary to understand how Sishen is performing. Due to the competitive environment and differences between mining operations it is hard to benchmark payloads. One can however look at manufacturers' guidelines on equipment capabilities to determine whether equipment is being optimally utilised.

### E:2.1 Payloads Policy

Clear guidelines exist concerning the levels a truck may be loaded at. Both Komatsu and CAT ascribe to the 10-10-20 load policy criteria which is some times referred to as the “CAT 10-10-20 payload policy”, it can be found in most Komatsu (5) and CAT (6) brochures.

The above mentioned Komatsu brochures described the 10-10-20 load policy criteria as follows:

*“Recognizing that variation occurs naturally in material density, fill factors, and loading equipment, Komatsu America Corp. deems it necessary to establish a consistent payload policy. This payload policy is intended to identify the guidelines and limitations for the loading of Komatsu mining trucks, and is valid for approved applications and haul profiles only.*

- *The average monthly payload must not exceed the rated payload of the truck*
- *90% of all loads must be below 110% of the rated payload of the truck*
- *10% of all loads may be between 110% and 120%vof the rated payload of the truck*
- *No single payload may exceed 120% of the rated payload of the truck”*

This is illustrated on Figure E56:

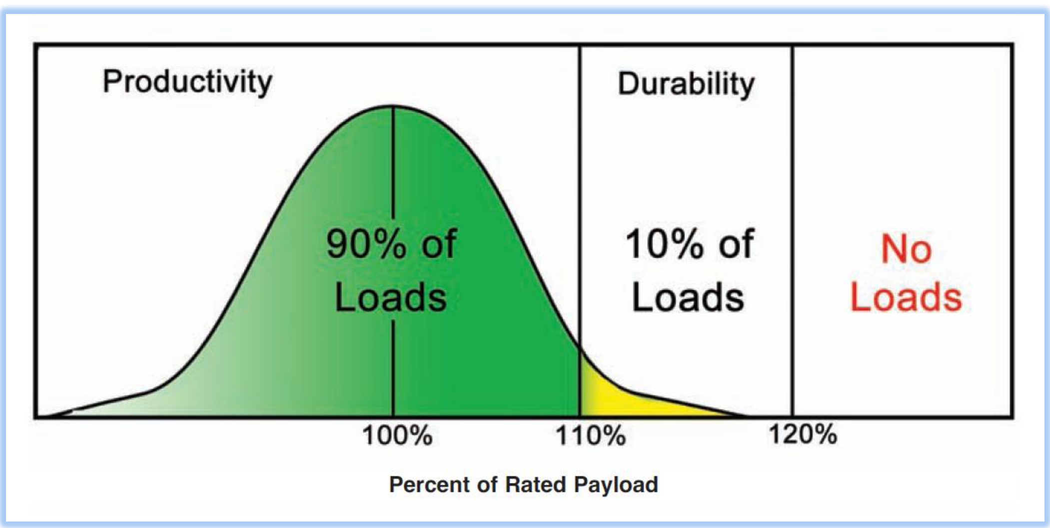



Figure E56: 10-10-20 Load Policy Criteria as found in Komatsu and Caterpillar brochures (5), (6).

The 10-10-20 load policy criteria makes it possible to have an average equal to the equipment’s rated tonnage, there is no need to operate safety below the this nominal value.

### E:2.2 Loading Practices – Partial Passes

As noted in Section E:2.1 whether or not to practice partial passes is an issue. Most research papers and popular handbooks in the field of earthmoving with trucks and loaders make no reference to the need for partially filled passes and consider only a whole number of full passes. These include Grove and Morgan (14), Smith et al (15), Lambropoulos et al (16), Smith (17), Kannan et al (18), and Marzouk and Moselhi (19).

Gransberg identifies the need to execute partial passes but disapproves of it, holding that is it poor practice (20). However, neglecting the partial pass militates against the achievement of the objective goal of the activity, which is hauling; thus such a choice should be justified. Furthermore Schexnayder et al propose the avoidance of the partial pass by selecting truck and loader combination that allow the achievement of the maximum load with a whole number of passes (21). This requires that the capacity of the truck is an exact multiple of the cooperating loader's capacity, which is a rather unreasonable expectation. On the other hand Burt and Caccetta approve the partially filled pass provided that a rule of thumb, requiring the use of at least a third of the bucket's volume, is applied (22).

In summary the literature is in favour of full passes, while the execution of partial passes has not been systematically evaluated. A recent paper by Marinelli and Lambropoulos (23) introduces a method which evaluates the impact of executing a last, partially filled pass on the unit cost of earthmoving with a fleet of loaders and trucks. As could be expected it found that savings could be made, but that a variety of factors needs to be taken into account, these include:

- Distance
- Fill of last pass
- Demand (availability of trucks)

## E:3 Status Quo at Sishen

This section takes a look at how Sishen operates and how well they are currently performing.

### E:3.1 Sishen Fleet

The Sishen fleet size based on the MMS DISPATCH Report System on the 30th of September 2012 (just prior to the 2012 October strike) is shown in Table E29:

Table E29: Sishen fleet on 30 October 2012

| ***HAUL TRUCKS*** | Number | Sishen Operating Weight (Ton) | Industry Norm (Ton) |
|---|---|---|---|
| Komatsu 960E | 13 | 320 | 327* |
| Komatsu 860E | 41 | 254 | 254* |
| CAT 793D | 8 | 220 | 216* |
| Komatsu 730E | 43 | 190 | 181* |
| Komatsu HD785 | 4 | | 91* |
| Euclid 85 | 10 | | 77.1* |

*Industry Data Sourced from Komatsu, Caterpillar and Volvo Company Brochures: (5), (24), (6), (25), (26) and (27). Sishen Figures from Payload Reports by Izak Moolman.

The fleet at Sishen is currently being ramped up according to a five year plan released in October 2009. This plan takes care to match loading and hauling equipment as well as possible to reduce the problems outlined in Section E:2.1. Figure E57 shows the how the Sishen fleet expansion project matchers loading and hauling equipment:

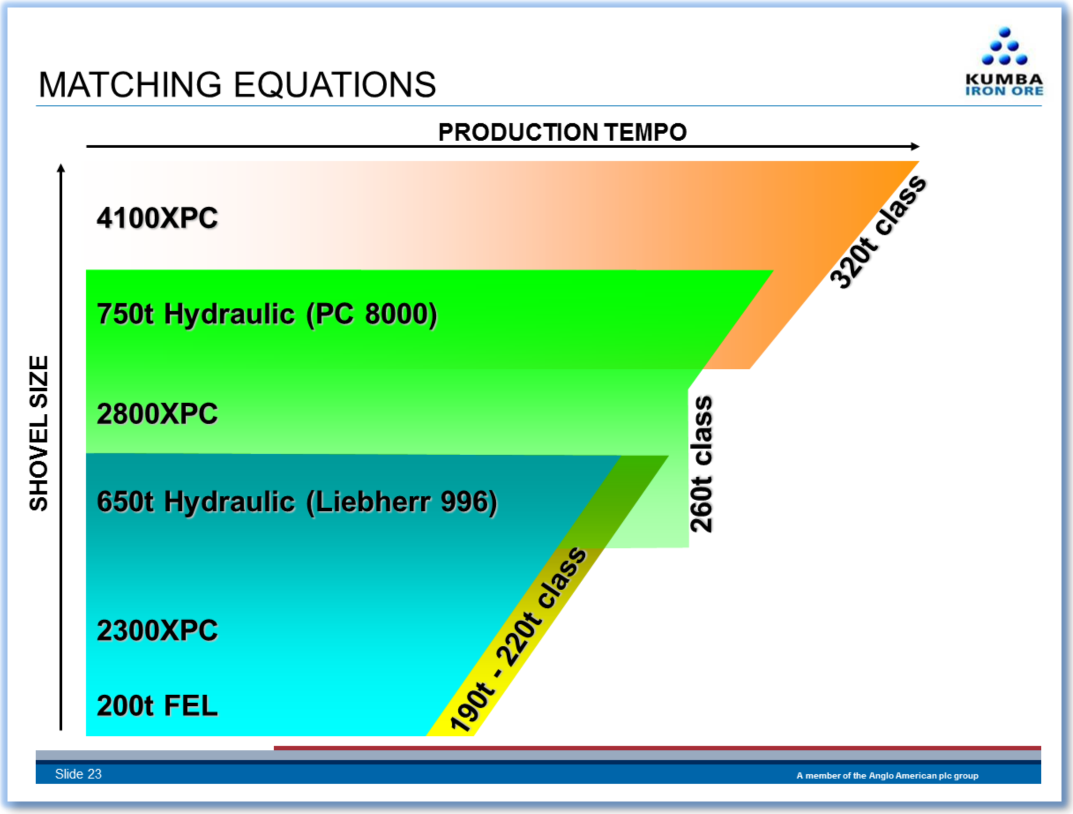



Figure E57: Sishen HME Matching Strategy (Source: Sishen October 2009 Five Year Plan)

This shows how each type of truck can efficiently load at more than one type of shovel. It aims to balance optimal matching efficiency and operational flexibility. Referring to Table E29 shows where the current trucks fit into the truck classes:

- 320t class - Komatsu 960E.
- 260t class - Komatsu 860E.
- 190t- 220t class - Komatsu 730E and CAT 793D.

Optimising payloads can have a negative effect on operational efficiency. One example of this would be that only having a specific shovel load a specific truck might yield great payloads, yet the flexibility of operations is reduced lowering overall utilization.

Data was sourced from the Joy Global (P&H) Electric Mining Shovels Product Overview (28) to determine what matching level Sishen uses its shovels at. The Red Stars on Figure E58 shows Sishen's performance:

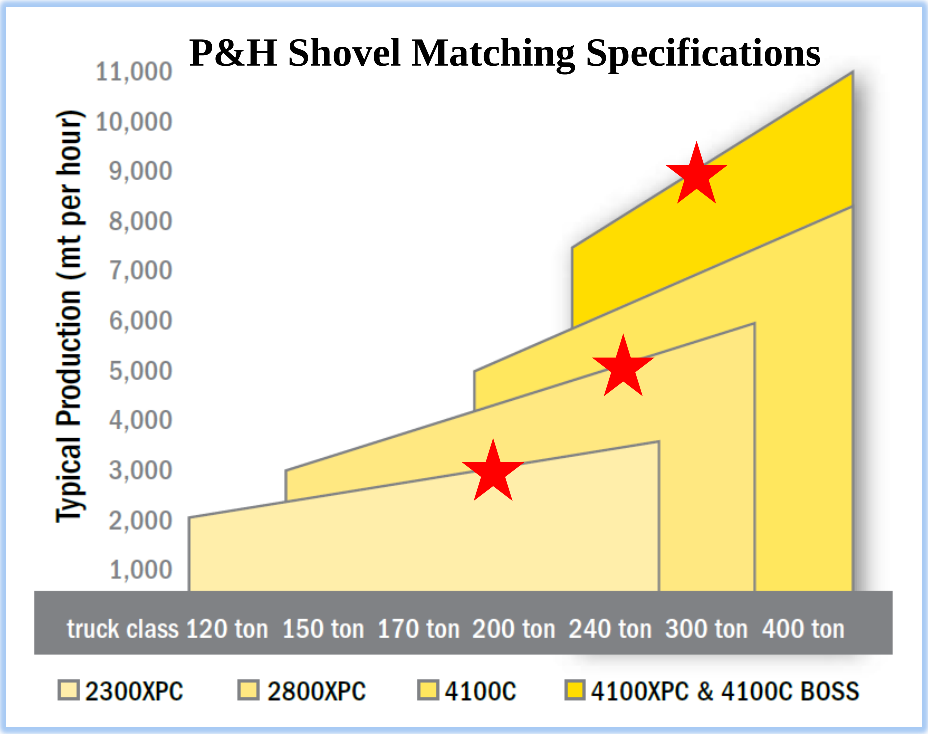



Figure E58: Joy Global / P&H Shovel Matching Specifications.

This shows that shovels are fairly well utilised, yet not as well as is possible. The trade off is most likely to ensure that enough flexibility exist to run efficient operations.

### E:3.2 Payload Averages

Sishen has done a lot of work on payloads in the last year, a significant increase in the average percentage payload has been achieved. Figure E59 shows the the monthly payloads for 2012, as well as the average payloads for the previous two years:

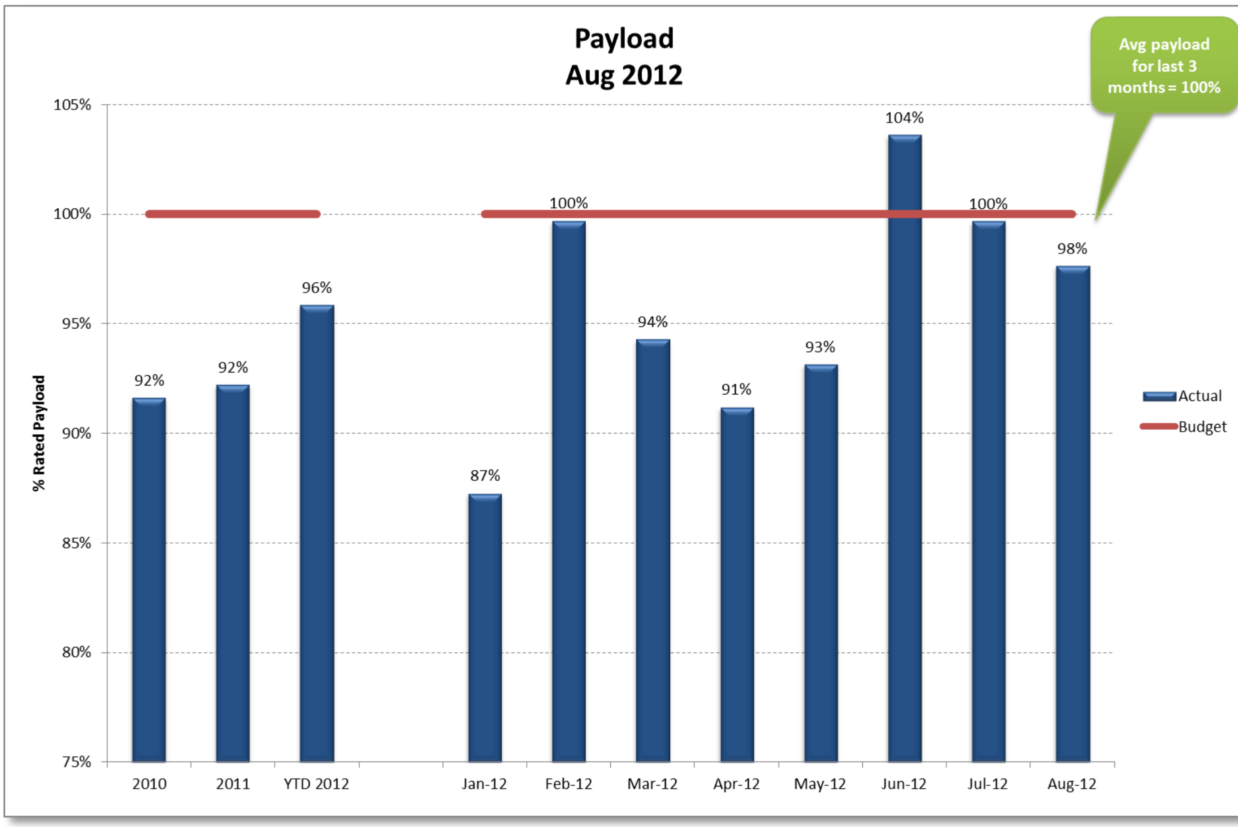



**Figure E59: Historic Payload Data, obtained from Izak Moolman**

At the time of this data the average payload for 2012 was 4% higher than for 2011 and 2010. This can be seen as a 50% reduction in tonnage lost due to under loading as the increase is from 92% to 96%. The average payload of the last three months is also at 100%.

This shows satisfactory performance levels. Further increases can not be done without abusing the haul trucks.

## E:4 Opportunities and Threats

As payloads are approaching a 100% of the target nominal value further improvements become harder. At this time threats and opportunities should be considered to ensure the 100% mark is sustainable and does not have negative cascading effects.

### E:4.1 Overloading

Overloading a truck has a range of negative effects on utilization. The main ones are as follows:

- Damages to trucks, catastrophic and accelerated deterioration: Even if a truck is not immediately damaged the increased loads causes cyclic loading on many components that are above the design levels. These abusive cyclic loads cause the number of loads to failure to dramatically increase and results in substantially shorter lifetimes due to metal fatigue.
- Delays: Overloading a truck causes a safety mechanism to stop the truck. This forces the truck to dump the load at the loading area and be loaded again.

It is thus important that the 10-10-20 rule (Section E:2.1) be followed. It may be better to have a lower payload percentage which results in lower maintenance times and less unnecessary dumps due to overloading as a result of pushing the limits. No figures are available at this stage and exact figures will require an in depth study, it is however important to realise that there is a price to pay for improperly increasing payloads.

Figure E59 shows 104% of nominal payload achieved for the month of June 2012. This violates the rule that, "*The average monthly payload must not exceed the rated payload of the truck*". The June 2012 payload data was studied to determine the extent of the overloading. Each payload entry for each truck was put into the sections defined by the 10-10-20 load policy, the results are shown in Table E30:

**Table E30: Payloads for June 2012**

| Nominal Load | 0%-100% | 100%-110% | 110%-120% | >120% |
|---|---|---|---|---|
| Komatsu 960E | 76.7% | 21.4% | 1.9% | ?* |
| Komatsu 860E | 87.0% | 11.7% | 1.0% | 0.4% (71 times) |
| CAT 793D | 74.0% | 21.5% | 3.9% | 0.6% (15 times) |

*The weight bridge only measured up to 360ton.

*No data was available for Komatsu 730E.

We can see that the 10-10-20 guidelines are overstepped by loading trucks above 120% on a number of occasions, though these instances only make up 0.4% and 0.6% of the loads for the respective truck classes.

The impact of these infringements are not knows. It is suspected that the trucks will deteriorate faster but whether the net gain is negated is not known. A study determining the impact of overloading, especially that of nominally overloading but not exceeding the 120% mark will be extremely difficult to conduct.

### E:4.2 Real Time Scales – Assisting Shovel Operators

Shovel operators comment that see the scale on the truck as they are loading is very helpful. These scales are referred to as PLMs at Sishen. Many of the PLMs are dysfunctional. The problems are:

- Zero weights
- Very low weights
- Stuck on a certain number
- Large fluctuations

This is a known issue, but one that must not be neglected. Shovel operators are more easily able to load the correct payloads if they can rely on the PLMs.

### E:4.3 Partial Passes

As discussed in Section E:2.2 partial passes is a grey area that is not often discussed. It is however practices in some circumstances and having clear guidelines can boost efficiency. When only full passes are made the loaders' capacity is being maximized, alternatively when partial passes are made the trucks' capacity is being maximized. It would be ideal if both of these could occur at the same time, but that requires trucks to have a capacity that is an exact multiple of the loaders' bucket capacity. As it is trade-offs can be made in different situations to improve the overall equipment utilization.

Shovel operators should thus be given guidelines, one example may be that: "If a there are no trucks waiting a half pass should be done". It must be noted that other factors like distance from dumping point also comes into the equation.

If a shovel is under trucked half a pass may add 20 ton or around 10% to the payload at the cost of only 20-30 seconds. This will extend the average Sishen cycle time by only 1%-1.5%. A considerable improvement to daily tonnage can thus be made, yet this requires the shovel operator to have a very good idea of how full a truck is.

## E:5 Summary

This section has reiterated the importance of optimising payloads. It was seen that Sishen has greatly improved its payloads over the last year, reaching an average of 100% of nominal payloads for the period June 2012 to August 2012. The percentage of nominal payload was found to be at 96% at the end of August 2012 for the year, compared with 92% for 2011 and 2012.

Overloading was identified as a possible threat. Another area that needed attention to ensure that the improvement in payloads is sustainable was the reliability of the PLMs or scales on dump trucks. It was further argued that partial passes could give total tonnage a good boost if implemented correctly. This relies on operators being able to tell how full a truck is.

## E:6 Conclusion

Sishen has greatly improved its payloads over the last year. At the end of the available data range, August 2012, the average percentage of rated payloads was at 100% for the last three months. This means that further improvements are not possible without consciously deciding to ignore the manufacturer's guidelines. Before such a decision is made an in depth study should be undertaken to determine the negative effects of nominally overloading trucks even if the 120% of nominal specified limit is not broken.

Management should now focus on ensuring that the payloads remain at 100% of nominal. In order to achieve this sustainability shovel operators should be supported as much as possible. The PLMs are to be kept in good working condition as they assist shovel operators to load correctly.

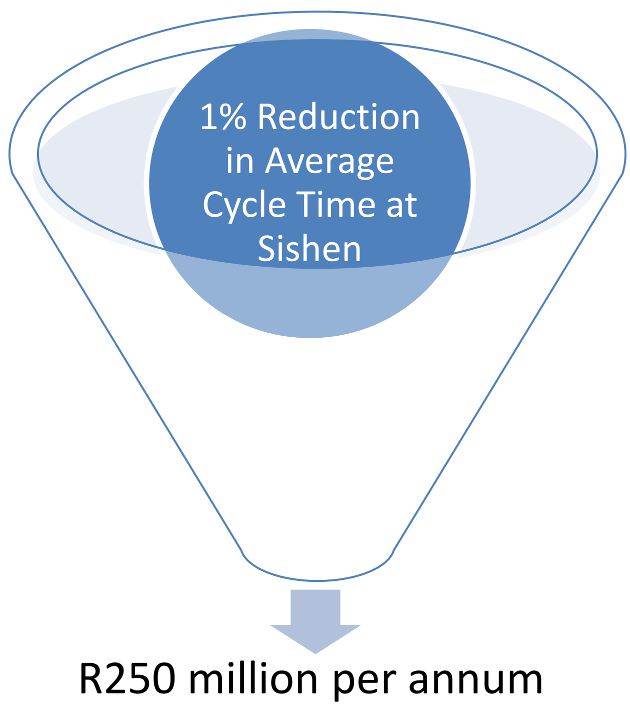
Partial passes should be considered. It has the potential to improve total tonnage by a considerable margin for situations where shovels are under trucked. For partial passes to be successful shovel operators need to know how full a truck is. This further motivates having PLMs in working condition.

# APPENDIX F: Value Analysis

# Executive Summary

In order to understand the value that an improvement to the average cycle time of haul trucks holds for Sishen it must be quantified in terms that are relevant to production and management personnel.

It was determined that decreasing the average cycle time at Sishen by 1% increases the profit or tonnage that Sishen makes by approximately R250 million or 250 thousand tonnes per annum, which equates to R2.5 million or 2,500 tonnes per truck. A seemingly small percentage which might be disregarded can thus equate to a substantial gain.



# Contents

## F:1 Motivation

A number of the findings in the overall report are in terms of "percentage saved on average cycle time". This value is useful for comparing different factors against each other, yet it does not give a clear impression on what the value added to the company might be. In order to do this percentage reduction in cycle time was converted into estimated monetary terms and tonnage.

The value of a 1% reduction in average cycle time will be determined per annum.

## F:2 Sources of Information

Financial estimates will be determined from the Financial Reports as found on the Anglo American website, the following documents specifically:

- KUMBA IRON ORE LIMITED, INTERIM FINANCIAL RESULTS for the six months ended 30 June 2012. Sourced from (29).
- 2012 INTERIM RESULTS, Presentation Prepared form above source. Sourced from (3).

Kumba segments the reports for each mining operation, of which Sishen is the flagship.

As a secondary check some operational estimates would be used to extrapolate. Specifically the estimated cost of truck down time provided from operations as noted in Section D:3.2.

## F:3 Assumptions

### F:3.1 Primary Assumption: Under Trucked 75% of Time

Estimations will be made based on the primary assumption that the mine is under trucked. As this does not hold 100% of the time a 75% modification will be applied to gains. This estimated ratio is based on undocumented observation and personal discussions with operation managers, it was confirmed as a realistic estimate by Marx, the Senior Mining Engineer: Mining Systems (Section H:1.1.7). An example of the need to adjust for over trucking is that 30 seconds might be saved in loading time at a specific shovel, but when the truck gets back to the shovel it has to wait for another truck to finish loading. The gain is thus negated by over trucking.

### F:3.2 Secondary Assumption I: 100 Trucks Operating on Average

The fleet size is approximated at 100. Table F31 is an extract of Table E1 as found in Section E:3.1. It shows 105 trucks were operating on 30 September 2012.

Table F31: Number of trucks in operation

| ***HAUL TRUCKS*** | **Number** |
|---|---|
| Komatsu 960E | 13 |
| Komatsu 860E | 41 |
| CAT 793D | 8 |
| Komatsu 730E | 43 |
| ***Total*** | ***105*** |

### F:3.3 Secondary Assumption II: Extra Product can be Sold

It is assumed that any extra product can be sold on the spot market. For the first half of 2012 as shown on page 14 of Kumba's 2012 INTERIM RESULTS presentation (3) 28% of exported sales or 5.8Mt of iron ore was sold this way. An extract is shown in Figure F60 :

**Export sales and prices**

| | 1H11 | 2H11 | 1H12 |
|---|---|---|---|
| Total export sales (Mt) | 18.4 | 18.7 | 20.7 |
| - Quarterly/monthly pricing(%) | 71 | 77 | 72 |
| - Spot (%) | 29 | 23 | 28 |
| Average FOB price received (US$/tonne) | 169 | 149 | 134 |

Figure F60: Percentage of exports on the Spot Market

A personal interview with Chris Minnie confirms that extra product can be sold this way. This is further verified by a global shortage in iron ore supply. This shortage is expected to diminish at the end of 2013 with prices falling back to $110 US a ton, down from a 15 month high of %158.5 US on 8 January 2013 (30). Projecting on prices form the first half of 2012 should thus be accurate. The unit cost of iron ore produced at Sishen was R181.9 per tonne for the first half on 2012 (Figure F61).

## F:4 Methods of Estimation

Three different methods will be used for financial estimations:

- Increased Tonnage value minus costs
- Percentage modification of Net Profit
- Extrapolation of operations' estimated cost of truck down time

The tonnage estimate will be based on production figures at Sishen as found in the financial statements.

## F:5 Calculations

### F:5.1 Increased Tonnage Value Minus Costs

#### *F:5.1.1 Extra Costs per Tonne*

In order to estimate the cost associated with reducing cycle times by 1% and thus processing 1% more ore Figure F61 is used:

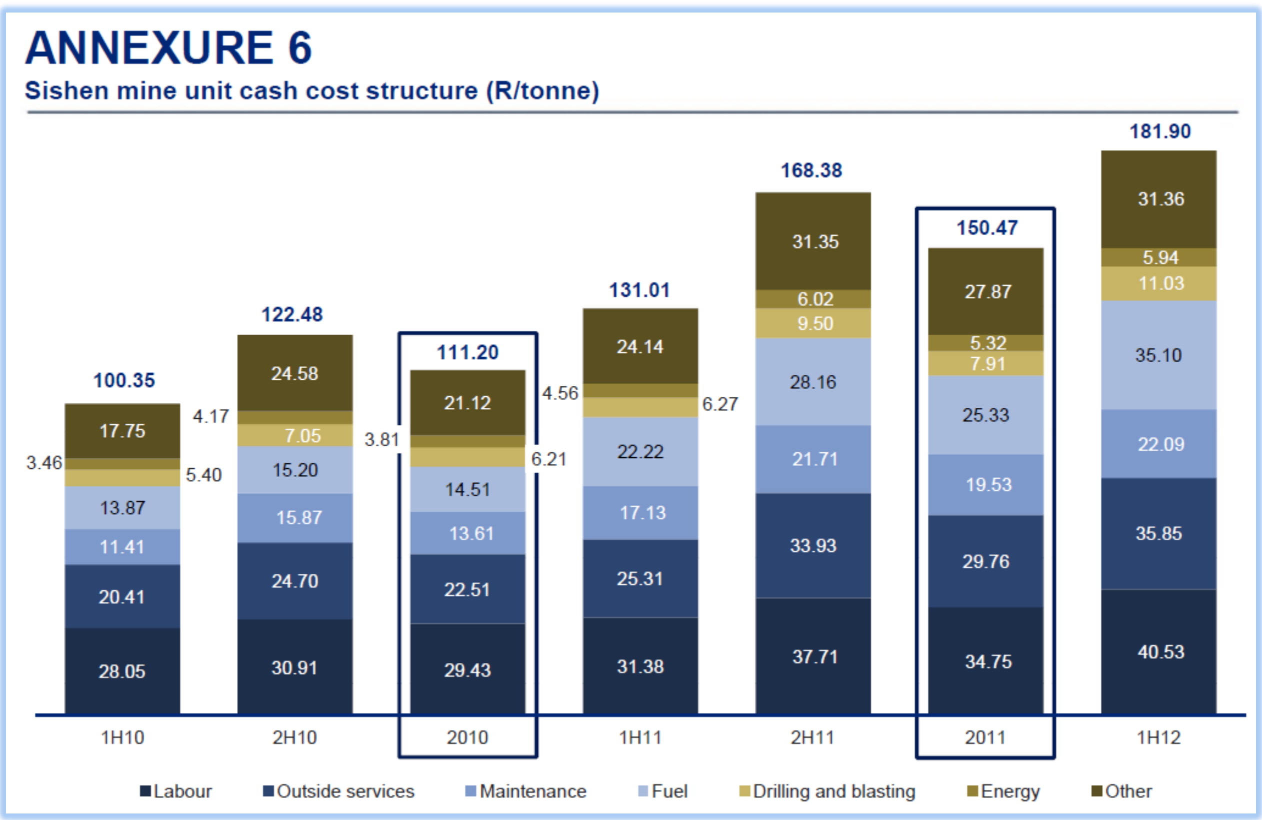



Figure F61: Cost breakdown for Sishen (Sourced from presentation of interim financial statement ending June 2012 (3))

The bar on the right represents the cost of producing one tonne of iron ore at Sishen. Reducing cycle time by 1% will not increase Labour or Outside services, there will however be a proportional increase in Maintenance, Fuel, Drilling and Blasting, Energy and possibly "Other".

It will thus be assumed that each extra tonne produced will increase the cost by R94.49 (31.36+5.94+35.1+22.09). This is compared to the average cost of R181.9.

### F:5.1.2 Extra Revenue per Tonne

The revenue per tonne for the term was R,1061 as found in Annexure 1 of the presentation of interim financial statement ending June 2012 (3).

### F:5.1.3 Extra Tonnes per Truck

With a 1% decrease in the average cycle time at Sishen approximately 1% more product can be produced (assumption holding, 75% modification will be applied at end).

As provided in the Operational Review of Sishen Mine on page seven of the presentation of interim financial statement ending June 2012 (3) Sishen produced 17.9Mt of product for the period, which equates to 35.8Mt per annum. It will be assumed that this rate and the stripping ratio remain constant for the purpose of this estimation.

The extra product will thus be 358,000tonnes.

### F:5.1.4 *Summary and Results*

Table F32 summarises the above findings and calculates the estimated extra annual profit from achieving a 1% reduction in the average cycle time at Sishen:

**Table F32: Calculation of the Estimated Profit for a 1% decrease in the average cycle time, method 1.**

| Item | Amount | Process/Source |
|---|---|---|
| Extra Cost per Tonne | R94 | F:5.1.1 |
| Extra Revenue per Tonne | R1,061 | F:5.1.2 |
| Extra Profit per Tonne | R967 | R1,061-R94 |
| Extra Tonnes per Annum | 358,000 | F:5.1.3 |
| Gross Extra Profit | R346.2 million | 358,000s X 967 |
| Estimated Extra Profit | R259.65 million | 346,200,000 X 75% |

Based on this calculation a 1% reduction in the average cycle time will yield an annual profit of approximately R260 million (before taxation).

## F:5.2 Percentage Modification of Net Profit

The net profit before interest and tax will be used for this estimation. As found in Section 7 of Kumba's interim financial results for the six months ended 30 June 2012 (29) the EBIT (Earnings Before Interest and Tax) was R12,601 million for Sishen. That is R25,202 per annum.

Assuming that a 1% decrease in average cycle time will result in 1% more profit being made, the estimated net profit as per the assumptions (including the 75% modification) is shown in Table F33:

**Table F33: Calculation of the Estimated Profit for a 1% decrease in the average cycle time, method 2**

| Item | Amount | Process/Source |
|---|---|---|
| EBIT | R25,202,000,000 | F:5.2 |
| Gross Extra Profit | R252,020,000 | 25,202,000,000 X 1% |
| Estimated Extra Profit | R194.7 million | 252,020,000 X 75% |

Based on this calculation a 1% reduction in the average cycle time will yield an annual profit of approximately R190 million (before taxation).

### F:5.3 Extrapolation of Operations' Estimated Cost of Truck Down Time

As shown in Table D27 in Section D:3.2 the estimated cost of truck down time is R37,440 per hour. Noting that 1% of an average cycle time at Sishen is 20 seconds the calculations in Table F34 determines the estimated extra net profit:

**Table F34: Calculation of the Estimated Profit for a 1% decrease in the average cycle time, method 3**

| Item | Amount | Process/Source |
|---|---|---|
| Cost of Truck Down Time | R37,440 per hour | F:5.3 |
| Seconds Saved per Cycle | 20 | 1% of 2,000 (Section A:1.3) |
| Savings per Cycle | R208 | (37,440 X 20) / (60 X 60) |
| Average Cycles per Day | 100 | Section A:1.3 |
| Savings per Day per Truck | R20,800 | 208 X 100 |
| Savings per Annum per Truck | R7,592,000 | 20,800 X 365 |
| Gross Extra Profit | R759,200,000 | 7,592,000 X 100 (F:3.2) |
| Estimated Extra Profit | R569.4 million | 346,200,000 X 75% |

Based on this calculation a 1% reduction in the average cycle time will yield an annual profit of approximately R570 million (before taxation).

This amount is substantially higher than the other calculations, it is assumed that this is due to an over exaggeration of the cost of truck downtime.

### F:5.4 Tonnage Estimation

Sishen mined 88.9Mt for the first half of 2012 with a production of 17.9Mt (page 7 of (3)). Calculating an annual average with the primary assumption, Section F:3.1, is done with the following formula:

$$Estimated\ Extra\ Tonnage = Total\ Tonnage\ \times 1\%\ \times 75\%\ \times 2$$

The estimated extra tonnage mined is thus 1.3Mt with the estimated extra production at 0.27 Mt or 270 thousand tonnes.

## F:6 Summary of Results

The results of the different financial estimation methods are shown in Table F35:

**Table F35: Additional profit via different methods of estimation for a 1% decrease in the average cycle time at Sishen**

| **Method** | **Estimated Additional Profits*** |
|---|---|
| Increased Tonnage Value Minus Costs | R260 million |
| Percentage Modification of Net Profit | R190 million |
| Extrapolation of Operations' Estimated Cost of Truck Down Time | R570 million |

*Before Tax

It was found that the estimated extra tonnage mined is 1.3Mt with the estimated extra production at 270 thousand tonnes for a 1% decrease in the average cycle times at Sishen.

## F:7 Discussion

As shown in Table F35 the different methods of estimation show material differences , yet they are within an expected range. The most accurate method was expected to be the "Increased Tonnage Value Minus Costs" approach. This estimate of R260 million is about a third higher than the straight "Percentage Modification of Net Profit" approach. This is due to the first method taking expected cost savings resulting from a more efficient operation into account. The R570 million estimate that is done by an "Extrapolation of Operations' Estimated Cost of Truck Down Time" is almost twice as high as the "Increased Tonnage Value Minus Costs" estimation; It is the same order of magnitude and serves as a check, but is not expected to be as accurate as a more detailed calculation based on the financial statements and cost breakdowns.

## E:8 Conclusion

The additional profit or tonnage gained from a 1% decrease in average cycle times at Sishen is estimated at around R250 million or 250 thousand tonnes of product per annum. This equates to approximately R2.5 million or 2,500 tonne per truck. It can be used to calculate the expected value that certain optimization exercises offer to Sishen.

# APPENDIX G: Night Shift Maintenance

# Executive Summary

An investigation was conducted to determine if more shovels should be serviced at night. By making use of dispatch data for the HME fleet it was found that the overall improvement of HME utilization or overall equipment efficiency (OEE) at Sishen was up 0.44% equating to approximately R150 million per annum. The improvements were mainly realised during the day shifts as shown in Figure G62:

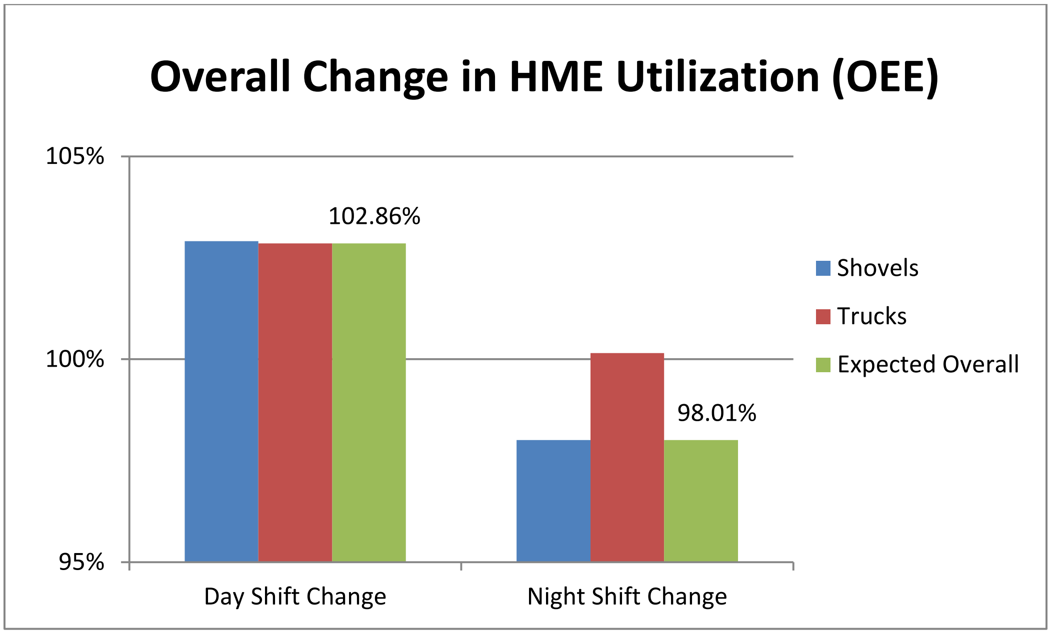



**Figure G62: Expected change in overall HME utilization at Sishen as a result of the new maintenance plan**

It was found that most of the improvements were due to a part of the haul truck fleet being serviced at night, haul truck availability went up by 2.69% for night shifts and 4.91% for day shifts. An estimation of the situation if front end loaders were not serviced at night revealed that the 0.44% increase in overall HME utilization would have been higher at 0.79%. This equates to an additional R100 million per annum.

The improvement is due to the decrease in night shift HME utilization being negated whilst most of the improvements to the day shift utilization would be sustained.

It is suggested that the decision to service front end loaders at night be reconsidered as well as any plans to service additional shovels at night. Servicing trucks at night seems to have had a positive effect on overall utilization and should be continued.

# Contents

## G:1 Introduction

### G:1.1 Overview

Sishen's maintenance department has recently started servicing the primary front end loaders and a part of the hauling fleet at night. This was done primarily to decrease the difference in availability for shovels during day and night shifts to better align trucks and shovels availability. A situation existed where the mine was over trucked at day and under trucked at night. This was due to shovel availability being poor during the day when they are all serviced. The problem is illustrated in Figure G63:

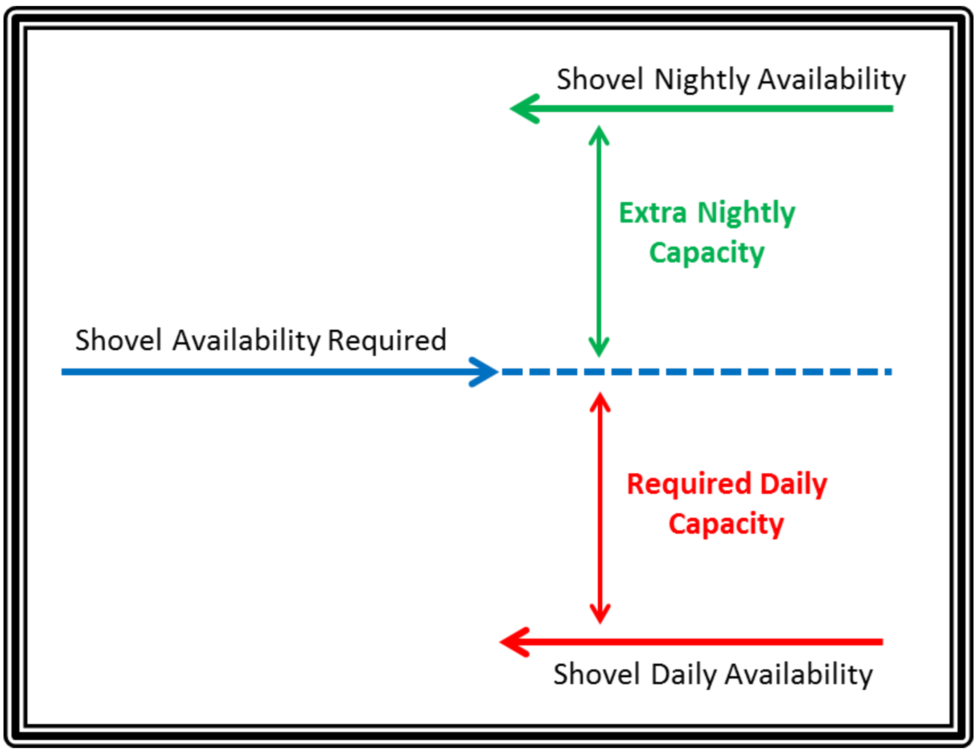



Figure G63: Problem due to difference in shovel availability between day and night shifts

It must be noted that the blue line does move around between day and night shifts, but not nearly as much as that of the shovels.

The new maintenance plan was aimed at reducing the difference between shovel availability during shifts. This would increase overall utilization as nightly over trucking is reduced in favour of reducing daily under trucking.

In this investigation three terms are used: "Availability" and "Use of Availability" which is multiplied to give "Utilization", which is sometimes referred to as "overall equipment efficiency" (OEE) at Sishen.

### G:1.2 Motivation

The gains from servicing the front end loaders at night will be determined. This will enable management to decide whether significant improvements can be made by servicing other shovels at night as well. The study will also verify whether servicing trucks and shovels at night yielded improvement to the overall utilization of HME at Sishen.

## G:2 Data

The data for this analysis is obtained from the dispatch system. Availability and Use of Availability figures is drawn for the month following the initiation of the new maintenance plan up to the strike as this introduced too much noise into the data. The months July through September is thus used. This data is drawn for 2012 as well as 2011 in order to compare data from before the change and after the change with as little other influences as possible. Data is drawn for:

- Day shifts
- Nights shifts
- Daily Average

This data is segmented for:

- Trucks
- Shovels
- Front End Loaders

When calculating utilization the averages of availability and use of availability is is multiplied as shown in Table G36:

**Table G36: Utilization calculating procedure**

| Use of Availability | Availability | Utilization |
|---|---|---|
| 70.00% | 80.00% | |
| 60.00% | 90.00% | |
| 65.00% | 85.00% | 55.25%* |

*65X85

This is due to the available dispatch data providing availability and use of availability but not utilization.

## G:3 Effect of Servicing HME at Night

In order to determine the benefit that the new maintenance plan holds for Sishen three values will be determined:

- Reduction in the difference between the daily and nightly availability of shovels.
- The effect on overall utilization
- The value that this adds to Sishen

### G:3.1 Reduction in the Difference between Daily and Nightly Availability for Shovels

Drawing the shovel availability data for June to September 2011 and June to September 2012 shows a marked decrease in the difference in availability between day and night shift as shown on Figure G64 and Figure G65:

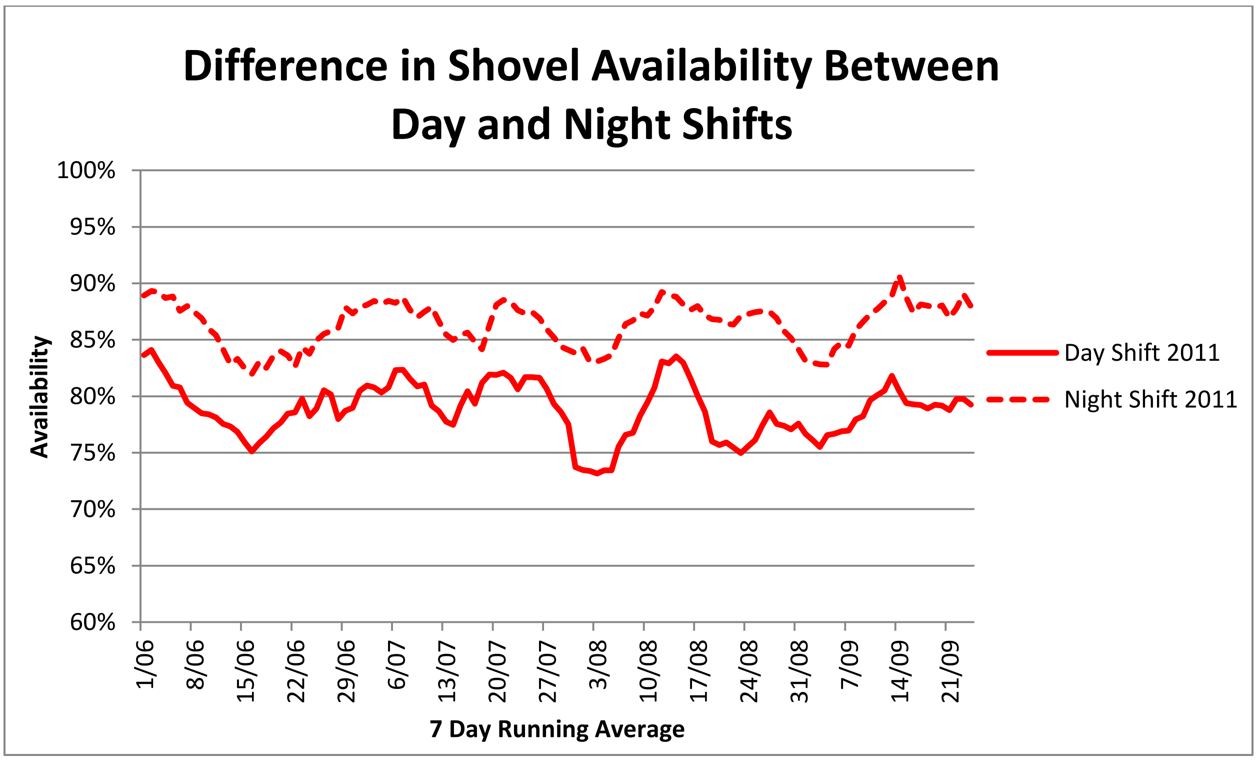



Figure G64: Difference in shovel availability between day and night shifts before the new maintenance plan

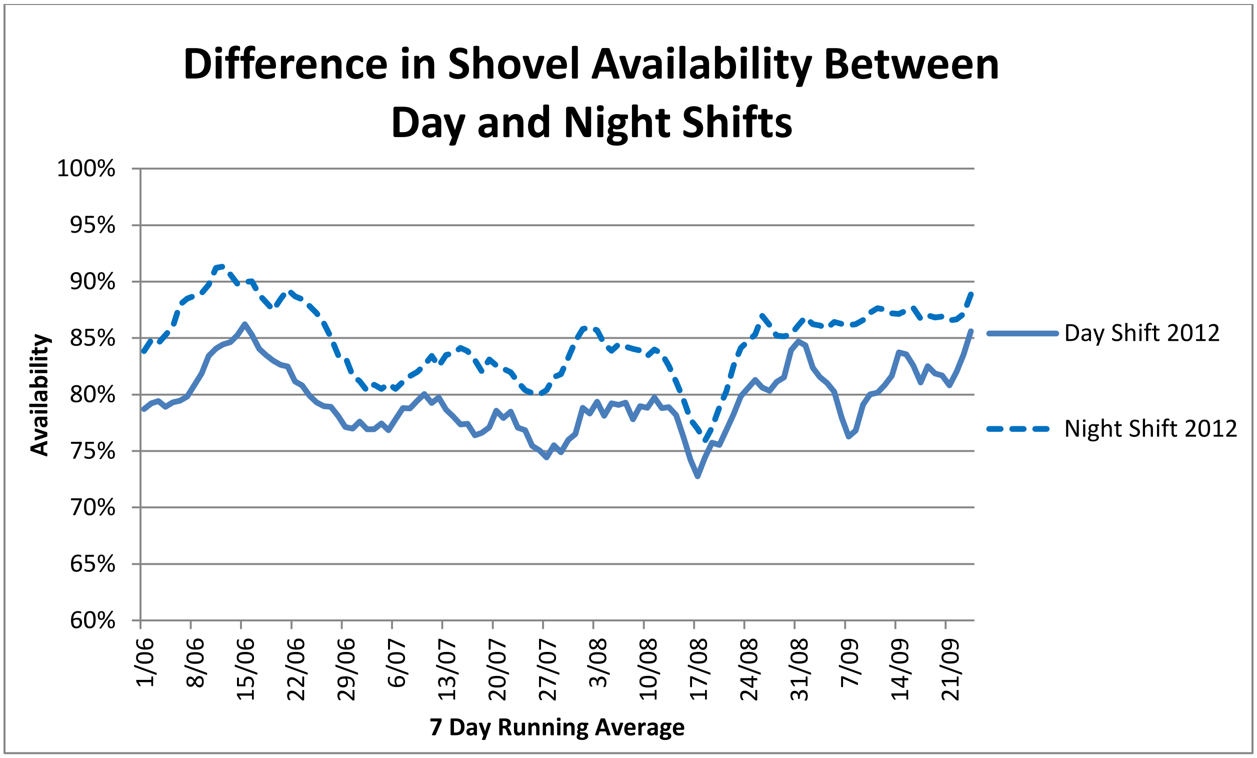



Figure G65: Difference in shovel availability between day and night shifts after the new maintenance plan

The change in the difference in availability between day and night shifts for shovels as shown in Figure G64 and Figure G65 equates to a 35% reduction as shown in Figure G66. This reduced the unsought difference by a third and is expected to have a positive influence on the overall utilization at Sishen as explained in Section G:1.1.

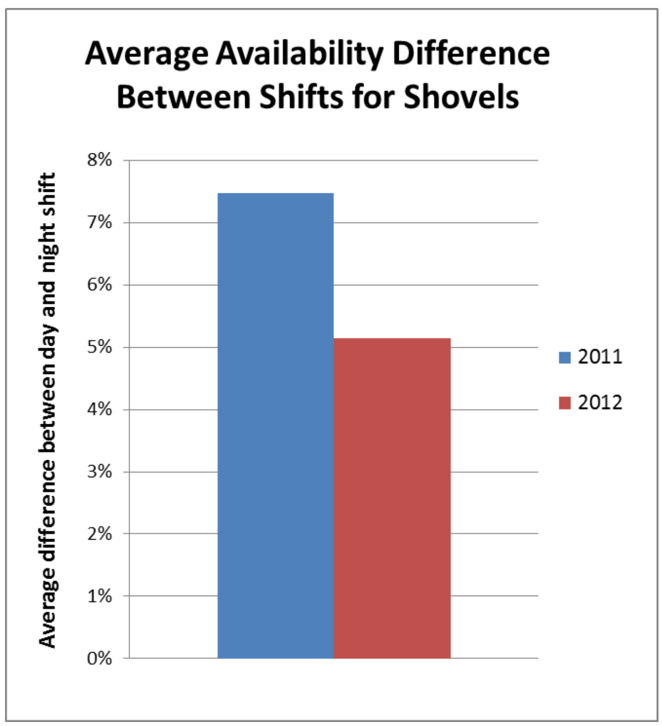



Figure G66: Reduction in the average availability difference between day and night shifts for shovels

### G:3.2 The Effect on Overall Utilization

Utilization, or overall equipment efficiency (OEE), is affected by changes in availability and use of availability. The average availability and use of availability is calculated for trucks and shovels for both 2011 and 2012. These figures are then used to determine the changes in HME key performance indicators (KPIs) due to front end loaders and part of the hauling fleet being serviced at night. In order to do this the data had to be checked to ensure that the same shifts were available for each year; If a shift was missing for one year it had to be removed for the other year to ensure the same data is compared. Figure G67 and Figure G68 shows the changes for shovels and trucks respectively:

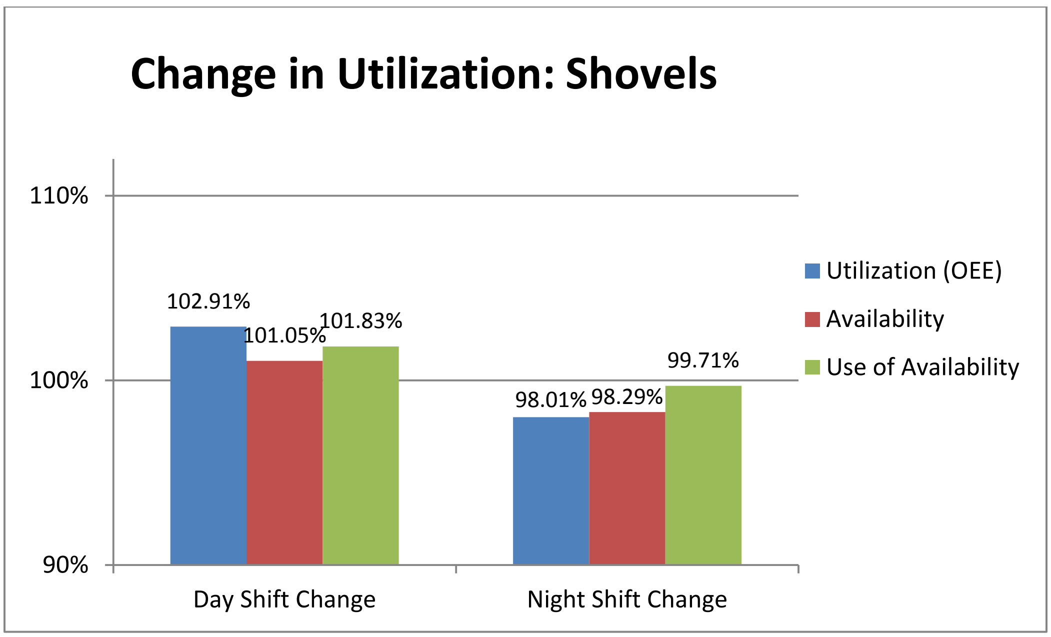



Figure G67: Changes in primary shovel KPIs at Sishen due to servicing front end loaders and some trucks at night

The results in Figure G67 trend as expected, yet do not show significant overall gains. As expected shovel availability is down during the night, by 1.71%, and shows an improvement of 1.05% during the day. The use of availability was similarly affected , up 1.83% for the day shifts and down 0.29% for night shifts. This results in a decrease in utilization or OEE of 1.99% during the night shift and an increase of 2.91% during the day shift. This is an average improvement of 0.46%.

It must be noted that the data was drawn in a hurry by the dispatch operators, some minor inconsistencies were detected and rectified. A thorough analysis should be done before this figure is used to make key decisions.

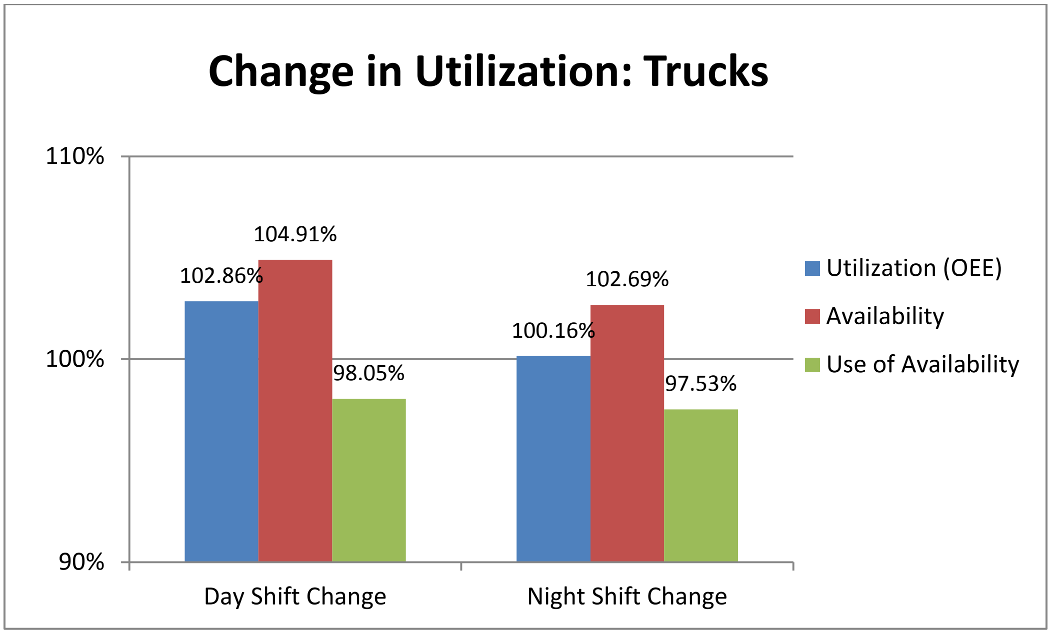



Figure G68: Changes in primary truck KPIs at Sishen due to servicing front end loaders and some trucks at night

The results in Figure G68 trend as expected, and show substantial improvements. Truck availability has substantially improved, up 2.69% for night shifts and 4.91% for day shifts. It would be reasonable to assume that this is not all due to servicing trucks at night, yet the amount by which availability increased more by day than by night suggests that the new maintenance plan had a significant effect. Use of availability was down by 1.95% and 2.47% for day and night shifts respectively. This results in a 2.86% increase in utilization or OEE during day shifts with night shifts remaining virtually constant at a 0.16% increase. This is an average improvement of 1.51%.

### G:3.3 The Value Added to Sishen

In order to determine the effect this has at Sishen's overall performance one primary assumption is necessary: "The new overall level of performance will be equal to the new lowest level of performance for shovels or trucks on the day and night shifts respectively". This assumption is based on the fact that the trucks and shovels form a linear system where the slowest component becomes the bottleneck. It is expected to be a realistic assumption and is not intended or expected to be overly conservative. The expected change in overall HME utilization is shown on Figure G69:

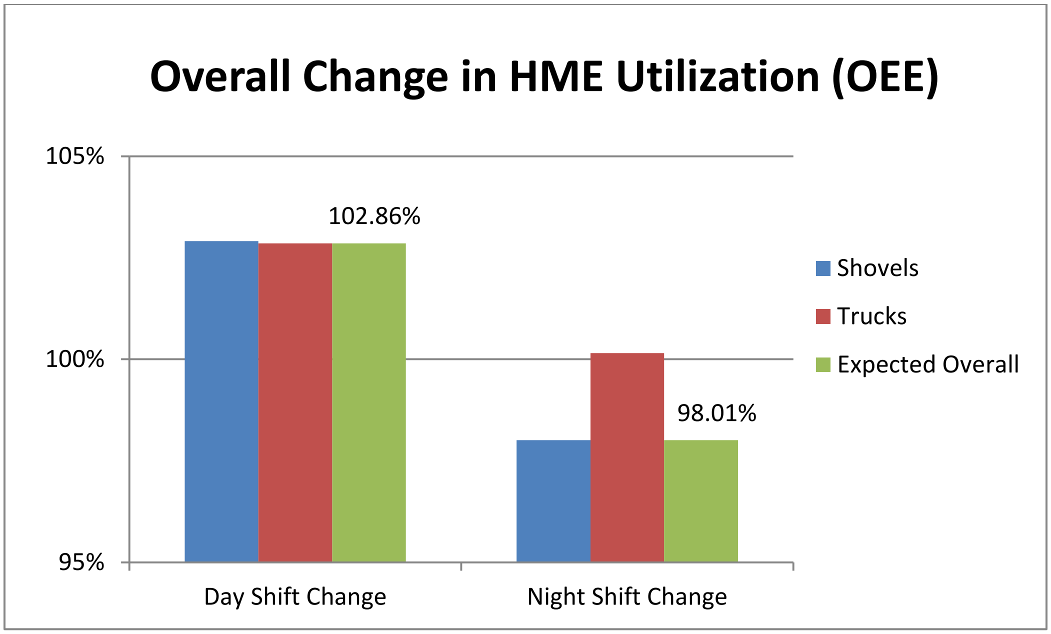



**Figure G69: Expected change in overall HME utilization at Sishen as a result of the new maintenance plan**

It can thus be assumed that overall HME utilization is up 2.86% during the day and down 1.99% during the night. The nightly performance is brought down by a decrease in the shovel utilization, truck utilization showed no material nightly changes. This equates to an average increase in HME utilization of 0.44%.

If the cost of production and selling profit is taken into account as discussed in the financial estimations shown in Section F:5.1 whilst ignoring assumption F:3.1 as the above assumption looks at bottle neck changes the 0.44% increase will equate to an additional profit of approximately R150 million [R346.2 million X 0.44].

## G:4 Summary of Results

Section 3.1 has shown a 35% reduction in the difference in availability between day and night shifts for shovels. A reduction in this area was the aim of the new maintenance plan, yet the effect that this reduction has on overall HME utilization at Sishen had to be studied. It was hence found that shovel utilization is up 2.91% for day shifts but down 1.99% for night shifts. The accompanying truck utilization was up 2.86% for day shifts and remained constant (up 0.16%) for night shifts. As it must be assumed that the new overall level of performance will be equal to the new lowest level of performance for shovels or trucks on the day and night shifts respectively the net effect was:

- A 2.86% increase in overall HME utilization for day shifts: The increase was similar for both trucks and shovels.
- A 1.99% decrease in overall HME utilization for night shifts: This was driven by a decrease from the shovels, trucks remained constant.

## G:5 Discussion

It is necessary to refer to Figure G67, Figure G68 and Figure G69 to follow this argument.

Figure G69 shows that the 1.99% decrease in overall night shift utilization (OEE) is due to a decrease in shovel utilization, shovel availability was up 1.05% for the day shift but down 1.71% for night shifts as shown on Figure G67. Servicing the shovels at day should get rid of the 1.71% decrease in nightly shovel availability which should see the 1.99% decrease in nightly shovel utilization disappear.

The question that must be asked is whether this will also reduce the 2.91% and 2.86% increase in utilization for shovels and trucks during day shifts:

**Daily Shovel Utilization**

The 2.91% increase in daily shovel utilization was driven by a 1.83% increase in daily use of availability for shovels and a 1.05% increase in daily availability as shown by Figure G67. Servicing shovels during the day would most probably get rid of the 1.05% increase in availability but should not decrease the 1.83% increase in use of availability. The increase in use of availability is most likely driven by the increase in availability of trucks, daily truck availability was up 4.91%. It can thus be consumed that Shovel utilization would be at [100% X 101.83%] 101.83% if the front end loaders were no longer serviced at night.

This decreases the expected increase in daily shovel utilization to 1.83%, down from 2.91%, but gets rid of the 1.99% nightly decrease in shovel utilization.

**Daily Truck Utilization**

The 2.86% increase in daily truck utilization was driven by a 4.91% increase in daily truck availability. It must be noted that the day shift truck use of availability is down 1.95% as shown in Figure G68. Servicing more shovels during the day is expected to see daily shovel utilization go down to 1.83% from 2.91% which could draw daily truck use of availability down further. It could thus be assumed that truck day shift utilization will fall by a similar amount as daily shovel utilization. Daily truck utilization is thus expected to be [ 102.86% - (2.91%-1.83%)] 101.78% if the front end loaders were no longer serviced at night.

This decreases the expected increase in daily truck utilization to 1.78%, down from 2.86%.

## G:6 Conclusion

No longer servicing the shovels at night is expected to yield the KPIs for shovels and trucks shown on Figure G70 based on the discussion in Section G:5.

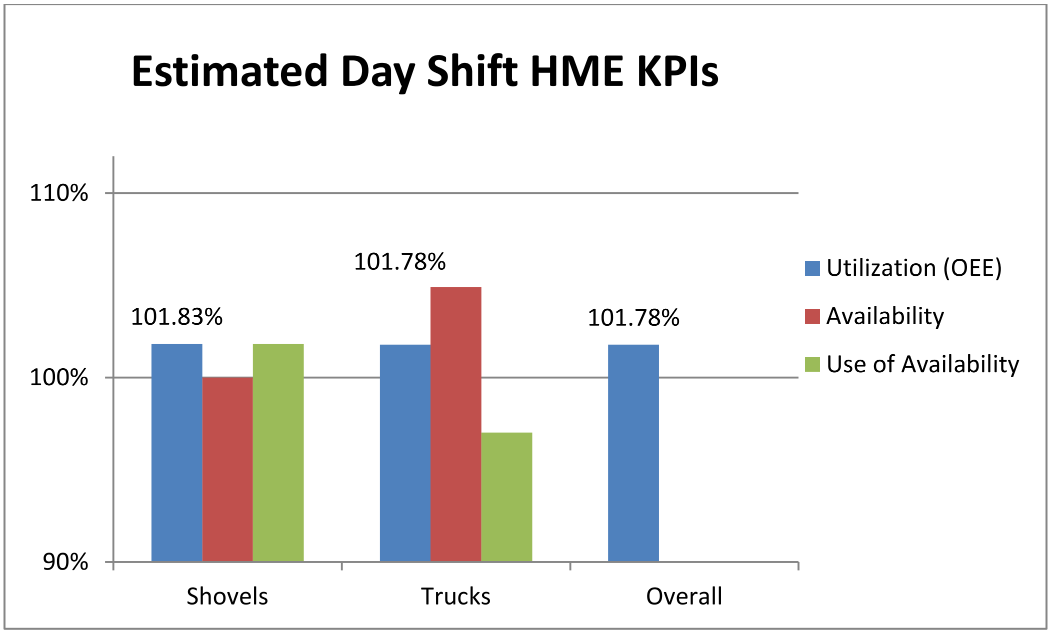



Figure G70: Estimated 2012 HME KPIs if front end loaders were not serviced at night

It must be noted that the night shift average is estimated to show no change as discussed in Section G:5.

The new overall gain in HME Utilization is thus expected to be [ (1.78% + 0) X 0.5] 0.89% as opposed to the realised 0.44% if front end loaders were not serviced at night. According to the calculation described in Section G:3.3 this will equate to an additional profit of approximately R270 million [R346.2 million X 0.79] instead of approximately R150 million.

It is thus believed that approximately R100 million can be saved per annum by not servicing front end loaders at night.

It is strongly recommended that no more shovels be serviced at night and that front end loader be serviced during the day.

# APPENDIX H: Ancillary Material

# Contents

# APPENDIX H:1 → Interviews and Observations

## H:1.1 Interviews

### *H:1.1.1 Dispatch Overseer: Johan Kotze*

**24 October 2012 (Duration: 2 Hours)**

At Sishen fleet management is done using the Modular Mining Systems (MMS) DISPATCH® system.

**Inputs and Decision Making**

A detailed explanation of the system and its implementation at Sishen Mine was given. Mr Kotze explained the main inputs to “pitdat” are pit data, material, and equipment. This data is used by the three primary “components” or the dispatch system’s decision making model; Best Path, Linear Programming and Dynamic Programming. The explanation was thorough and consistent with the literature, see the Section H:3.2.4 for more details.

**Limited Information**

As mentioned in the Section H:3.2.4 information on the workings of MMS Dispatch is hard to obtain, it seems to be withheld as a form of Intellectual Property Protection. Mr Kotze was able to provide information that could not be obtained for the literature review due to his long standing familiarity with the system. An example of this was the philosophy with which the system was created, by way of an illustration each shovel can be thought of as a node or closed system. Basic conservation of mass theorems dictate that material-in has to equal material-out, otherwise the system will “create a vacuum” or “build pressure”.

One of the drawbacks to this limited information according to Mr Kotze is that faults or oddities observed in the field are hard to understand. The dispatch crew would at times observe trucks going to points that seem illogical. He is convinced that this has to do with the “neediest” principal that drives truck assignment, but is unable to diagnose the problem as MMS refuses to release sufficient information on the workings of the system logic.

**Components of a hauling cycle**

A typical cycle as recorded on the dispatch system at Sishen has the following components:

- Assign Empty
- Arrive
- Start Spotting
- Start Loading
- Assign Full
- Arrive
- Start Spotting
- Start Dumping

**Unintended Maintenance Department assistance**

The Dispatch system is used to provide daily information to maintenance departments, it also records key performance indicators (KPIs) that show how well different maintenance departments are operating. In order to do this time categories are created in addition to the four states that the system records, the four states are; Ready, Delay, Down and Standby. These are not sufficient to provide information recording why the truck is standing and what department the down time should be booked against. To this end seven time categories are created:

- Used
- Down-Mechanical
- Down-Electrical
- Down-Other
- Delay
- Standby
- Exclude

This data can be now be used to determine how well sections are performing. An example would be that all the Down-Mechanical times for each piece of equipment for a particular section is recorded and accrued. This is then used to determine the overall availability of that section.

**Strong points**

Strong points extracted from comments made throughout the interview:

- ✓ Linux – The system runs on Linux and is thus very stable.
- ✓ Adaptability – Changes to critical inputs are responded to very quickly.

**Issues**

The following issues are extracted form comments made throughout the interview:

- Crusher – Can be a choke point in operations.
- Manual Truck Buttons – Certain events have to be signalled manually by the truck drivers. This is not done well.
- "Neediest" system logic – At times illogical truck allocations are made. This is hard to understand and can not be fixed due to the MMS closely guarding their system logic.
- Rerouting – Truck drivers are not happy when they are rerouted. This is caused by changes in critical inputs.
- Truck Assignment Orders Ignored – At times drivers ignore their assignment after dumping and go to other loading points. This upsets the system and decreases utilization.

### *H:1.1.2 SAP: Senior Planner*

**12 November 2012 (Duration: 1 Hour)**

This is a continuation on previous discussions regarding the SAP system used by maintenance to record data, specifically downtimes. The discussion was based on data covering the year before the recent strike, which is 1 October 2011 to 31 September 2012. Whilst the student analysed this data he found significant inconsistencies in it. These are to such a degree that any analysis done on the data would not be reliable. After running various parsing functions on the data around 4,000 entries out of a total of 27,332 could not be categorised. This accounted for 26% of the physical time according to the data. Then there is also massive times recorded, which proved faulty when the planner double checked with data from dispatch. Other entries show no time, as they were not closed down.

The student and senior planner concluded that in access of a third of the data is not reliable. It is thus advised that an analysis of the report itself is done, not the data as it is unreliable. The analysis can be used to show deficiencies and prove that the data is not reliable in its present form. Recommendations can then be made on how and why to correctly enter the data.

The comment was made that 80% of the required work is being done with little benefit, a little more effort is needed and the system will function reliably. The hypothesis is that it must be done correctly, or be ceased. A lot of time is wasted at present.

### *H:1.1.3 Operations: Production Manager, Loading and Hauling*

**13 November 2012 (Duration: 0.5 Hours)**

This interview with the Production Manager – Loading and Hauling is a follow on from a previous meeting. The initial meeting is not recorded in this document as it was more guidance than information oriented. This second meeting however was used to answer some questions about certain practices and issues that were observed in and around the pit during the on going investigations.

(The content is summarised in a Q&A format. Both Questions and Answers are paraphrased)

***Q1- The 860E trucks are rated at 254ton, according to the 10-10-20 principle (see Sections E2.1) it should be possible to average near this nominal load. Yet it was observed that trucks are often under loaded?***

This issue is indeed very important, and plays a big role in truck utilization. We have recently done in-depth studies in the area, there is a Mining Engineer who has all the details.

***Q2 – What is the regulations around the no-entry signs? Are they sometimes neglected causing longer cycle times due to increased spotting times?***

It is possible, they are supposed to be 50 behind a shovel. Another factor that has to be considered is double sided spotting. This is making sure that a shovel can load on both sides, it is a great time saver and must be implemented whenever possible. Making sure this happens where possible has a significant effect on cycle times, it only happens around 20% of the time at present.

***Q3 – What is the deal with all the stop signs?***

Due to trucks running away upper management has implemented conservative regulations. It would be worth knowing what the cost in cycle times are.

***Q4 – Why the big losses on shift changes, 2-3 hours per day seems extreme.***

Legislation. The only way to significantly reduce it is to have 8 hours shifts. The same Mining engineer can give you some further information.

***Q5 – Bruce A is a stockpile, everything that goes there is double handling. Would you care to explain the reasons behind using it?***

It was originally used when the crushers was not able to cope with ore coming out of the mine, or was down. We now tip everything at these stockpiles as it is quick compared to the crushers. This reduces cycle times and saves the system from being upset when a crusher goes down, which happens sporadically. Having one front end loader and a few trucks is enough to occupy the crusher from the near stockpile.

### *H:1.1.4 Payloads: Mining Engineer, Projects*

**13 November 2012 (Duration: 1 Hour)**

A mining engineer who did and in-depth analysis on load factors at Sishen was able to supply the researcher with reports and answer some questions.

**Payloads**

The low weights displaced on the trucks are not accurate, depending on which truck they can be 5%-10% low. More details and data were provided in reports. In recent years analysis has led the target to be moved from 100% of the nominal load to 93% of the nominal load, improvements have increased the actual numbers to 96%. Again details can be found in the report.

Dispatch records the nominal amount, or target load. Actual average payloads are calculated by the geology department periodically.

When waste material is handled the loading target is lowered.

**New Technology / False waste detector**

A scanner that scans the volume of loads on the way to waste dumps. This gives a warning when ore is to be wasted. How often this occurs is not knows. The technology is being used in Australia, but is too expensive to implement in South Africa at present.

**Key Factors Influencing Utilization**

The following measures were given as key to improving utilization:

- Cycle Time
- Payloads
- Utilization (Maintenance Availability and Use of Availability)

**Shift Changes**

They are large, the budgets is for an hour per change. Hot seat changes are used by some of the contractors, it is not currently in the Sishen planning framework. The losses in 12 hour shifts are Shift Changes, Fatigue Breaks, Other Breaks, Inspections and Briefings. Many of these are required by law. You can not have shifts longer than 12 hours to save time with overlaps.

After a shift change it also takes an hour for the system to settle, some contractors mitigate this by having half of the trucks loaded for the shift change.

### *H:1.1.5 Operations: Production Manager, Loading and Hauling*

**28 November 2012 (Duration: 0.5 Hours)**

This interview with the Production Manager – Loading and Hauling is one of a number of meetings and conversations. It is recorded as a new piece of information was revealed. (A previous meeting is recorded in Section G:1.1.3)

After discussing field test methodologies and requirements the researcher asked who or what determined the 50m distance and made a suggestion that trucks not be required to wait at the no-entry signs, and that some other procedure might be more efficient unless prohibited by law or safety considerations. Mr Barry gave the following explanation:

**Legislation and Company Procedures**

There is no direct law that requires trucks to hold at 50m, the signs are placed at 50m in accordance with company procedures put in place to adhere to general safety requirements. Their main purpose is to keep light vehicle and other personnel away from danger.

**Pre-Spotting**

Trucks are not required to wait at the no-entry signs during double sided loading, they should pre-spot. This means that whilst the current truck is being loaded the next truck should pass the no-entry sign and get into position to back up to the shovel once the current truck leaves. It significantly reduces spotting times but is not done as often as might be possible at Sishen.

### *H:1.1.6 Operations: Foreman*

**5 December 2012 (Duration: 0.5 Hours)**

During the field study on loading rates the researcher had a chance to discuss some issues with a foreman. The following points were covered:

**Remuneration**

Shovel and Truck operators receive the same salaries according to this foreman. He went on to discuss that shovel operators have a harder and more crucial role. This does seem to be the case. It was suggested that this be adapted to ensure that the more skilled people become shovel operators and that they are justly rewarded.

**Coffee Breaks**

Coffee breaks cost a fair amount of time and are required by law on a 12 hour shift. The foreman noted that this time loss is compounded by the fact that trucks stop and wait while a shovel operator takes a coffee break. The truck operator then takes his coffee break in addition to this. The dispatch system does not seem to reallocate trucks when a shovel takes a coffee break. One suggestion would be to set times for coffee breaks, the flexitime causes compound time losses and makes the system difficult to optimise.

**Responsibilities of Shovel Operators**

Shovel operators seem to neglect their duties to varying degrees, such as moving no-entry signs to doing periodic maintenance checks.



**Old Shovel for Benchmarking**

When shown the benchmarking results for the American operator on the shovel the foreman noted that S564 is a slower shovel as it has not been upgraded like the other rope shovels and is still analogue controlled. Due to the slow loading speeds differences in operator skill would be less apparent.

#### *H:1.1.7 Senior Mining Engineer: Mining Systems*

**16 December 2013 (Duration 5 minutes)**

Mr Marx was asked what he thinks a realistic would be to use to approximate degree of under trucking at Sishen. He suggested that 80% -90% would be a good estimate at present, and agreed that 75% is a realistic estimate for the first half of 2012.

### H:1.2 Observational Studies

#### *H:1.2.1 Dispatch Control Room*

**1 September 2012 (Duration 1 Hour)**

The Dispatch Control Room is used by the “dispatchers” to guide the fleet. The dispatchers are equipped with screens showing all the data needed to run operations. Anomalies are handled via radio.

At the time of this interview only 19 trucks were running. This is due to the fired truck drivers following the illegal strike which ended two weeks ago. There was only one dispatcher, he commented that the normally control up to 160 units. Even though there are facilities for three dispatchers the dispatcher noted that one person could perform the primary operations.

**Issues noted**

During this session there were complaints that drivers get to trucks that have been booked of for unscheduled repairs only to find that they are still not operational. Unscheduled repairs are handled by Mikom, whose KPI is dependant on the time these repairs take. Further enquiries revealed that this occurrence is not uncommon. The case was made that Mikom rushes repairs to minimise their own downtime. This leads to drivers getting to the truck only to find it is still not operational. This naturally leads to double work, as Mikom needs to be called out again. It has an obvious negative impact on overall utilisation.

It was further revealed that these occurrences are not kept track off, the downtime might still be against Mikom, but there is no measure of these unnecessary "double call-outs". It is argued that this is a case of one department trying to improve their KPI at an overall cost to the company.

### *H:1.2.2 A view from inside the cab of a 860E Dump Truck –1*

**6 November 2012 (Duration: 5 Hours)**

These observations were made during half a shift spent with am experienced truck driver who has been working in dispatch for 17 years. He is temporarily driving trucks full-time as part of the strike mitigation actions.

The shift was severely over trucked. Long queues formed at shovels and crushers.

**Shift Changes**

Trucks and shovels are run on 12 hour shifts, the shift change occurs at 8am and 8pm. These changes were observed to be extremely inefficient. Discussions with the driver (who has many years of experience both driving and manning the control room at Dispatch) revealed that approximately an hour and a half is lost during each shift change. This is three hours a day seven days a week. A seventh of 14% of total time is thus lost just due to shift changes. A far cry from the efficient "hot-seat" shift changes you might expect where expensive equipment is used in a production critical environment. The comment was made that the foremen do not do enough to minimise this loss.

**Stop Signs**

As the truck travels to the shovels it is held up by a surprising amount of stop signs, some of them seemingly very unnecessary. A lot of time is lost deceleration, stopping, and accelerating again. It is understood that these signs are there to increase safety, yet a number of them seems to be unnecessary. It must be noted that there are less stop signs on the way back from the shovels to the crushers, a time when the trucks travel much slower. Due to taking different routes no measurements were taken.

**Weight**

It was surprising to see how often trucks are under loaded, and by how much. It was very common to see trucks loaded to only 80% of weight (a scale on both sides of the truck indicates the load). This information is recorded on the dispatch system and would make for an interesting study.

When the trucks are queuing due to over trucking shovels can consider only doing full passes to optimise shovel utilization. If the reverse occurs where shovels have to wait for trucks due to under trucking a shovel should consider doing a “filling pass” or “half pass” to optimise truck utilization. Conditions in the pit vary unpredictably. A dynamic system should be implemented that favours trucks or shovels based on the real time demand.

**Stockpile Usage**

It was curious that that the stock pile next to the primary crusher was used even though there was a long line at the crusher. Is this not the time when over capacity should go to the stockpile? Instead of loosing time at the shovel extra trucks could dump on the stock pile for use when the crusher has extra capacity. The driver mentioned that dispatch allocates trucks to the stockpile if more than 6,500 ton/hour is heading to the crusher, yet the reverse was happening on this shift.

**Americans**

There are currently four Americans on the mine, they have been brought over to assist with training new personnel after the bulk of the regular truck drivers were fired following the illegal strike. At the moment they are manning some of the shovels and trucks. Loading at a shovel manned by an American was noticeably quicker than some other shovels. This provides a good opportunity for bench marking the local operators performance.

### *H:1.2.3 A view from inside the cab of a 860E Dump Truck –2*

**8 November 2012 (Duration: 5 Hours)**

These observations were made during half a shift spent with an instructor from America. Four Americans have been on the mine since mid-year, they are on site for training purposes, but with the short numbers following the strike they have been put on equipment. The American, Frank, has spent 27 years as a miner.

The shift got of to a cluttered start with 7 trucks queued up at Bruce-A near the primary crusher, yet primary was down. Frank was then relocated to 562 tipping low-grade ore at I-sentraal.

Note, observations serve as extension of that in Section G:1.2.2.

**No-Entry signs / holding zones**

When a truck arrives at a shovel it waits at the no-entry sign or holding zone until the current truck is clear. This is designed to keep trucks from colliding. It was noted that some of the holding zones are excessively far from the shovels. Frank notes that they are often not shifted for weeks. It is hypothesized that a fair amount of time can be saved by putting these no-entry signs at the best position. At one site it took 25 seconds from the time the loaded trucks passes what Frank described as a realistic holding position until the the next truck reached the same position. The cycle time on this moderately short run was close to 10 minutes. This meant that roughly 5% was added to Frank's cycle time due to this incorrect no-entry sign positioning. It must be noted that this was a relatively short cycle with a moderately difficult loading position. A field study is called for investigating the time losses at different loading zones. This can only be done once the practical and legislative factors governing the position of the signs are understood.

**Shift Changes**

Shift changes were again noted to be very sluggish, Frank observes that there is no sense of urgency. Operators and supervisors alike don not seem overly concerned about the large amount of time being wasted. Once Frank was in the truck, finished with inspection, logged in and ready to go there was nobody at dispatch for five minutes.

**Stop Signs**

Frank noted that many of the stop signs are unnecessary and inflates cycle time.

**Weight**

Under load was again observed. It was noted that the 10-10-20 rule does not seem to be implemented.

**Stockpile Usage**

Once again the truck I was with initially got assigned to Bruce A, which is the stockpile near the primary crusher. Many trucks were queued up here yet dispatch only noticed that the primary crusher was done after four trucks had been loaded. Frank explained that he has loaded down at Bruce A just to dump up the hill at Bruce B on some occasions. It must be remembered that all the material at Bruce A is essentially double handled.

### *H:1.2.4 Communication Failure: Shovel, Truck and Dispatch*

**1 December 2012 (Duration: During Field Study)**

The follow time losses were observed during a field study, they are due to ineffective communication between the truck, shovel and dispatch. The observation was made whilst visually studying a loading operation and monitoring the primary radio chatter. It centres around a shovel breaking down. The following delays were noted:

- After waiting at the immobile shovel for 17 minutes the truck operator asked whether there was a problem with the shovel on the radio.
- After 23 minutes the shovel was repetitively called by dispatch with no answer.
- After 25 minutes the shovel was booked of: No Power.
- After 28 minutes the half loaded truck left.

Almost half an hour was lost for each truck in this cycle and the maintenance response was delayed by half an hour due to weak lines of communication.

## APPENDIX H:2 → Memorandums

### H:2.1 Sustainable Method for Reliable SAP Breakdown Data Recording

# MEMO

**To** **1. SEM: MINING MAINTENANCE PRIMARY**

**2. SENIOR PLANNER: MINING MAINTENANCE**

**From** **E LOOTS**

**STUDENT, MINING ENGINEERING AND PROJECTS**

**Date** **13/11/2012**

**Subject** **Trial for a Sustainable Method in Reliable SAP Breakdown Data Recording**

**1. PURPOSE**

The Purpose of this memorandum is to seek approval for the trial of a method to record SAP breakdown data that is both reliable and sustainable.

**2. DISCUSSION**

The SAP system used by maintenance aims to record all the break downs. This creates an opportunity for precise analysis, trend tracking and strategic planning. Yet the system is not reliable enough to be confidently used in this manner. The attached analysis draws this conclusion. A small amount of effort is needed to get the system operating reliably and yielding results that management can use with confidence to form maintenance plans and adjust strategies for observed trends.

In order to achieve this somebody must take responsibility, ensuring data is entered correctly, and following up on mistakes. The year analysed had 27,332 entries, it equates to 77 entries per day. Checking up to a 100 entries a day is a manageable undertaking. As discussed in the attached analysis the year analysed had 7,314 entries which were incorrect, the average is 20 per day. It can be assumed that once mistakes are followed up on they will decrease as knowledge of the expectation spreads. These averages will be lower at present due to the decreased number of trucks after the strike.

**3. RECOMMENDATION**

It is strongly recommended for you approval that a person be given the trial task of checking the entries of the previous day each morning, and correcting the mistakes.

____________

**E LOOTS**

STUDENT, Mining Engineering and Projects

RECOMMENDED/

NON RECOMMENDED: ______________ ______________

G LOOTS DATE

RECOMMENDED/

NON RECOMMENDED: ______________ ______________

W LUBBE DATE

## H:2.2 Spotting Time Benchmarking Exercise with "Americans"

# MEMO

**To** **PRODUCTION MANAGER: LOADING AND HAULING**

**From** **E LOOTS: STUDENT, MINING ENGINEERING AND PROJECTS**

**Date** **29/11/2012**

**Subject** **Spotting Time Benchmarking Exercise with "Americans"**

1. **PURPOSE**

The Purpose of this memorandum is to seek approval for a benchmarking exercise that will measure spotting times and involve the Americans currently on site.

2. **DISCUSSION**

In order to perform physical spotting time measurements for benchmarking purposes with the Americans that are currently on site the following procedure will be followed:

1) Select a shovel that has a long cycle time.
2) Fix trucks to it, one of them being an American.
3) Record the spotting times for each truck, noting other practical variances, until enough data is collected to calculate reliable averages.

**This requires the follow arrangement to be made**:

- Fix an American and other drivers to the selected shovel for a number of hours (estimated required time is 2-4 hours)
- Switch the drivers that are fixed to the selected shovel with a new set of drivers.

Depending on feasibility, the accuracy of the data can be improved by:

- Repeating the exercise with more that one American.

- Increasing the number of sets of drivers that are observed.
- Having trucks that are of the same class.

**3. RECOMMENDATION**

It is strongly recommended for you approval that the above mentioned arrangements be made .

___________

**E LOOTS**

STUDENT, Mining Engineering and Projects

RECOMMENDED/

NON RECOMMENDED: _____________ _____________

C BARRY DATE

## H:2.3 Loading Time Benchmarking Exercise with "Americans"

# MEMO

**To** **PRODUCTION MANAGER: LOADING AND HAULING**

**From** **E LOOTS: STUDENT, MINING ENGINEERING AND PROJECTS**

**Date** **29/11/2012**

**Subject** **Loading Time Benchmarking Exercise with "Americans"**

1. **PURPOSE**

   The Purpose of this memorandum is to seek approval for a benchmarking exercise that will measure loading times and involve the Americans currently on site.

2. **DISCUSSION**

   In order to perform physical loading time measurements for benchmarking purposes with the Americans that are currently on site the following procedure will be followed:

   1) Select a shovel that is likely to have consistent loading conditions
   2) Fix trucks to it, all of them being of the same class.
   3) Put an American on the shovel.
   4) Record the loading times until enough data is collected to calculate reliable averages.
   5) Place a local operator on the same shovel and repeat step 4.

   **This requires the follow arrangement to be made**:

   - Have an American operate the designated shovel for half a shift.
   - Switch the American with a local operator for the second half of the shift.
   - Repeating the exercise with local operators under the same conditions to widen the sampling pool.

**Alternatively**:

- ❖ Have a different operator on the shovel for 5 consecutive days.

**3. RECOMMENDATION**

It is strongly recommended for you approval that the above mentioned arrangements be made .

____________

**E LOOTS**

STUDENT, Mining Engineering and Projects

RECOMMENDED/

NON RECOMMENDED: ______________ ______________

C BARRY DATE

# APPENDIX H:3 → Sishen's Dispatch System

## H:3.1 Introduction

At Sishen fleet management is done using the Modular Mining Systems (MMS) DISPATCH® system. Two dispatch overseers run the system administration whilst a dedicated dispatch room is used to manage primary mining equipment.

The dispatch system play an important role in managing Sishen's fleet and also records data that is used to monitor various divisions' performances. Strategic decisions are often made from data extracted from this dispatch system.

## H:3.2 Literature Review

### *H:3.2.1 Overview*

Modular's flagship product, the DISPATCH system for open-pit mines, has become established as a standard for fleet management software in the mining industry. At its core, the system optimizes haul truck assignments, reducing truck queuing at loading and dumping locations, through the use of multiple optimization algorithms, including linear programming, best path, and dynamic programming. A mine's dispatcher uses the system to centrally manage mine operations, including equipment allocation, shift change, refuelling, and equipment downtime events. Other features of the system include GPS-based equipment positioning, equipment health monitoring, maintenance tracking, blending, and production reporting. The DISPATCH system enables real-time, computerized, central management of mine operations to maximize production and efficiency, while increasing safety and control (31).

### *H:3.2.2 Origin*

The concept of optimized fleet management was first introduced by Dantzig and Ramser in 1959 (32). They were concerned with the optimum routing of a fleet of gasoline delivery trucks between a bulk terminal and a large number of service stations. Since then this field of research has been applied to a wide variety of relevant industries, such as emergency services (33), courier and delivery services (34) and of course open pit mining (35).

The application of optimized fleet management in mining started in the 1970's. At the time, certain open pit mines such as the Mt. Wright iron ore mine in Quebec (36) and the Palabora copper mine in

South Africa (37) had grown into large scale operations that employed large truck fleets and relatively complex haul routes. In order to remain competitive in the mining industry, researchers saw the need to move away from conventional radio/visual dispatching methods.

At the forefront of this research was a small company based out of Tucson, Arizona called Modular Mining Systems Ltd. They are credited with the deployment of the world's first computer based mine management system at the Tyrone Mine in 1982 (35). By 1993, MMS was manufacturing, installing and supporting its computer based DISPATCH® system at mines worldwide (38).

### *H:3.2.3 The Theory Behind Fleet Management*

The system that controls, manages and implements these strategies is generally referred to as a fleet management system or a dispatch system. The main goal of such a system is to help mines optimize efficiency of their loading and haulage resources (39). To this end, White et al. (35) and Hagenbuch (40) proposed that two of the principal objectives are maximum shovel utilization (i.e., minimum shovel idle time) and maximum truck utilization (i.e., minimum truck queue time). Hagenbuch describes these as the "two key premises of truck dispatching" as reproduced below:

1. *"Where can a hauler go to be loaded the quickest (it needs to be fully comprehended and understood that haulers are only productive when they are carrying a load)? Empty haulers are the essence of nonproductive equipment. In the highway trucking industry, any empty travel is called dead heading and justly so likewise in mining. Yes, some dead heading is always going to occur in a mining environment, but the point is it has to be minimized.*
2. *What piece of equipment will need a hauler soonest (with the corollary being where can a hauler get loaded the quickest)? It needs to be understood that loading equipment is also only productive when loading material for haulage. Idle loading equipment is again the essence of nonproductive equipment."*

### *H:3.2.4 Technical Workings*

**MMS DISPATCH®**

The DISPATCH® system is a large scale, computer-based mine management system that controls the dispatching of all haul trucks in any open pit (35). It is based on a set of algorithms that require a comprehensive set of data, consisting of both real-time information (collected continuously during operation), and quasi-static data based on mine specific parameters (usually inputted and updated frequently by mine dispatchers). White et al. (38) provide a list of what is required:

- Haul road information such as positions, elevations and distances;
- Truck positioning data (from GPS);
- Cycle time information such as truck loading and dumping times;
- Operational states of trucks and shovels;
- Miscellaneous mining constraints such as shovel priorities, dump capacities, truck capacities, and scheduled operator breaks.

Due to the proprietary nature of the MMS DISPATCH® software, a full set of details pertaining to its dispatching method are not available in the literature. Attempts by the author to obtain further information were fruitless. According to MMS authorities, they have not and do not publish much in the way of technical details due to the competitive nature of their business. Therefore, the bulk of what is publicly available in terms of technical details is rather out-dated, with papers published by MMS such as White et al. in 1982 (35) and White et al. in 1993 (38). Other publications such as (41) and (42) summarize the content of these papers.

DISPATCH® uses a multi-stage approach. The three stages are Best Path determination (BP), Linear Programming (LP) for each significant change in a time-dependent variable, and Dynamic Programming (DP) for truck assignment in real-time (42). Figure H71 shows a flow chart describing the inputs and outputs for each module and how they interact.

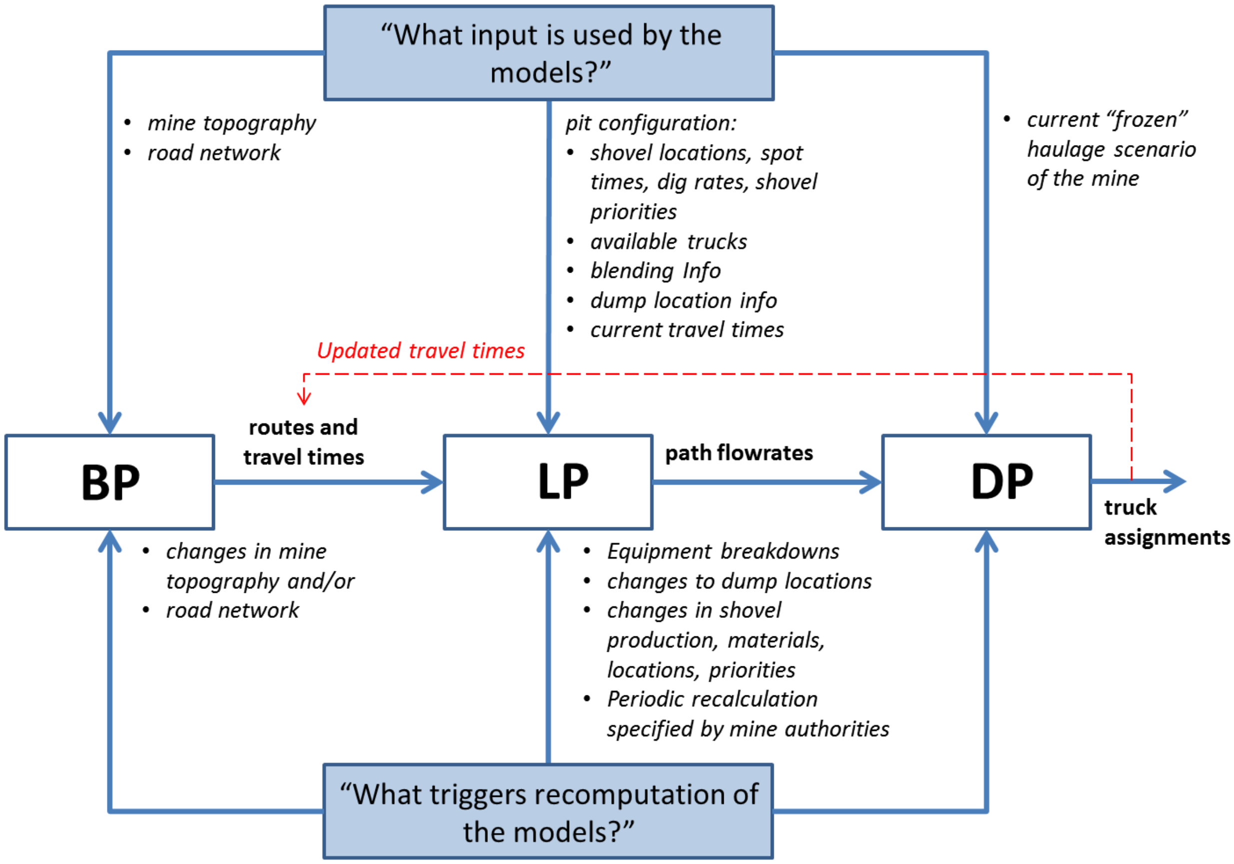



Figure H71:DISPATCH® algorithms (adapted from (42))

### H:3.2.5 *Is Modular's Dispatch the best solution?*

Modular's Dispatch is currently running at more than 140 active mine sites; among these are nine of the ten highest-producing surface mines in the world (31).

## H:3.3 Sishen Review

Sishen dispatch overseers were found to have a good understanding of how the system works. Details on how Sishen implements the dispatch system can be found in the interview with senior dispatch overseer Johan Kotze in Section H:1.1.1.

This section is not an exhaustive review of Sishen's dispatch system, but contains information supplementing other investigations.

# APPENDIX H:4 → Examples of Raw Data

## H:4.1 SAP Data

22,468 entries of this data was used for the SAP data analysis in Appendix C:

| Notification | Functional Location | Short Description of Notification | Malf Strt | Malf. end | Un | Brdwn.Ind | Problem Code Text | Item Text | Person Responsible | Malf. start | Malf End | Breakdown |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 620622160 | MIS-M01-HA01-F559-0500-03 | AIRCON DEFECT | 00:15:00 | 01:17:00 | H | X | Cab_Gauges | AIRCON BELT GERUIL | JOHANNES DANIEL BOTHA | 1/10/2011 | 1/10/2011 | 1.03 |
| 620622244 | MIS-M01-HA01-F559-1500-05 | ANDER MEGANIES | 01:19:00 | 01:36:00 | H | X | Elect_Sys_Contactors Auxillary | BRAKE LOCK CIRCUIT FAULT RESET | JOHANNES DANIEL BOTHA | 1/10/2011 | 1/10/2011 | 0.28 |
| 620622248 | MIS-M01-HA02-F514-0534 | ANDER ELEKTRIES | 04:01:00 | 08:56:00 | H | X | Eng_Add Water | WATER GEGOOI | GOPANE ANDRIES MOLOKWANE | 1/10/2011 | 1/10/2011 | 4.92 |
| 620622250 | MIS-M01-HA01-F514-0529-05 | ANDER MEGANIES | 04:33:00 | 05:00:00 | H | X | 24V_Sys_Indicator Lights | KODE 87 RESET | JACOBUS PETRUS DE BEER | 1/10/2011 | 1/10/2011 | 0.45 |
| 620622255 | MIS-M01-HA01-F559-1800-03 | ANDER MEGANIES | 01:20:00 | 01:44:00 | H | X | Cab_Emergency Stop | SELF GEREADY | TERENCE HENRY SPERLING | 1/10/2011 | 1/10/2011 | 0.40 |
| 620622257 | MIS-M01-HA01-F559-1500-05 | ANDER MEGANIES | 01:42:00 | 02:55:00 | H | X | Elect_Sys_ Contactors Auxillary | BRAKE BLOCK SOLENOID SKOON | LOUIS JOHANNES CORNELIUS FISHER | 1/10/2011 | 1/10/2011 | 1.22 |
| 620622259 | MIS-M01-HA01-F620-0100-03 | ANDER MEGANIES | 02:04:00 | 02:46:00 | H | X | Cab_Door | WIPERS HERSTEL | TERENCE HENRY SPERLING | 1/10/2011 | 1/10/2011 | 0.70 |
| 620622260 | MIS-M01-HA01-F514-0545-05 | ANDER ELEKTRIES | 02:06:00 | 02:55:00 | H | X | Eng_Add Oil | GOOI ENGINE OLIE | GERT JACOBUS VAN DEN BERG | 1/10/2011 | 1/10/2011 | 0.82 |
| 620622273 | MIS-M01-HA07-F063-0100-04 | ANDER ELEKTRIES | 02:11:00 | 02:40:00 | H | X | Cab_Emergency Stop | AIR FILTER BLOCK RESET | JACOBUS PETRUS DE BEER | 1/10/2011 | 1/10/2011 | 0.48 |
| 620622290 | MIS-M01-HA01-F559-0300 | ANDER MEGANIES | 09:28:00 | 10:05:00 | H | X | Other_SelfFix-NoProblem? | SELF GEREADY | | 1/10/2011 | 1/10/2011 | 0.62 |
| 620622292 | MIS-M01-HA07-F063-0500-04 | ANDER ELEKTRIES | 02:30:00 | 03:00:00 | H | X | Eng_Add Oil | OLIE LEK/LOOP SO | JACOBUS PETRUS DE BEER | 1/10/2011 | 1/10/2011 | 0.50 |
| 620622293 | MIS-M01-HA01-F514-0541-05 | ANDER ELEKTRIES | 02:48:00 | 03:15:00 | H | X | WMotor_Park Brakes | R/H WIELDOP VASGEMAAK | TERENCE HENRY SPERLING | 1/10/2011 | 1/10/2011 | 0.45 |
| 620622294 | MIS-M01-HA02-F514-0534-03 | ANDER MEGANIES | 02:59:00 | 03:07:00 | H | X | Cab_Door | GEEN FOUT | LOUIS JOHANNES CORNELIUS FISHER | 1/10/2011 | 1/10/2011 | 0.13 |
| 620622296 | MIS-M01-HA01-F514-0526-05 | MA ANDER ELEKTRIES | 03:23:00 | 06:57:00 | H | X | 24V_Sys_Wiring | MF EN GF TIPS VERVANG | WELILE DONALD BOZWANA | 1/10/2011 | 1/10/2011 | 3.57 |
| 620622297 | MIS-M01-HA01-F559-1500-03 | ANDER MEGANIES | 03:26:00 | 03:50:00 | H | X | Elect_Sys_Electrical Panels | NET IN NEUTRAL GESIT | LOUIS JOHANNES CORNELIUS FISHER | 1/10/2011 | 1/10/2011 | 0.40 |
| 620622298 | MIS-M01-HA01-F559-0600 | MA ANDER ELEKTRIES | 04:35:00 | 07:17:00 | H | X | Elect_Sys_Contactors Auxillary | PARK BRAKE FAILURE RESET | PATRICK ELLIS | 1/10/2011 | 1/10/2011 | 2.70 |
| 620622311 | MIS-M01-HA01-F514-0524 | ANDER ELEKTRIES | 05:39:00 | 06:57:00 | H | X | Elect_Sys_Contactors Auxillary | KODE 73 RESET | DANIEL NTSUTLANE MOGALANYANE | 1/10/2011 | 1/10/2011 | 1.30 |
| 620622313 | MIS-M01-HA02-F514-0537 | ANDER MEGANIES | 06:23:00 | 07:35:00 | H | X | Cab_Hooter | IST HERSTEL | PETRUS CORNELIUS BOOYSEN | 1/10/2011 | 1/10/2011 | 1.20 |
| 620622314 | MIS-M01-HA01-F559-0800 | ANDER ELEKTRIES | 06:53:00 | 07:20:00 | H | X | Elect_Sys_Contactors Auxillary | PARK BRAKE FAILURE RESET | DANIEL NTSUTLANE MOGALANYANE | 1/10/2011 | 1/10/2011 | 0.45 |
| 620622327 | MIS-M01-HA01-F559-1300 | ANDER MEGANIES | 09:17:00 | 09:26:00 | H | X | Hydr_Unloader Valve | ACCUM RESET | PATRICK ELLIS | 1/10/2011 | 1/10/2011 | 0.15 |
| 620622332 | MIS-M01-HA01-F559-0800 | ANDER ELEKTRIES | 09:24:00 | 17:00:00 | H | X | Other_ No Operator - ANDER ELEKTRIES | | PATRICK ELLIS | 1/10/2011 | 1/10/2011 | 7.60 |

## H:4.2 Single Sided Loading Data

Data from field studies:

| Shovel | Date | Truck Class | Truck | Starting | Pre-Spotting | Waiting for shovel | Spotting-Complete | Loaded | Past Pre-Spot | Out | Buckets | Payload | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Spotting Times for 860E's at 564** | | | | | | | | | | | | | |
| S564 | 29-Nov | 860E | 45 | Standing | 33 | 0 | 56 | 224 | 246 | 257 | | | |
| S564 | 29-Nov | 860E | 40 | Standing | 23 | 6 | 54 | 211 | 224 | 231 | | | |
| A 765 Tips HMS, it is level out by a CAT grader - 16mins | | | | | | | | | | | | | |
| S564 | 29-Nov | 860E | 34 | Running | 29 | | 55 | 313 | 337 | 354 | | | |
| S564 | 29-Nov | 860E | ? | Standing | 23 | 48 | | | | | | | |
| New Day, similar loading condition, assuming conditions will not impact spotting or loading times. | | | | | | | | | | | | | |
| S564 | 1-Dec | 860E | 22 | Running | 24 | 8 | 53 | 205 | 230 | 245 | | | |
| S564 | 1-Dec | 860E | 4 | Running | 49 | 0 | 74 | 213 | 244 | 260 | | | Failed Pre-Spotting |
| S564 | 1-Dec | 860E | 22 | Running | 24 | 20 | 65 | 230 | 252 | 266 | | | |
| S564 | 1-Dec | 860E | 4 | Running | 29 | 27 | 78 | 243 | 282 | 295 | | | |
| S564 | 1-Dec | 860E | 22 | Standing | 26 | 0 | 50 | 265 | 288 | 298 | | | Waited at no entrant reasonry sign for no app |
| S564 | 1-Dec | 860E | 23 | Running | 33 | 130 | 196 | 350 | 377 | 396 | | | |
| S564 | 1-Dec | 860E | 4 | Running | 28 | 0 | 60 | 203 | 237 | 0 | | | Delays getting going, stops? |
| S564 | 1-Dec | 860E | 22 | Standing | 29 | 0 | 52 | 220 | 235 | 250 | | | |
| **Spotting Times for 730E's at567** | | | | | | | | | | | | | |
| S567 | 1-Dec | 730E | 532 | Standing | 27 | 10 | 49 | 198 | 225 | 235 | | | |
| S567 | 1-Dec | 730E | 537 | Standing | 25 | 0 | 50 | 153 | 176 | 185 | | | |
| S567 | 1-Dec | 730E | 536 | Standing | 24 | 0 | 46 | 149 | 176 | 186 | | | |
| S567 | 1-Dec | 730E | 553 | Standing | 30 | 0 | 50 | 153 | 170 | 177 | | | |
| S567 | 1-Dec | 730E | | Standing | 31 | 0 | 53 | 159 | 189 | 205 | | | random 7sec wait |
| S567 | 1-Dec | 730E | CAT0700 | Standing | 34 | 0 | 60 | 160 | 185 | 198 | | | |
| S567 | 1-Dec | 730E | 537 | Standing | 29 | 0 | 53 | 151 | 183 | 196 | | | |
| S567 | 1-Dec | 730E | 555 | Standing | 23 | 0 | 43 | 160 | 180 | 189 | | | |
| S567 | 1-Dec | 730E | 530 | Standing | 25 | 0 | 48 | 158 | 177 | 184 | | | |
| S567 | 1-Dec | 730E | 538 | Standing | 42 | 0 | 60 | 166 | 197 | 211 | | | |
| S567 | 1-Dec | 730E | 548 | Standing | 40 | 33 | 102 | 215 | 250 | 260 | | | |
| **Benchmarking American at 564** | | | | | | | | | | | | | |
| S56 | 5- | 860E | 40 | Runni | 22 | 0 | 41 | 154 | 169 | 17 | 4 | brok | underloaded |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Dec | | | ng | | | | | | 6 | | en | |
| S564 | 5-Dec | 860E | 40 | Running | 22 | 0 | 50 | 168 | 182 | 190 | 4 | broken | underloaded |
| S564 | 5-Dec | 860E | 23 | Standing | 23 | 0 | 54 | 225 | 241 | 249 | 6 | 290-330 | jumping round |
| S564 | 5-Dec | 860E | 40 | Running | 24 | 0 | 44 | 194 | 210 | 217 | 5 | broken | |
| S564 | 5-Dec | 860E | 23 | Running | 23 | 0 | 49 | 240 | 260 | 269 | 6 | 320 | |
| S564 | 5-Dec | 860E | 23 | Running | 26 | 0 | 58 | 216 | 234 | 242 | 5 | 270-320 | |
| S564 | 5-Dec | 860E | 23 | Running | 23 | 0 | 49 | 188 | 207 | 217 | 5 | ? | |
| S564 | 5-Dec | 860E | 40 | Standing | 29 | 0 | 52 | 186 | 204 | 212 | 5 | broken | |
| S564 | 5-Dec | 860E | 23 | Running | 24 | 0 | 49 | 186 | 206 | 212 | 5 | 250-340 | |
| S564 | 5-Dec | 860E | 40 | Running | 21 | 0 | 40 | 182 | 197 | 207 | 5 | broken | |
| S564 | 5-Dec | 860E | CAT? | Standing | 33 | 0 | 51 | 181 | 206 | 213 | 5 | broken | |
| S564 | 5-Dec | 860E | 40 | Running | 25 | 0 | 40 | 187 | 203 | 210 | 5 | broken | |
| S564 | 5-Dec | 860E | CAT | Running | 25 | 0 | 45 | 187 | 207 | 217 | 5 | broken | |
| S564 | 5-Dec | 860E | ? | ? | ? | 0 | ? | 122 | ? | ? | 5 | ? | from cabin |
| S564 | 5-Dec | 860E | ? | ? | ? | 0 | ? | 142 | ? | ? | 5 | ? | from cabin |
| **Benchmarking Local at 564** | | | | | | | | | | | | | |
| S564 | #REF! | 860E | 14 | Running | 27 | 0 | 91 | 261 | 283 | 292 | 5 | broken | Asked truck to respot costing 1:31 - 0:53 |
| S564 | #REF! | 860E | 16 | Running | 30 | 0 | 58 | 220 | 242 | 265 | 6 | 203 | does look visually emptier |
| S564 | #REF! | 860E | 14 | Running | 146 | 0 | 174 | 346 | 370 | 380 | 6 | broken | Shovel 'sleeps' for 108 seconds before spotting truck |
| S564 | #REF! | 860E | 16 | Running | 28 | 0 | 60 | 263 | 280 | 307 | 7 | ? | |
| Cat grader had to be called in to clear rocks from loading area | | | | | | | | | | | | | |
| S564 | #REF! | 860E | 14 | Standing | 30 | 0 | 60 | 216 | 237 | 247 | 6 | broken | |
| S564 | #REF! | 860E | 16 | Running | 28 | 0 | 54 | 248 | 270 | 292 | 7 | 212 | |
| S564 | #REF! | 860E | 14 | Standing | 31 | 0 | 60 | 218 | 239 | 250 | 6 | broken | |

## H:4.3 Double Sided Loading Data

Data from field studies:

| Shovel | Date | Truck Class | Truck | Side | S-Readying | Late Hoot | Total Readying Time | T-Backing Up | Loading | Exit | Payload | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Benchmarking Drivers, locals vs American, on 860Es at S565 | | | | | | | | | | | | |
| S565 | 6-Dec | 860E | 34 | Left | 37 | | 37 | 0 | 184 | 23 | | |
| S565 | 6-Dec | 860E | 40 | Right | ? | | #VALUE! | ? | 134 | 34 | | |
| S565 | 6-Dec | 860E | 8 | Left | ? | | #VALUE! | ? | 120 | 30 | 228 | |
| S565 | 6-Dec | 860E | 14 | Right | ? | | #VALUE! | ? | 198 | 23 | broken | |
| S565 | 6-Dec | 860E | 34 | Left | 38 | | 38 | 0 | 144 | 23 | 244 | |
| S565 | 6-Dec | 860E | 40 | Right | 20 | | 20 | 40 | | | broken | |
| S565 | 6-Dec | 860E | 14 | Left | ? | | #VALUE! | ? | 149 | 32 | broken | |
| S565 | 6-Dec | 860E | 34 | Right | 32 | | 32 | 38 | 115 | ? | 185 | |
| S565 | 6-Dec | 860E | 8 | Left | ? | | #VALUE! | ? | 115 | ? | 242 | |
| S565 | 6-Dec | 860E | 40 | Right | ? | | #VALUE! | ? | 131 | 21 | | |
| S565 | 6-Dec | 860E | 34 | Right | ? | | #VALUE! | 9 | 165 | 15 | 186 | |
| S565 | 6-Dec | 860E | 14 | Left | 22 | 8 | 30 | 23 | 195 | 27 | broken | |
| S565 | 6-Dec | 860E | 40 | Right | 35 | | 35 | 13 | 150 | 25 | broken | |
| S565 | 6-Dec | 860E | 11 | Left | 37 | | 37 | 0 | 145 | ? | | |
| S565 | 6-Dec | 860E | 34 | Right | ? | | #VALUE! | ? | 110 | 20 | 140 | |
| S565 | 6-Dec | 860E | 40 | Left | ? | | #VALUE! | ? | 138 | 32 | broken | |
| S565 | 6-Dec | 860E | 14 | Right | 42 | | 42 | FAIL | | | broken | Miss-Spot |
| S565 | 6-Dec | 860E | 11 | Left | 42 | | 42 | 0 | 135 | 33 | | |
| S565 | 6-Dec | 860E | 14 | Right | 35 | | 35 | 30 | 125 | 21 | broken | |
| S565 | 6-Dec | 860E | 34 | Left | 30 | | 30 | 0 | 140 | 17 | | |
| S565 | 6-Dec | 860E | 13 | Right | 28 | | 28 | 12 | 143 | 24 | | |
| S565 | 6-Dec | 860E | 40 | Left | 30 | | 30 | 28 | 169 | 40 | broken | |
| S565 | 6-Dec | 860E | | Right | 40 | | 40 | 12 | 155 | 20 | 252 | |
| S565 | 6-Dec | 860E | 34 | Left | 36 | | 36 | 0 | 137 | 22 | 236 | |
| S565 | 6-Dec | 860E | 11 | Right | 38 | | 38 | 12 | 120 | 24 | 206 | |
| S565 | 6-Dec | 860E | 13 | Left | 20 | 7 | 27 | 12 | 152 | 28 | | |
| S565 | 6- | 860E | 14 | Rig | 485 | 3 | 488 | 26 | 175 | 25 | broken | Moving around and |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dec | | | ht | | | | | | | | Checking floor |
| S565 | 6-Dec | 860E | 40 | Left | 51 | | 51 | 21 | 235 | 20 | broken | |
| S565 | 6-Dec | 860E | 34 | Right | 229 | 5 | 234 | 8 | 253 | 17 | 190 | Again Moving Checking floor |
| S565 | 6-Dec | 860E | 11 | Left | 69 | | 69 | 9 | 180 | 44 | | |
| S565 | 6-Dec | 860E | 13 | Right | 1200 | | 1200 | 22 | 111 | 26 | 197 | Grader, 5:15 on left then 7:45 on right |
| S565 | 6-Dec | 860E | 40 | Left | 29 | | 29 | 31 | 118 | 41 | broken | |
| S565 | 6-Dec | 860E | 14 | Right | 28 | 5 | 33 | 24 | 207 | 18 | broken | |
| S565 | 6-Dec | 860E | 34 | Left | 33 | | 33 | 0 | 154 | 21 | 220 | |
| S565 | 6-Dec | 860E | 11 | Right | ? | 6 | #VALUE! | ? | 175 | 25 | 231 | |
| S565 | 6-Dec | 860E | 13 | Left | ? | | #VALUE! | 0 | 420 | 28 | 160 | Delay while loading, then stops, and walks around on the shovel |
| S565 | 6-Dec | 860E | 40 | Left | 720 | 8 | 728 | ? | 130 | 30 | broken | Delay while loading, then stops, and walks around on the shovel |
| S565 | 6-Dec | 860E | 34 | Right | 19 | 7 | 26 | 16 | 350 | 17 | 212 | |
| S565 | 6-Dec | 860E | 11 | Left | 31 | 3 | 34 | 0 | 150 | 25 | | |
| S565 | 6-Dec | 860E | 14 | Right | 42 | 2 | 44 | 22 | 363 | 28 | broken | Delay while loading, then stops, and walks around on the shovel |
| S565 | 6-Dec | 860E | 13 | Left | 39 | | 39 | 0 | 125 | 33 | 220 | |

### H:4.4 Utilization Averages

Sample of daily Utilization Data from Dispatch System:

| Utilization | Grawe 2011 | Trokke 2011 | Front 2011 | Grawe 2012 | Trokke 2012 | Front 2012 |
|---|---|---|---|---|---|---|
| 1/06/2011 | 64.82 | 54.54 | 70.60 | 63.40 | 66.10 | 54.06 |
| 2/06/2011 | 63.38 | 56.11 | 71.11 | 70.52 | 60.87 | 62.74 |
| 3/06/2011 | 63.36 | 55.85 | 67.09 | 67.40 | 59.66 | 61.45 |
| 4/06/2011 | 74.06 | 58.54 | 79.32 | 65.50 | 58.98 | 64.29 |
| 5/06/2011 | 67.47 | 63.28 | 68.35 | 56.81 | 62.50 | 55.20 |
| 6/06/2011 | 61.32 | 58.85 | 54.97 | 61.89 | 56.90 | 64.91 |
| 7/06/2011 | 57.14 | 53.36 | 59.97 | 57.88 | 61.55 | 57.68 |
| 8/06/2011 | 45.20 | 42.87 | 61.27 | 73.37 | 62.35 | 72.27 |
| 9/06/2011 | 36.11 | 44.53 | 61.93 | 65.55 | 65.12 | 59.68 |
| 10/06/2011 | 52.95 | 56.88 | 59.51 | 70.61 | 69.16 | 67.30 |
| 11/06/2011 | 62.75 | 65.03 | 72.75 | 71.56 | 63.29 | 69.02 |
| 12/06/2011 | 61.66 | 65.19 | 69.03 | 69.74 | 62.94 | 68.44 |
| 13/06/2011 | 63.59 | 59.10 | 64.73 | 67.90 | 61.78 | 73.02 |
| 14/06/2011 | 59.65 | 58.74 | 64.53 | 70.27 | 61.93 | 71.72 |
| 15/06/2011 | 67.19 | 63.35 | 68.95 | 70.81 | 63.23 | 68.39 |
| 16/06/2011 | 64.61 | 67.85 | 63.34 | 36.25 | 28.12 | 35.38 |
| 17/06/2011 | 48.11 | 64.22 | 52.31 | 76.33 | 60.35 | 74.57 |
| 18/06/2011 | 61.89 | 61.06 | 63.17 | 71.12 | 61.94 | 76.75 |
| 19/06/2011 | 68.06 | 68.83 | 67.97 | 63.66 | 65.45 | 64.75 |
| 20/06/2011 | 49.56 | 63.57 | 42.11 | 71.07 | 62.91 | 64.69 |
| 21/06/2011 | 58.01 | 58.74 | 54.08 | 65.15 | 56.29 | 60.71 |
| 22/06/2011 | 64.23 | 60.96 | 59.41 | 55.07 | 49.03 | 56.66 |
| 23/06/2011 | 60.29 | 59.99 | 62.75 | 69.88 | 64.83 | 64.21 |
| 24/06/2011 | 56.82 | 62.73 | 60.90 | 75.52 | 65.22 | 68.50 |
| 25/06/2011 | 56.92 | 68.43 | 62.32 | 64.47 | 61.67 | 69.00 |
| 26/06/2011 | 58.72 | 65.35 | 74.01 | 71.96 | 66.61 | 69.60 |
| 27/06/2011 | 53.16 | 58.27 | 48.89 | 70.28 | 65.18 | 72.79 |
| 28/06/2011 | 55.98 | 58.48 | 56.98 | 63.85 | 64.85 | 63.79 |
| 29/06/2011 | 42.15 | 56.69 | 50.62 | 61.81 | 61.07 | 58.46 |
| 30/06/2011 | 62.35 | 59.67 | 65.37 | 67.71 | 61.50 | 71.46 |
| 1/07/2011 | 58.80 | 56.78 | 52.47 | 75.96 | 65.95 | 64.41 |
| 2/07/2011 | 69.50 | 61.07 | 67.46 | 56.45 | 59.91 | 51.38 |
| 3/07/2011 | 73.43 | 59.68 | 71.17 | 63.63 | 63.99 | 65.60 |
| 4/07/2011 | 69.57 | 63.14 | 60.96 | 63.23 | 60.78 | 55.80 |
| 5/07/2011 | 67.33 | 59.76 | 66.42 | 61.29 | 67.23 | 67.90 |

## H:4.5 Availability Averages

Sample of daily Availability Data from Dispatch System:

| Availability | Grawe 2011 | Trokke 2011 | Front 2011 | Grawe 2012 | Trokke 2012 | Front 2012 |
|---|---|---|---|---|---|---|
| 1/06/2011 | 84.98 | 86.33 | 85.89 | 77.35 | 88.87 | 70.03 |
| 2/06/2011 | 87.76 | 86.98 | 95.83 | 85.73 | 93.68 | 75.94 |
| 3/06/2011 | 87.15 | 91.03 | 86.95 | 87.27 | 88.16 | 76.03 |
| 4/06/2011 | 92.53 | 92.92 | 92.90 | 86.16 | 90.57 | 77.85 |
| 5/06/2011 | 86.19 | 91.71 | 88.56 | 80.56 | 88.86 | 71.45 |
| 6/06/2011 | 78.12 | 89.01 | 67.45 | 84.53 | 87.45 | 79.13 |
| 7/06/2011 | 84.38 | 89.44 | 82.74 | 77.22 | 86.36 | 70.28 |
| 8/06/2011 | 80.20 | 87.58 | 83.31 | 92.03 | 88.02 | 87.48 |
| 9/06/2011 | 83.11 | 89.16 | 81.11 | 83.72 | 91.02 | 71.13 |
| 10/06/2011 | 85.58 | 93.57 | 77.57 | 84.73 | 91.12 | 79.27 |
| 11/06/2011 | 88.35 | 91.16 | 88.55 | 85.73 | 88.99 | 82.44 |
| 12/06/2011 | 87.48 | 92.81 | 88.71 | 85.75 | 88.03 | 80.77 |
| 13/06/2011 | 84.27 | 86.12 | 77.01 | 84.88 | 85.82 | 88.58 |
| 14/06/2011 | 83.31 | 86.18 | 79.57 | 83.92 | 87.79 | 83.00 |
| 15/06/2011 | 85.68 | 89.19 | 87.11 | 87.73 | 90.15 | 84.00 |
| 16/06/2011 | 78.55 | 90.97 | 76.11 | 95.11 | 96.04 | 92.78 |
| 17/06/2011 | 68.92 | 91.11 | 68.27 | 92.12 | 90.27 | 90.08 |
| 18/06/2011 | 81.58 | 93.70 | 77.26 | 84.63 | 92.72 | 87.94 |
| 19/06/2011 | 84.18 | 91.22 | 82.16 | 79.52 | 88.96 | 80.30 |
| 20/06/2011 | 71.76 | 89.06 | 60.06 | 85.95 | 86.69 | 77.94 |
| 21/06/2011 | 74.17 | 85.42 | 68.78 | 85.04 | 89.49 | 76.43 |
| 22/06/2011 | 87.10 | 88.11 | 81.35 | 81.94 | 89.04 | 78.60 |
| 23/06/2011 | 80.72 | 88.92 | 75.89 | 84.72 | 91.42 | 88.29 |
| 24/06/2011 | 80.30 | 90.27 | 75.76 | 87.27 | 92.97 | 81.13 |
| 25/06/2011 | 82.10 | 93.20 | 79.12 | 83.12 | 90.65 | 86.38 |
| 26/06/2011 | 84.43 | 86.99 | 84.97 | 87.37 | 90.85 | 84.49 |
| 27/06/2011 | 74.68 | 84.09 | 65.48 | 88.66 | 88.29 | 85.24 |
| 28/06/2011 | 87.42 | 82.98 | 78.51 | 83.44 | 90.13 | 82.70 |
| 29/06/2011 | 77.53 | 81.25 | 74.46 | 84.77 | 92.23 | 76.78 |
| 30/06/2011 | 83.28 | 84.14 | 81.95 | 85.86 | 90.76 | 86.62 |
| 1/07/2011 | 84.71 | 86.32 | 72.61 | 88.65 | 87.33 | 76.12 |
| 2/07/2011 | 84.20 | 87.52 | 75.81 | 77.36 | 86.61 | 70.46 |
| 3/07/2011 | 91.10 | 88.63 | 82.74 | 84.73 | 87.25 | 84.12 |
| 4/07/2011 | 83.48 | 87.75 | 74.52 | 81.33 | 88.43 | 71.65 |