COALTECH 2020

Task 3.14.1

Evaluation of stripping techniques

by

CJ Moolman, CSIR Miningtek

GA Fourie, University of Pretoria

March 2000

PROJECT INFORMATION

- **Researcher details**

Project leader:	CJ Moolman
Postal address:	Kloppersbos
	PO Box 395
	Pretoria
	0001
Tel:	(012) 544-0150/80
Fax:	(012) 544-0181
Industry champion:	I MacFarlane
Postal address:	Duiker Mining
	Ground floor
	19 Girton Road
	Parktown
	2193
Tel:	(011) 484-8485
Fax:	(011) 484-1806
Collaborator:	Prof. GA Fourie
Postal address:	University of Pretoria
	Department of Mining Engineering
	Pretoria
	0002
Tel:	(012) 420-2443
Fax:	(012) 362-5304

- **Sponsor details**

Sponsor:	Coaltech 2020
Contact person:	J Beukes
Postal address:	PO Box 91230
	Auckland Park
	2006
Tel:	(011) 358-0000
Fax:	(011) 726-7338

ABSTRACT

This study was part of the Coaltech 2020 research initiative into the sustainable exploitation of the Witbank coalfield. It focused on the different stripping techniques used in South African mines and evaluated their efficiencies in terms of capital invested, labour productivity, production outputs, operational expenditures and other productivity measures.

These results were used to benchmark each individual South African surface coal mine with every other mine and with selected international mines in order to identify the critical performance areas that need to be improved upon in order to make South African surface coal mines more competitive in the international market environment.

On average, the South African surface coal mining industry recorded a lower stripping productivity performance as determined from the analysis of a survey of mines in the Powder River Basin, United States of America, and in New South Wales and Queensland, Australia. The low productivity performance was mainly due to moderate labour and capital productivity performance levels.

Recommendations are made on how to improve the labour and capital productivity performance by identifying the critical performance areas that need to be improved upon in order to make South African surface coal mines sustainable and competitive well into the 21^{st} century.

ACKNOWLEDGEMENTS

- Coaltech 2020 Management Team
- Johan Beukes – Coaltech 2020
- Jan du Plessis – CSIR Mininigtek
- Rowan Karstel – Ingwe
- Henk Lodewijks – Anglo Coal
- Ian MacFarlane – Duiker Mining
- Jan Pretorius – ISCOR Mining
- Industry suppliers

NOMENCLATURE / DEFINITIONS

BCM: Bank cubic metre

LCM: Loose cubic metre

TCM: Total cubic metres for equipment only (LCM + rehandle)

Total BCMs Sum of coal and waste BCMs mined

Rehandle: Material that is handled by the same equipment for a second time.

Blast gain: Material moved by chemical energy and never touched by any other equipment. It must be deswelled or expressed as a percentage.

Doze-over gain: Blasted material that is dozed to its final resting position (expressed as BCM).

Digging availability: Operational and mechanical availability of the dragline to dig.

Coal exposure rate: Linear advance over the cut width of the pit, measured in square metres.

Digging index: Effective utilisation of each cubic metre of bucket capacity, measured over every passing hour.

Bucket fill factor / Bucket factor: Ratio between the available bucket capacity and the amount of the available bucket capacity that is filled with material during one pass, expressed as a percentage.

Swell factor: The percentage increase in volume when in situ rock is subjected to mechanical or chemical energy.

Powder factor: Mass of explosives used per BCM rock blasted.

Softs: Material that can be free dig or can be remove by mechanical means without the use of chemical energy.

Hards: Material that requires chemical energy to break in order for it to be handled by standard mining equipment.

Bush clearing: The activity of removing all groundcover vegetation prior to mining, including the removal of tree stumps and roots.

Topsoil stripping: The activity of removing topsoil as per the definition of topsoil contained in the Minerals Act, 1991.

Subsoil removal: The activity of removing all soft material other than topsoil.

Highwall control: The activity of controlling the highwall stability by means of chemical or mechanical energy.

Drilling: The activity of creating a shot hole by means of rotary and/or percussion drilling equipment.

Blasting: The activity of harnessing chemical energy in the form of explosives to fracture or break the in-situ rock into a manageable size fragmentation.

Pre-stripping: The activity of removing blasted material that cannot be accommodated by the primary stripping tool.

Primary stripping: The activity of removing blasted material in order to expose coal.

Coal removal: The activity of removing the coal in order to expose the parting or interburden in multi-seam operations.

Parting removal: The activity of removing the parting or interburden in order to expose the underlying coal seam in multi-seam operations.

Rehabilitation: The activity of levelling and/or profiling before revegetating the spoil material.

Haul distances: The distance that haul trucks travel in kilometres from the shovel loading point to the dump site.

Truck spotting time: Time (in seconds) taken from when a haul truck arrives at the loading shovel until it has positioned itself at the shovel ready for loading.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

ROM	Run-of-mine
CAPEX	Capital expenditure
OPEX	Operating expenditure
TPF	Total Productivity Factor
PFP	Partial Factor Productivity
ERM	Exposure Rate Measurements
USA	United States of America
NSW	New South Wales
QLD	Queensland
KPI	Key Performance Indicators

SYMBOLS

km	kilometre
h	hour
t	ton
m^3	cubic metre
Rm	Rand million

1. INTRODUCTION

1.1 Background

South Africa's coal deposits occur in three geologically separate, though closely related, environments within the Karoo Sequence. One is the Lower Beaufort Group with coalfields such as:

- Springbok Flats
- Waterberg
- Limpopo
- Soutpansberg, and the
- Vryheid formation.

The Vryheid Formation is by far the most important from a coal-bearing point of view as it underlies traditional coal mining areas such as:

- Witbank
- Highveld
- Ermelo
- KwaZulu/Natal coalfields, and the
- Molteno Formation, which hosts the Molteno Indwe coalfield; that is, however, of minor economic importance due to its thin seams and high ash content (Minerals Bureau, 1999).

South Africa has 18 principal coalfields spread over an area of some 700 km from north to south and 500 km from west to east.

Coal mining activities take place primarily within the Province of Mpumalanga, which produces some 83,8 % of the country's total output.

Approximately 44 % of South Africa's coal is mined underground by bord-and-pillar methods which are almost entirely mechanised; some 0,9 % by longwalling, 10,6 % by pillar recovery (stooping) and 44,5 % by opencast mining methods.

The general occurrence of the coal seams in the Witbank coalfield is of a shallow nature and favourable stripping ratios can be found over large areas, making the use of surface mining methods the ideal option for most of the available mineable reserves. For this reason a large number of opencast mining operations can be found in this region, ranging in size from relatively small contractor-based operations to large multi-dragline mines.

Because of its significance, surface mining was one the of six technology areas, identified under the Coaltech 2020 collaborative research programme that required pertinent research tasks to be undertaken.

Coaltech 2020's objective is to develop technology and apply research findings that will enable the South African coal industry to remain competitive and sustainable well into the 21st century. The initial focus has been on extending the life of coal mines in the Witbank/Highveld coalfield while sustaining employment and utilising the available infrastructure up to 2020 and beyond.

1.2 Problem statement and objectives

The cost-effectiveness of removing overburden from the underlying coal seams ("overburden stripping") holds the key to the success of any surface mining operation. Overburden stripping techniques vary from one mining operation to another, depending on the size of the operation, the prevailing geological conditions and the type of equipment selected.

The primary objectives of this research project were to identify the various mining techniques used on South African coal mines and to evaluate their efficiencies in terms of capital invested, labour productivities, production outputs, operational efficiencies and/or any other measurable items that could be identified. These results were used to benchmark individual South African operations with each other and with selected overseas mines in order to identify the critical performance areas that need to be improved upon in order to make South African operations more competitive in the international market environment.

1.3 Outline of the study

Section 1 provides the background, problem statements and the objective of this research study. The research methodology is outlined in Section 2 and the benchmarking process, which formed the basis for the data collection and evaluation is also discussed in this section.

A brief description of the data collection process is given in Section 3. The data analysis and the results are discussed in Section 4 and Section 5 contains the conclusions. Possible recommendations for improving the productivity levels of the South African surface coal mining industry are presented in Section 6.

2. RESEARCH METHODOLOGY

2.1 Introduction

This study formed part of the Coaltech 2020 research initiative into the sustainable exploitation of the Witbank coalfield. Coaltech 2020's objective is to develop technology and to apply research findings that will enable the South African coal industry to remain competitive and sustainable well into the 21st century.

The initial focus has been on extending the life of coal mines in the Witbank/Highveld coalfield while sustaining employment and utilising the available infrastructure up to 2020 and beyond. The Coaltech research programme consists of six technology areas: Geology, Underground Mining, Surface Mining, Beneficiation, Environmental Aspects and Socio-economic Aspects. This research study formed part of the Surface Mining research programme.

After the Coaltech Management Committee had approved Task 3.14.1, "*Evaluation of stripping techniques*", in March 1999 the study started in April 1999 with an international literature survey. In May 1999 an industry workshop was held during which the scope, objectives, rules and guidelines for the project were evaluated and approved. The workshop was also used to identify the various stripping activities with associated mining methods. This workshop ensured that the scope and direction of the study would address the real issues with which the industry is faced.

The information required on actual stripping operations was very sensitive and not readily available in the public domain. The decision was taken to follow the international accepted benchmarking protocol for information gathering. On the basis of the benchmarking guidelines and code of conduct, ground rules were established for constructing the benchmarking checklist and partners. Coaltech's confidentiality agreement was signed, agreed to and made data collection from the mines possible.

Once approval of the evaluation (benchmarking) checklist and the benchmarking partners had been obtained the confidentiality agreement had been signed, the South African survey commenced. That was followed by an international survey.

The benchmarking checklist was sent to each surface coal mine two weeks before the mine visit. The completed benchmarking checklist and any additional productivity related information was collected during the site visit. The local site visits were followed by an international site visit to the USA and Australia.

The data collected were analysed and evaluated to determine South Africa's current stripping practices and performance levels. The international survey was used to establish the best practice scenario against which the South African surface coal mining industry was evaluated. By evaluating the mining methods, labour practices and equipment utilization in this way, it was possible to draw conclusions and make recommendations from the analyses of the available data. Future stripping trends and techniques were also determined.

2.1.1 Literature survey

The aim of the literature survey was to:

- Identify the stripping class activities and mining methods that formed the basic structure of the checklist
- Identify mining supply companies that could provide information on the evaluation and identification of available methods and international benchmark sites
- Determine future mining and mining equipment trends.

2.2 The benchmarking process

To evaluate the stripping activities, a comprehensive analysis of the mines' stripping performances was required. For this purpose an extensive amount of information on actual stripping operations was required, which was very sensitive and not readily available in the public domain.

Benchmarking was chosen as the process that would be used to collect information for the study. In essence the process consists of performing a comparative study of specific processes in an industry that are considered to hold some potential for improvement.

Michael Spendolini, in “The Benchmarking Book”, summarises this practice as follows:

> *“Benchmarking is a continuous, systematic process for evaluating the products, services and work processes of organisations that are recognised as representing best practices for the purpose of organizational improvement”*

An internal benchmarking approach was first used to collect and compare the mine performance data of the South African surface coal mining industry in order to establish the “*South African scenario*”. The competitive benchmarking approach was then used to compare the South African scenario against international competition.

The two benchmarking activities were carried out on strategic and operational levels. On the strategic level, the level of investment, level of automation and strong functional areas were analysed and compared. On the operational level, the mining operations, cost performances, production processes and service levels were analysed and compared.

The benchmarking process followed can thus best be described as addressing various sub-sets of strip mining activities: subsoil removal, pre-stripping, primary stripping, parting and coal removal. Various productivity measures were used to evaluate these activities.

These measures do not focus only on obtaining comparative performance statistics. In fact, according to Dr Robert Camp (BENSA, 1999), the pioneer and international benchmarking guru, finding benchmarks is only about 10 to 15 % of the effort involved in a benchmarking study; 85 to 90 % of the effort must go into finding and studying practices that will deliver exceptional performance. Once the differences between these exceptional practices and processes and those of a mine’s own organisation have been established, the mine can adapt these practices creatively and implement them.

Benchmarking identified the managerial focus areas and opportunities for improving the productivity and ultimately the economic sustainability of the South African surface coal mining industry. It also fostered organisational learning, broadened the organizations’ experience base, assisted in employee development and stimulated teamwork.

2.2.1 What to benchmark

The study identified, compared and evaluated the best stripping operations available. The internationally accepted method for measuring productivity was used as the main measuring or evaluation criterion.

Productivity is a measure of the physical output produced from the use of a given quantity of inputs. Mines use a range of inputs including labour, machines, fuel, materials and services. If the mine is not using its inputs as efficiently as possible, then there is scope to lower costs and increase profitability through productivity improvements. This may come about through the use of better-quality inputs, including a better-trained workforce, the adoption of technological advances, the removal of restrictive work practices and other forms of waste, and better management through a more efficient organizational and institutional structure.

2.2.1.1 Productivity measures

In practice, productivity is measured by expressing output as a ratio of inputs used. There are two types of productivity measure: the total productivity factor (TPF) and the partial factor productivity (PFP) (Tasman, 1997). TPF measures the total output relative to all the inputs used. Output can be increased by using more inputs, making better use of the current level of inputs, through technological improvements and by exploiting economies of scale. The TPF index measures the impact of all the factors affecting growth in output other than changes in input levels. The PFP measures one or more outputs relative to one particular input (for example, labour productivity is the ratio of output to labour input).

Partial productivity measures are widely used, as they are simple to calculate. Thus it is now widely accepted that TPF is a robust measure of the overall performance of an organisation.

2.2.1.2 Expected deliverables

From the industry workshop and literature survey an initial expected TPF and PFP measures were established.

The checklist constructed aimed at capturing the information required to report on the expected outputs or deliverables of this study.

The initial indication was that the output data would consist of the following partial productivity factors:

- Variations in productivity within mine categories
- Variations in stripping costs between mines
- Variations in capital costs between mines
- Efficiency of the labour force
- Efficiency of equipment utilisation
- Efficiency of each stripping activity
- Efficiency of stripping equipment or associated mining methods.

2.2.2 Analyse the process

Before the actual benchmarking process started, ground rules were established and the current available international performance levels were determined.

2.2.3 Set ground rules

Each mine is known to have its own units of measure. Standardised units of measure were created as a means of measuring the different strip-mining operations in South Africa and internationally. In order to determine what to measure, performance measures were created. Using the known performance measures, the units of measure were finalised and the evaluation checklist constructed. (Appendix 2 details the units of measure and assumptions used for this study.)

This research did not examine the revenue-generating capabilities of a surface coal mining operation but rather looked at the effectiveness of removing the overburden in order to expose the underlying coal seams. The main process is thus the removal of overburden and coal material by means of surface mining methods, or stripping activities as they are more commonly known. The data obtained for the different stripping methods were evaluated and compared in terms of “exposure rate measurements” (ERM) and TPF. The ERM seemed to be a unique stripping evaluation method.

Although the Coaltech 2020 Management Team developed its own code of conduct and confidentiality clause, this study also operated according to Benchmarking South Africa's Code of Conduct. This provides a structure and an international standard by which the benchmarking study was conducted.

2.2.4 Current performance levels

This was the first study that the project team was aware of for benchmarking strip mining activities. It was not surprising then that very little literature was found that could contribute to this study. The available literature reports on the evaluation of some primary stripping methods, but nowhere was the total overburden stripping activity evaluated.

Almost all the productivity and efficiency results published discuss the performance of the total mining operation in terms of run-of-mine (ROM) coal or saleable coal tons. This reporting was in line with the core business of the coal mines. Measuring the efficiency of overburden removal was not the core activity and therefore each mine generally used its own measuring or reporting system.

In October 1997 the Industry Commission of Australia contracted Tasman Asia Pacific to undertake a benchmarking study of the productivity performance of Australia's black coal mines. Tasman benchmarked Australia's black coal industry against best-practice world coal mines and best-practice Australian metalliferous mines. They benchmarked 44 separate mine operations in 1996; 22 truck-and-shovel and 13 dragline operations in the first nine months of 1997.

Presented in Appendix 3 is a summary of their findings and the only documentation on the current benchmark levels available in the industry.

2.3 Benchmarking partners

Most of the South African surface coal mines were already part of the study through the Coaltech 2020 initiative. Sasol joined the Coaltech programme in early 2000, which added a possible two more surface mines. However, time constraints prevented the survey and analysis of the Sasol mines. As soon as they have been surveyed, their results will be added by means of an addendum to this report.

The international surface coal mines were identified according to benchmarking criteria i.e. throughput, unit cost quality and relative productivity performance.

The Coaltech 2020 Management Team, consisting of members from Anglo Coal, Billiton, Eskom, Iscor and Duiker, provided information on their own South African mining operations. The industry project members and the manufacturers of surface mining equipment assisted with information gathering on mines in the USA, Asia, Europe and Australia.

2.3.1 South Africa

Of the 14 South African surface mines identified, only nine submitted their information. Checklists were received for evaluation from only two of the three truck-and-shovel operations. Eight of the 11 strip mines submitted their dragline and stripping information.

Table 2.3.1 outlines the number of mines per mining house that participated in the benchmarking exercise and the number of mines not surveyed.

Table 2.3.1 Potential participating South African mining operations

Mining house	***Surface mines per mining house planned to be surveyed***			***Number of mines not surveyed***
	Truck and shovel	***Dragline***	***Total***	
Ingwe	0	4	4	2
Anglo Coal	0	4	4	0
Iscor	2	0	2	1
Duiker	1	1	2	0
SASOL	0	2	2	2
Total	3	11	14	5

Time due to its late joining of the Coaltech 2020 programme, the survey, evaluation and analysis of the Sasol surface coal mines was not undertaken. Three other mines received the checklists but had not submitted the completed checklists before this report was compiled.

2.3.2 International

Table 2.3.2 outlines the mines per country identified and surveyed during the international survey. The USA mines were chosen for their good overall productivity standards, the New South Wales mines for their good truck-and-shovel operations and the Queensland mines for their outstanding dragline performances.

Table 2.3.2 Participating international surface coal mines

Country	***Truck and Shovel***	***Dragline***	***Total***	***Usable information***
PRB, USA[1]	1	2	3	2
NSW, Aus[2]	3	0	3	2
QLD, Aus[3]	0	3	3	2
Total	4	5	9	6

1. PRB – Powder River Basin, United States of America
2 .NSW – New South Wales, Australia
3. QLD – Queensland, Australia

The mining information of one NSW mine and one Queensland mine could not be used for the evaluation process. The data and relative productivity performances of these mines were insignificant and could not be used as a best practice.

The mines used as benchmarks are internationally known for their high mining productivity performances. One mine in NSW was judged as the most productive mine during 1998 (Tasman 1998).

3. DATA COLLECTION

In order to bring credibility to the benchmarking process it was necessary to agree at the outset that this data collection should be free from any personal and manual manipulation. It was decided that the results of the 1997/98 financial year would be used as mine and group management had already approved those results.

The physical collection of data was initiated by using a comprehensive questionnaire or checklist. The checklist was required to capture the information on each mine. See Appendix 4 for the checklist template.

Mining industry suppliers were also asked to assist with this study. A supplier-specific questionnaire was used to obtain relevant information from the industry suppliers.

The checklist was also used to capture the geological characteristics of each surveyed surface coal mine, i.e. factors such as seam thickness, hardness and specific gravity of rocks that affect the explosive requirements and the digging and loading components of the mining cycle. These data were required to determine the effects that mine-specific geology had on each mine's performance.

4. ANALYSIS AND DISCUSSION OF THE RESULTS

4.1 Characteristics of the benchmarking sites

The geological characteristics of the mines surveyed are presented in Table 4.1. South African overburden material appears to be the most competent and hardest of the surveyed international sites. Australian overburden material appears to be of average hardness but softer than the South African overburden. Drilling and blasting on the international benchmark mines appears to be easier than in South Africa. However SA reported the lowest overburden powder factor. This was as a result of the higher bench heights (Table 4.1) and bigger blast holes. The average overburden blasting holes drilled on SA mines were 200 to 250 mm compared to USA, NSW and QLD average of 170 mm, 120 mm, 200 mm. (The smaller the blast hole the smaller the burden and spacing and the bigger the powder factor).

The Queensland and NSW coal mines appear to have the most difficult mining conditions with thin, multiple, deep and dipping coal seams, yet NSW possesses the most productive coal mine. The South African surface coal mines appear to have the second most difficult mining conditions. The coal seams are horizontal and on average thicker and not as deep as those of the Australian mines, but the harder overburden affects the productivity performance of the local mines.

Table 4.1 Characterisation of geological conditions on mines surveyed

	Number of coal seams	Average thickness of seams (m)	Overburden powder factor[1] (kg/m^3)	Stripping ratio (BCM / ROM ton)	Overburden thickness (m)	Number of overburden benches[3]
SA	3	4.7	0.46	2.19	33	1
NSW[2]	8	3	0,50	2.45	10.4	1
QLD	4	9	0,53	9.8	70	5
USA	2	25	0,59	1.69	45	3

1. Overburden powder factors
2. Coal seams dipping on average 42°
3. Number of individually blasted benches within overburden.

The highly productive USA surface coal mines in the Powder River Basin area appear to enjoy favorable mining conditions with thick horizontal coal seams underlying a combination of clay, sand and shale overburden. Their stripping ratios are the most favorable of the surveyed mines. They also do not need to beneficiate their ROM coal.

The variations in operating factors (Louw, 2000) such as borehole diameter, burden and spacing, face height, type of formation, minimum required pit width and ratios of wall height to pit width also affected blasting performances on mines. Mining equipment linked with different blasting factors, such as the type of explosives, designed powder or energy factor, energy distribution, drill pattern and timing delay, made blasting on each surveyed mines unique with, as expected, mixed blasting results.

The recorded percentage of primary overburden BCMs cast-blasted to final position for South African mines was:

- 15 to 25 % for benches lower that 25 metres
- 32% to 38% for 25 metre benches
- 38% to 45% for 30 metre benches.

The international mines reported cast-blast results of 15 to 45 %. Only one mine was evaluating cast-blastings' potential as primary stripping method. This mine reported casts of up to 45% but refused to elaborate on their cast-blasting project.

Very few mines planned and scheduled cast-blasting as the primary method of moving overburden. Those who did appeared to believe in the production and cost benefits gained from cast-blasting. The rest of the mines had various reasons for not using cast-blasting despite its potential benefits but, in general, they all agreed that cast-blasting had great potential as a stripping method.

4.2 Productivity performance evaluation

Overburden removal involved broad functions and two physical outputs. The outputs were coal and waste. These outputs were only obtained after a set of inputs had been obtained and utilised. The inputs used and the outputs obtained were evaluated as follows:

- Inputs
    - Labour
    - Capital invested in mining equipment
    - Operating expenditure
- Outputs
    - Coal exposure rate
    - Total BCMs mined
    - Overburden BCMs mined
    - ROM coal tons mined.

Total BCMs were used to evaluate a mine's overall stripping productivity performance as data on each stripping activity were difficult to obtain and required manual manipulation.

4.3 Labour

The internationally accepted standard for measuring labour productivity on coal mines is to calculate the average coal tons removed per man-year. For this productivity analysis, labour included mine labour and contractors working on a mine. The USA achieved the highest ROM tons per man-year, including contractors, of all the participating benchmark mines (Figure 4.3a). The South African standard was nearly nine times lower than the USA benchmark as reflected in Figure 4.3a. See figure 4.3b for the individual South African mines performances. The SA ROM tons per man-year excluding contractors is summarised in Appendix 1: Figure 1.

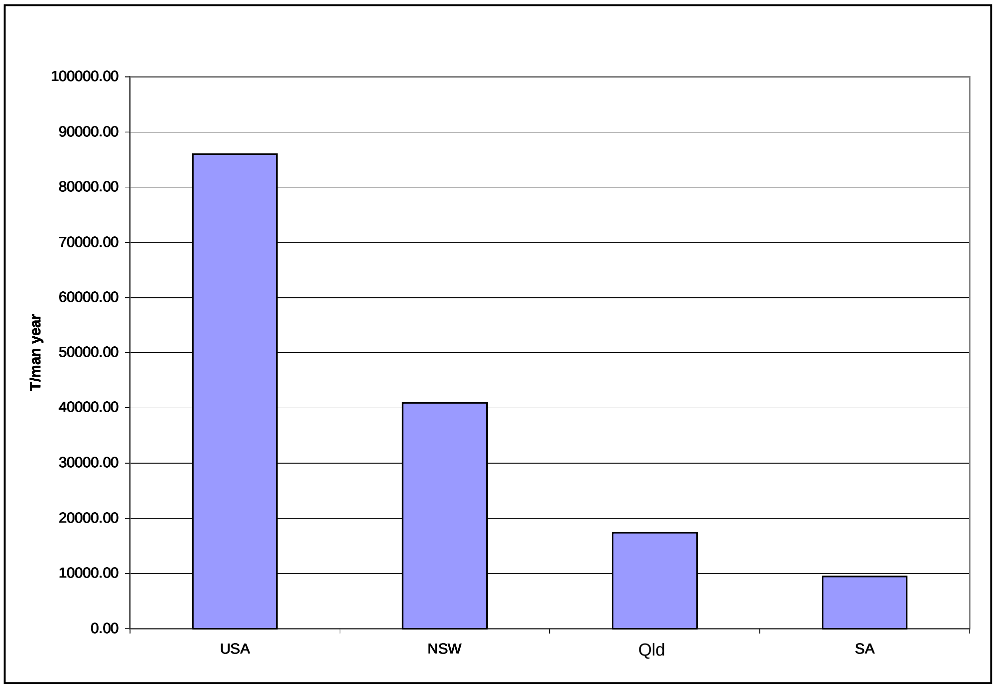


Figure 4.3a: ROM tons per man-year, including contractors

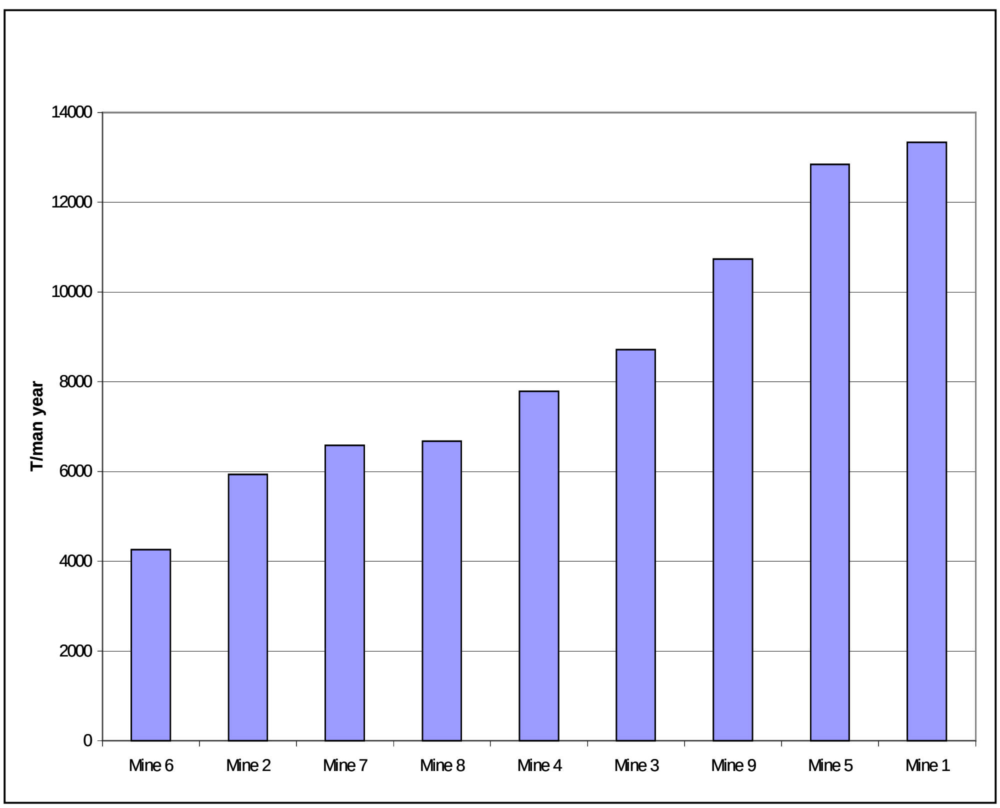


Figure 4.3b: SA ROM tons per man-year, including contractors

The total BCMs (BCMs shown in Figure 4.3a + waste BCMs in Figure 4.3c) moved per man-year, including contractors, were easier to interpret as they were a measure of the performance of the total stripping operations. The ROM and overburden analysis only explained partially the performance of the stripping activities. As can be seen from Figures 4.3c and c the South African performances lags the overseas operations.

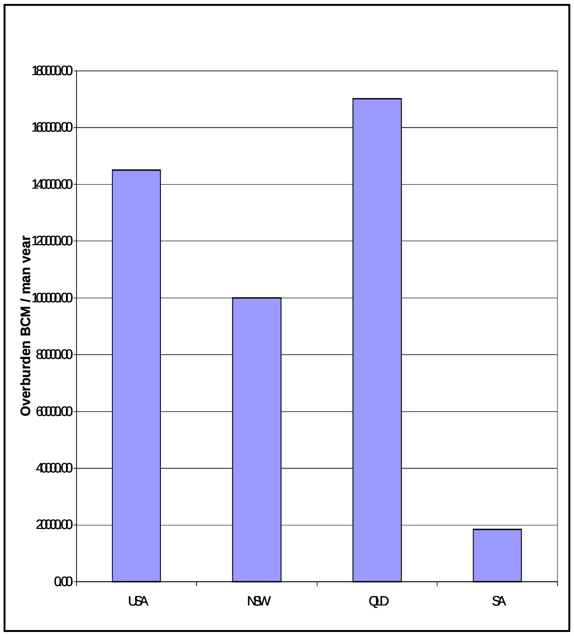


Figure 4.3c: Overburden BCMs per man year, including contractors

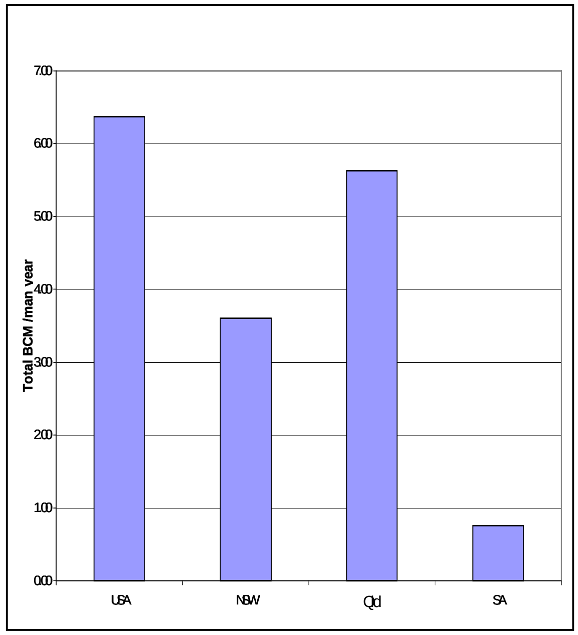


Figure 4.3d: Total BCMs per man year, including contractors

4.3.1 Labour productivity indicators

Table 4.3.1 shows the labour productivity indicators. Some of the main observations from this labour productivity analysis indicated that South Africa:

- had more contractors per mine site
- had more people not directly involved with mining
- was more labour-intensive
- had moderate operating practices,
- had fewer available production hours annually
- had moderate production incentive schemes
- had a moderate working culture.

Table 4.3.1 General labour productivity indicators

Productivity measures	International benchmark	SA standard
Labour		
Percentage of contractors working on mine	10 (Estimate)	29.8
Total labour per mining equipment unit	6.93	18.82
Mining labour per mining equipment unit	3.71	5.81
Work practice		
Hot seat changes	Yes	Rarely
Meal breaks	Yes	No
Staggered meal breaks	Yes	No
Operators move between equipment within shift	Yes	Rarely
Haulage equipment fuelled during breaks	Yes	No
Cleanup equipment does not impede production	Yes	Yes
Production days per week	7	5 to 7
Shifts per day	2 or 3	3
Number of crews	4	3
Production Bonus scheme [1]	Good	Moderate

Note: 1 Results based on management's perception of existing production bonus incentives.

Initially all the South African mines reported their total mine labour figures without the contractors working on the mine. The recorded international figures included contractors and therefore the numbers of contractors working on South African operations were also obtained and included in the labour productivity analysis.

It also appeared that most of the international contractors were directly involved with mining or equipment maintenance, unlike in South Africa. The remote Queensland mines, like most South African mines, appeared to have a greater socio-economic responsibility and thus a larger non-mining labour component and infrastructure than the NSW and USA benchmark mines. (See Appendix 1: Figure 2 for the contractors as a percentage of mine employees working on SA mines)

Very few of the total number of contractors working on the South African mines were directly involved in mining or mining maintenance. The contractors that worked in mining during the survey were contracted to:

- Move topsoil and sub-soils
- Do rehabilitation
- Supply explosives.

The international benchmark operations utilised contractors for the same activities, but also sub-contracted the maintenance of mining equipment to the original equipment suppliers. It appeared that most overseas equipment operators assisted with general maintenance and fuelling of equipment.

Further investigation into the labour composition of the mines surveyed revealed that a relatively high percentage of the total labour force on the USA and NSW mines worked directly in mining. The difference between the number of mining labour (workmen) per mining equipment unit and the total mine labour per mining equipment unit gave an indication of the number of people not directly involved with the mining operation. The larger number of people not working directly in mining reduced the labour productivity performance level of the South African surface coal mining industry.

Expressing the total amount of capital invested per person working on a mine one can determine whether the operation is labour or capital-intensive. The international benchmark operations appeared to be more capital-intensive and South Africa more labour-intensive (Figure 4.3.1). (See Appendix 1: Figure 3 for the South African scenario)

The USA and NSW benchmark mines used relatively large pieces of equipment (requiring relatively less labour to operate). A 320 t truck operator in the USA produced 1.6 BCM units for every one BCM unit produced by a 200 t South African truck operator, all other things being equal. The use of larger pieces of equipment on the international mines resulted in the need for fewer mining and relief operators. This partially explains the low mining labour per mining equipment unit reported for the international mines.

It did not appear that South Africa employed more labour on ancillary equipment than the international benchmark mines, as the ratio of ancillary equipment versus total mining equipment was basically the same for the South African and international benchmark mines as indicated in Table 4.5.1 (page 37).

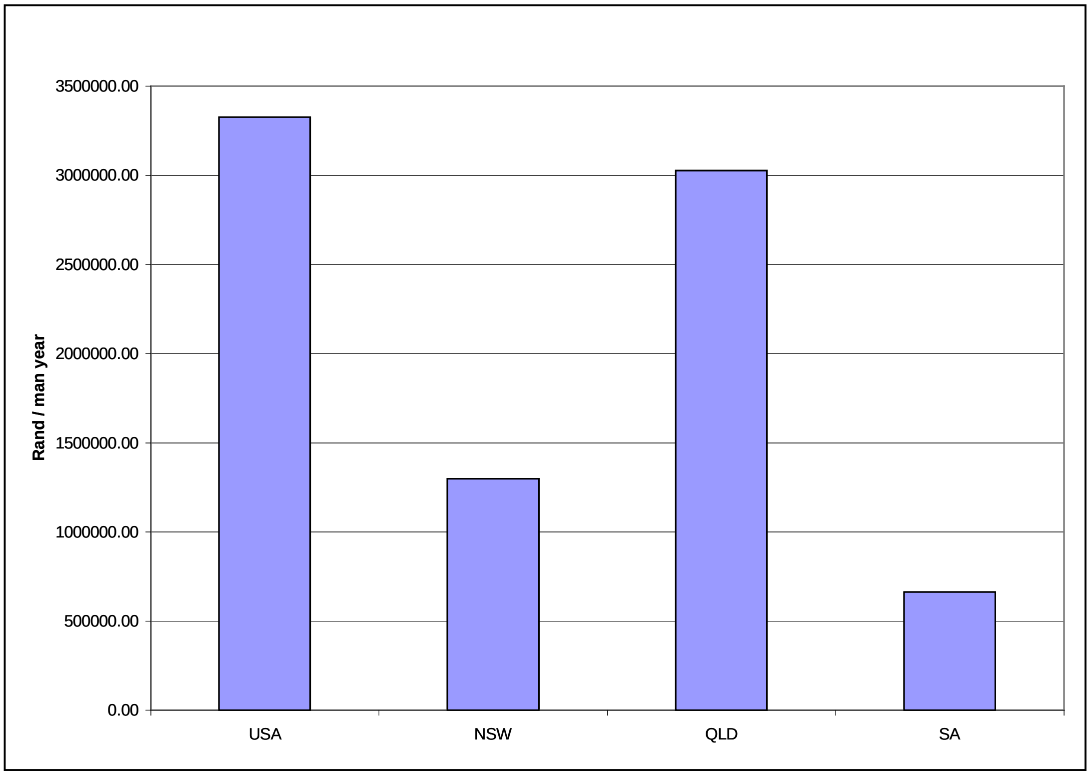


Figure 4.3.1: Mining CAPEX per mine employee, including contractors

Work practices in the international benchmark operations appeared to be more efficient, resulting in a higher productivity performance. In the international mines, staff used effective hot-seat changes, took meal breaks on machines or staggered meal breaks and moved between pieces of equipment to ensure that the core equipment continued to operate. Operators also fuelled the equipment between breaks and ensured that clean-up equipment did not impede production. Only some of the South African operations were found to implement a few of these work practices in order to improve operational efficiency.

All the international best-practice mines worked on a four crew, two to three shifts per day, full calendar principle, (365 days x 24 h per day = 8 760 h). Of all the mines surveyed in South Africa, only three coal mines worked on a full calendar year. The rest of the South African operations worked a six-day or 11 shift fort-night. For every day a mine is not operating, there is a 0,27 % drop in annual available operating hours. If a mine only works a six-day work week, there is 14,3 % reduction in annual available operating hours.

On the South African mines no normal production was reported for the 11 official public holidays in this country. Both the Australian and USA benchmark mines reported normal production on their official public holidays. Once more a possible 3 % of available annual operating hours is lost. This brings the total annual calendar hours lost due to holidays and Sundays to 1 512 hours (17,2 % of annual available hours).

The work culture of the local people is also a factor that might have a significant impact on South Africa's labour productivity. The USA and Australia utilise highly skilled labour on the mining equipment; this is in direct contrast to the standard of practice in South Africa. As it is not within the scope of this study to evaluate the work culture on mines, no further investigation was made in this regard.

During this survey, no proof could be found that good bonus schemes improve labour productivity, practice and/or efficiency. It was commonly agreed by international benchmark mining operations that they had effective bonus schemes in place and used them as an incentive to foster better labour productivity, practice and efficiency. In contrast, the South African mines agreed that their bonus schemes were not good and did not serve their purpose as an incentive to improve labour productivity, practice and/or efficiency.

4.4 Coal exposure rate

As defined by the project team, coal exposure rate per annum was planned as the prime productivity measurement. The coal exposure rate analysis did not produce meaningful and measurable results and therefore the project team decided not to use these results as a productivity measure.

In this analysis the tons mined from the two thick coal seams in the USA benchmark mines were reduced to a single surface area as per definition. This negatively affected the performance of the USA mines. The Australian and most of the South African surface coal mines, which opened multiple coal seams per unit of pit length, benefited from this productivity measurement. The results obtained were confusing, difficult to interpret and deemed to be impractical by the project team.

4.5 Capital invested

The USA, followed by Queensland had the most mining capital invested in their mining operations (Figure 4.5a). One USA mine, all the Queensland mines and most of the South African mines had draglines with truck and shovel fleets for moving overburden and coal.

The NSW mines, two South African mines and one USA mine were the only mines using only truck-and-shovel.

The capital invested on each of the South African mines surveyed is summarised in Appendix 1: Figure 4.

On average the international benchmark mines produced 1,47 total BCM units for every unit of mining capital invested. The South African mines achieved only one total BCM unit for every unit of mining capital invested (see Figures 4.5b, 4.5e and 4.5f for all the South African mine results). The capital productivity of the international benchmark mines formed a linear relationship, with the South African operations substantially lower, also in a linear relationship (Figure 4.5e). The South African mines did not move the same amount of BCM's per mining capital invested as the international benchmark operations.

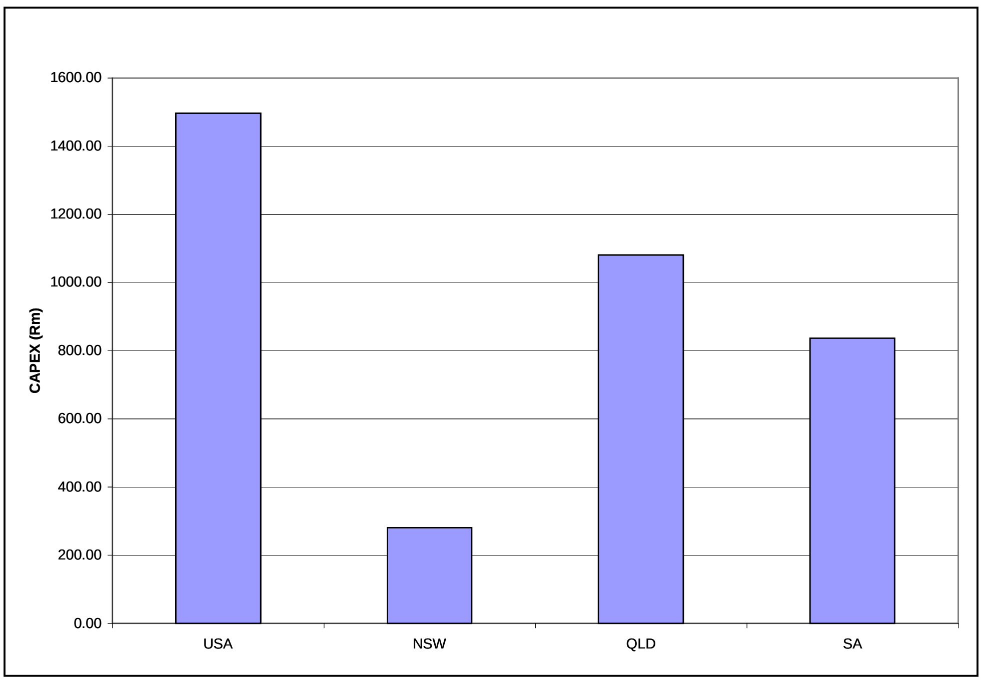


Figure 4.5a: Average mining capital invested on a benchmark mine

Mining capital invested and the total digging capacity available appeared to have a direct relationship (Figure 4.5g). It also appeared that there was not a significant difference between the capital invested on dragline and truck-and-shovel mines (Figure 4.5g).

From figure 4.5f it is also clear that the international benchmark mines moved more BCM's per cubic metre of digging capacity deployed per mine than the South African mines.

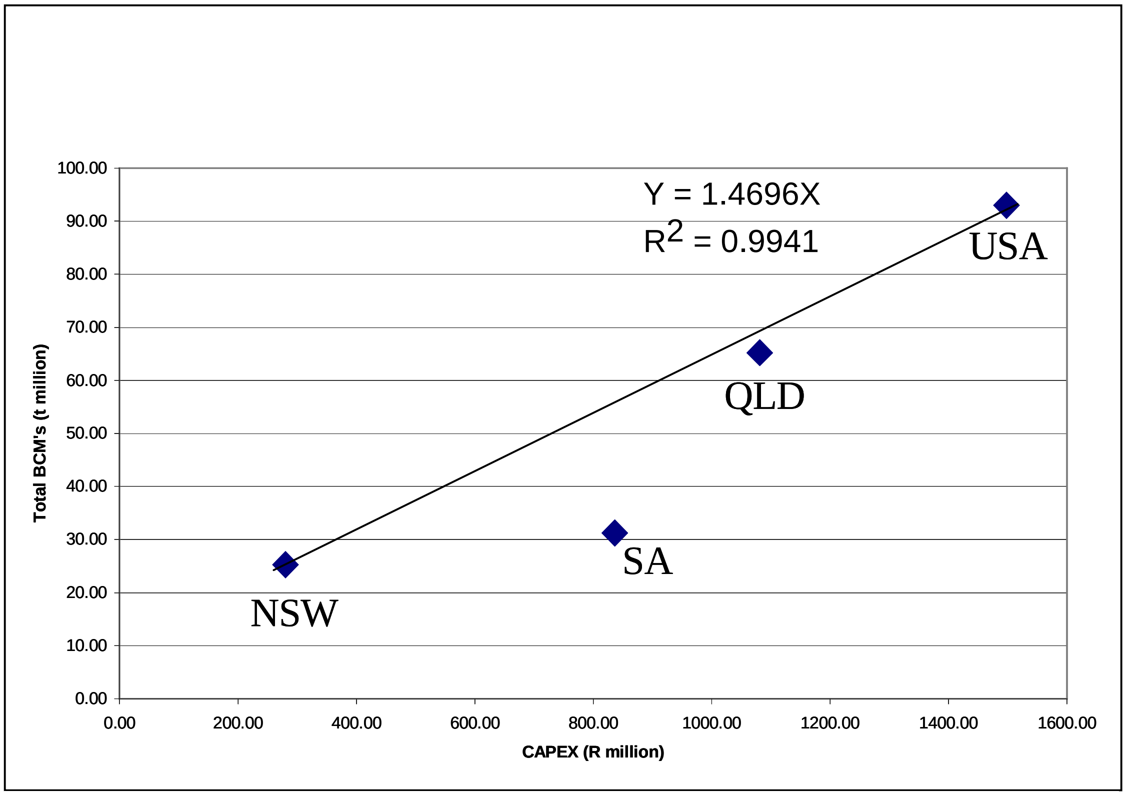


Figure 4.5b: Mining capital productivity - (Total BCMs moved vs. mining CAPEX)

When examining the mining capital invested per total BCM moved, South Africa reported R26.00 per total BCM's moved, the highest level of investment (Figure 4.5c). This was primarily due to the low productivity and labour indicators achieved in general on most South African mines. Further investigation into the capital productivity indicators partially explained South Africa's moderate capital productivity performance.

When examining the mining capital invested per ROM coal tons, Queensland with R174.00 was found to have the highest level of investment (Figure 4.5d). The high stripping ratios were the main reason for the high level of mining capital required. The South African operations appeared to be on the expensive side when compared with the NSW operations that had similar stripping ratios. However, the NSW operations were entirely truck-and-shovel operations.

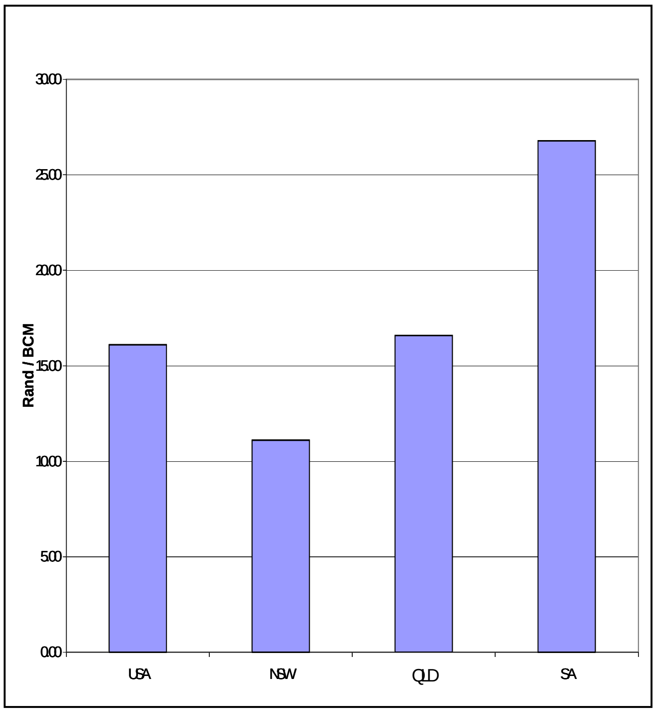


Figure 4.5c: Mining CAPEX per total BCMs moved

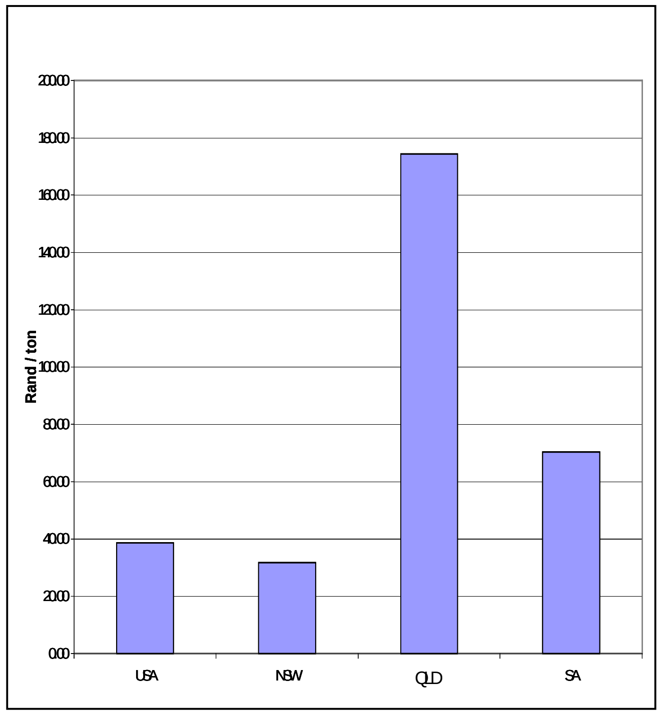


Figure 4.5d: Mining CAPEX per ROM tons

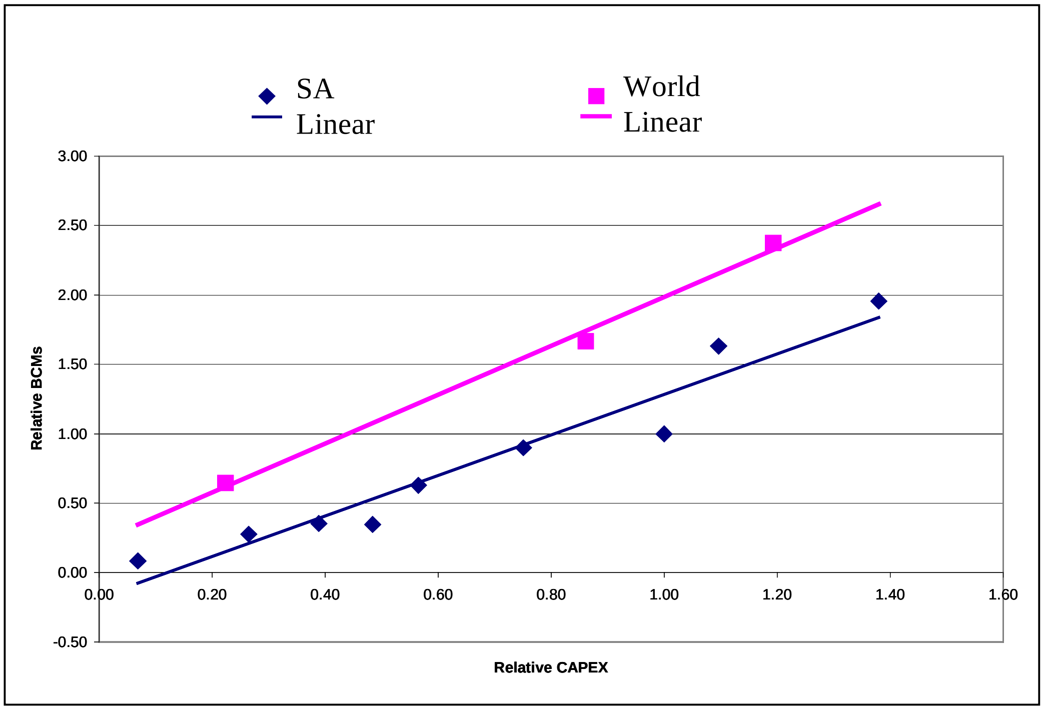


Figure 4.5e: Relative total BCM's moved vs. total mining CAPEX

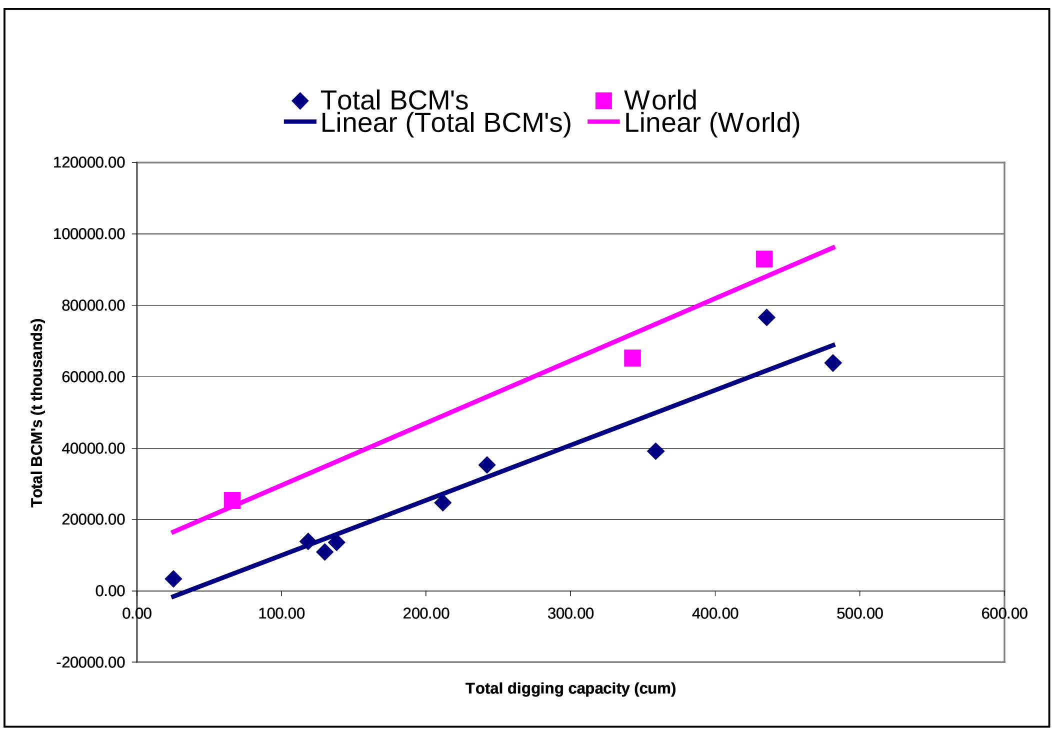


Figure 4.5f: Total BCM's moved vs. total digging capacity

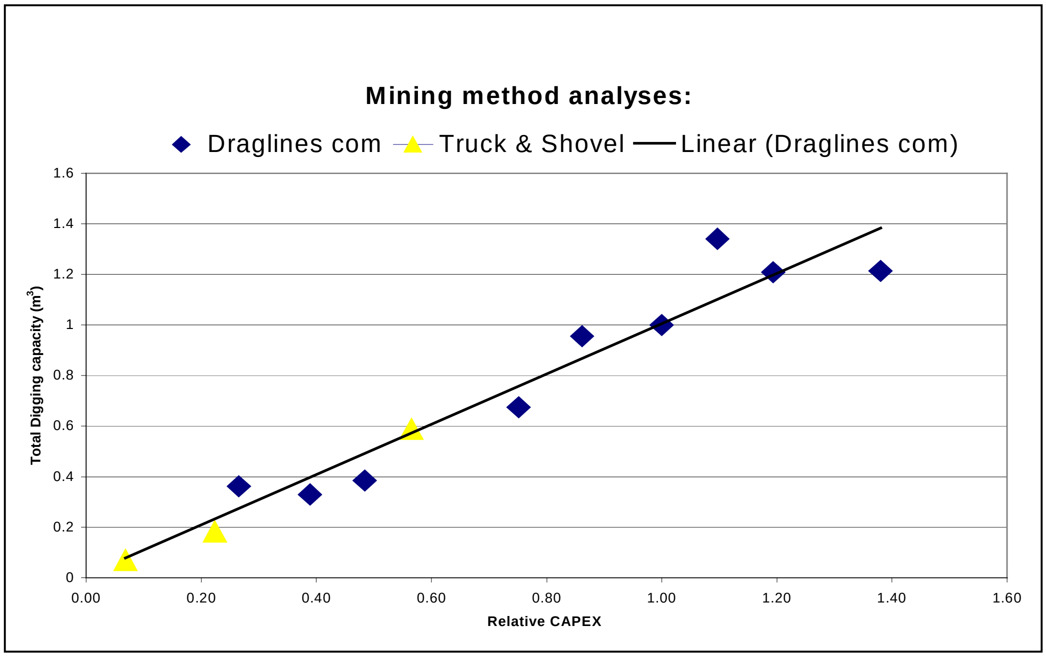


Figure 4.5g: Relative digging capacity vs. mining CAPEX for mining methods

4.5.1 Capital productivity indicators

Some of the main findings to emerge from this capital productivity analysis were that South Africa:

- had moderate labour practices
- achieved low truck-and-shovel productivity
- achieved low dragline productivity.

As discussed in Section 4.3, South Africa had moderate operating practices linked with low production bonus incentives. The work culture of the local labour force could have impacted on South Africa's capital productivity performance.

South Africa's equipment productivity performances were lower than expected. Key performance and technical measures were compared for the international benchmark operations and the standard South African surface coal mining operation. See Table 4.5.1 for a summary of these partial performance indicators.

Table 4.5.1: Summary of equipment performance analysis

Productivity measures	International benchmark	SA standard
Production		
Number of mining equipment units on a mine	50	52
Number of ancillary equipment units on a mine	20	18
Ancillary equipment as a % of total mining equipment	39 %	34 %
Total BCM moved / mining equipment	1 151 934	602 993
Truck and Shovel		
One-way haul distance for coal (m)	3 200	6 000
One-way haul distance for overburden (m)	2 000	1 970
Main loading method	Single sided	Single sided
Truck spotting time (seconds)	30	90
Shovel swing time per load (seconds)	30	35
Truck utilisation (% of annual hours)	78	62
Shovel utilisation (% of annual hours)	76	60
Draglines		
Swings per hour	51	46
Cut width	55-60	55
Pit lengths	3 500	3 450
Utilisation (% of annual hours)	79	73

The low truck-and-shovel productivity performance can be attributed to:

- Moderate truck-and-shovel utilisation – number of annual hours in which trucks and shovels were producing
- Longer haulage distances
- Longer truck spotting time
- Smaller equipment used.

A marginal difference was reported in the number of pieces of mining and ancillary equipment deployed on the mines surveyed. It must be noted that the USA mines reported 65 mining equipment units per mine and the NSW mines reported only 28 mining equipment units per mine. These areas had on average three primary mining equipment units for every ancillary unit respectively. (See Appendix1: Figure 5 for the South African scenario)

The international benchmark for the total BCM moved per mining equipment was almost double the South African reported result (Table 4.5.1 and Figure 4.5.1a). Once more South

Africa's poor capital productivity performance is highlighted. (See Appendix 1 - Figure 7 for the BCM's moved per mining equipment unit on South African mines.)

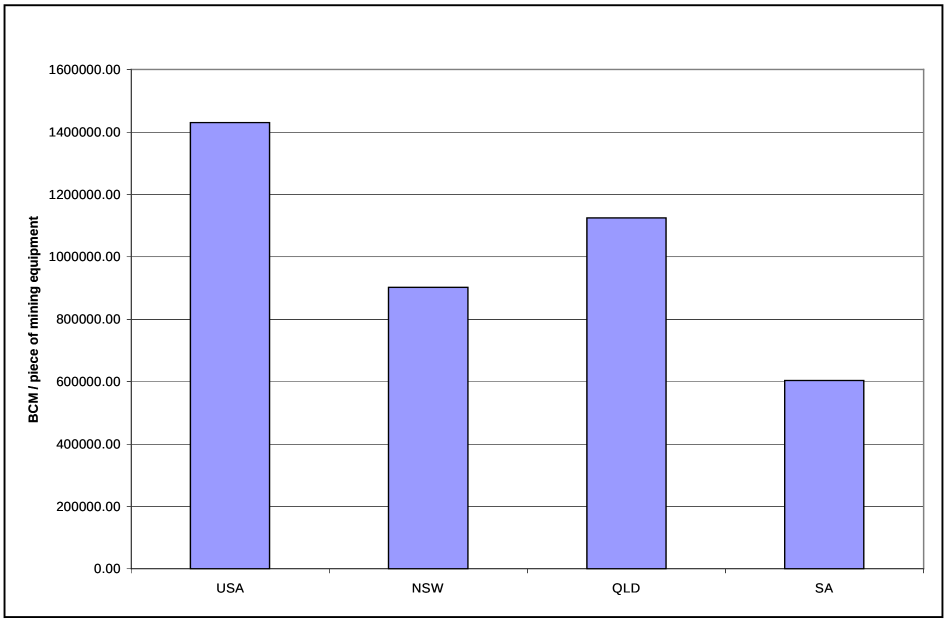


Figure 4.5.1.a:Total BCM's per mining equipment

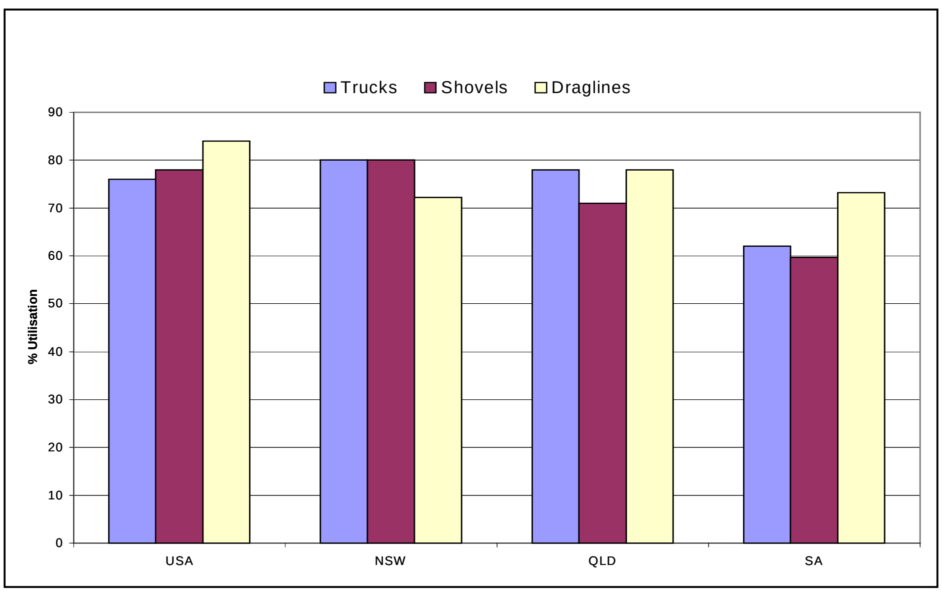


Figure 4.5.1.b: Equipment utilisation

NSW, USA and Queensland mines reported average truck utilisation data respectively 1,29; 1,22 and 1,26 times higher than the South African coal mines' average. Shovel utilisation data for NSW, the USA and Queensland were on average respectively 1,34, 1,31 and 1,19 times higher than the South Africa coal mines' average (Figure 4.5.1.b).

Most of the South African mines work a 6 days per week or a 11-shift fortnight work week compared with the full calendar year work practice of the international benchmark mines.

The average coal haulage distances on the South African mines were nearly twice as long as on the international mines. The average haulage distances on the international mines, between the pits and the coal tips, have been reduced by the installation of in-pit crusher conveyor belt systems. The scale of these operations and the favourable geological conditions warranted the capital outlays for the crusher conveyor belt systems. Most of the South African surface coal operations mine far fewer coal tons per pit due to the thinner multiple coal seams present. Thus the capital outlay for a crusher conveyor belt system is not always justifiable. (See Appendix 1 Figure 8 for the average overburden haulage distances on South African mines.)

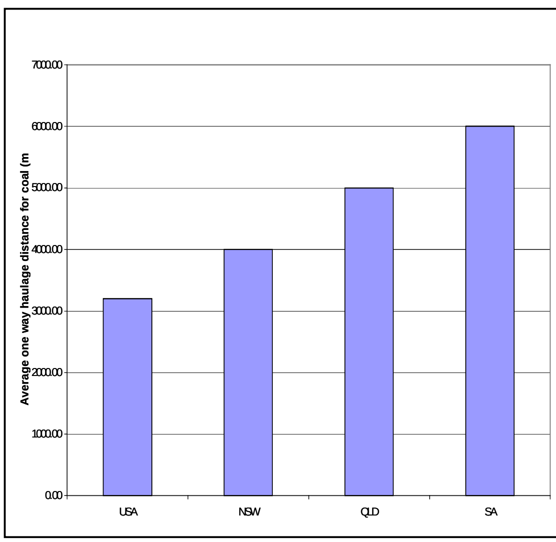


Figure 4.5.1.c: Overburden Haulage distances (m)

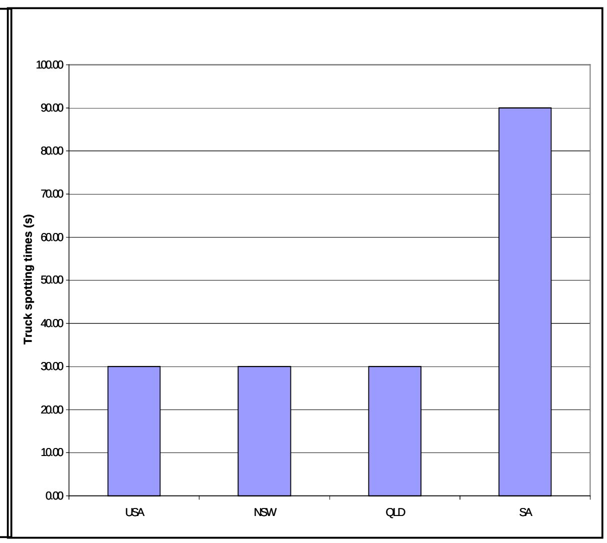


Figure 4.5.1.d: Truck spotting times (s)

Where trucks and shovels are used on the international benchmark operations as the main method of moving overburden, the mining layout is designed to keep haulage distances shorter than 2 400 m. Where trucks and shovels are used with draglines for pre-stripping and parting removal, cross-pit bridges are constructed to keep haulage distances as short as possible. This practice is used on the Queensland benchmark operations where cross-pit bridges are spaced between 1 000 and 1 500 m apart.

Truck spotting times on the South African mines were on average 30 seconds higher than on the benchmark operation (Figure 4.5.1d). Shovel swing times and truck loading methods are basically the same. See Appendix 1 Figure 10 for the South African scenario.

Mine haul trucks used on South African mines appear to be two truck-size generations behind the USA and one generation behind NSW and Queensland (Figure 4.5.1e). The largest trucks operating on the South African surface coal mines are 200 t haul trucks (See Appendix 1 Figure 9 for the truck sizes on SA mines). The biggest trucks operating in Queensland and NSW were 220 – 240 t trucks. The USA operates 320 t trucks and was testing the new 360 t trucks. The smallest production truck operating on the international benchmark mines was a 153 t rear dumper used for coal haulage. The smallest truck operating on the overburden was a 190 t truck.

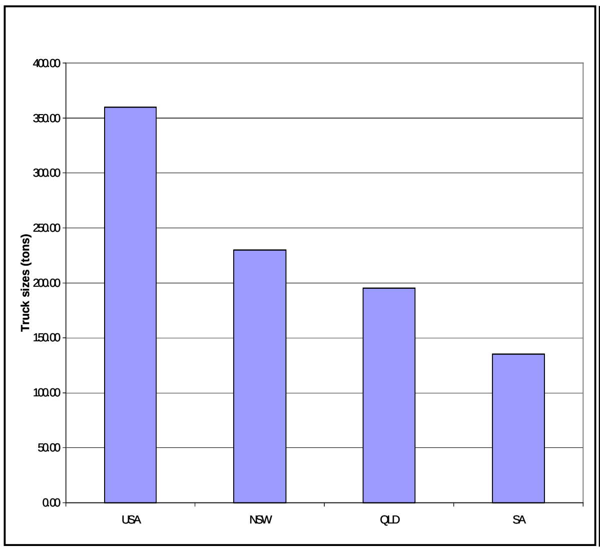


Figure 4.5.1.e: Truck sizes (t)

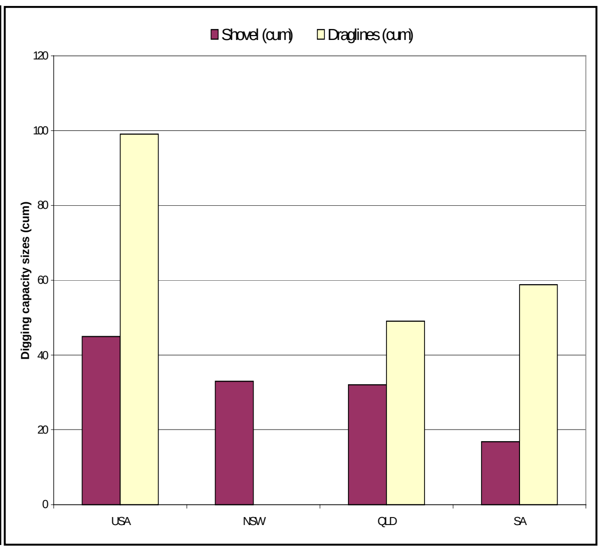


Figure 4.5.1.f: Digging capacity (cum)

Shovels used on South African mines appear to be three shovel-size generations behind the USA (Figure 4.5.1f). The largest operating shovel on any South African surface coal mines is a 25 m^3 hydraulic shovel (See Appendix 1 - Figure 9 for the shovel and dragline sizes operating on SA mines). NSW and Queensland are using 33 m^3 shovels. The USA is already implementing 90 metric ton shovels (51,2 m^3). This new generation of shovels was introduced into the USA at the end of 1999. South Africa is only one shovel generation behind the Australian benchmark mines who still operate 28 m^3 shovels.

The South African draglines generally achieved a low productivity performance level, when compared with overseas operations. Although some individual mines achieved outstanding dragline productivity performance levels. The overall moderate dragline productivity performance can be attributed to:

- Digging capacity (m^3)
- Equipment utilisation.

The largest international dragline surveyed was a Marion 8750 fitted with a 99 m^3 bucket operating in the USA (Figure 4.5.1f). The Australian benchmark mines had larger draglines in operation than South Africa, but with similar bucket sizes. The smaller buckets were dictated by the pit width and bench height configurations.

Although the South African dragline operations operate in general under the same pit-and-bench geometries as the international benchmark mines, their bucket swings per hour are substantially lower (Figure 4.5.1.g and Appendix 1 - Figure 11 for the dragline swings per hour on SA mines). There appears to be an excess of dragline digging capacity on some South African strip mines, which reduces South Africa's dragline productivity level. Not all the South African mines reported low bucket swings per hour. Indeed, the best swings per hour reported in this benchmarking survey were by two South African strip mines.

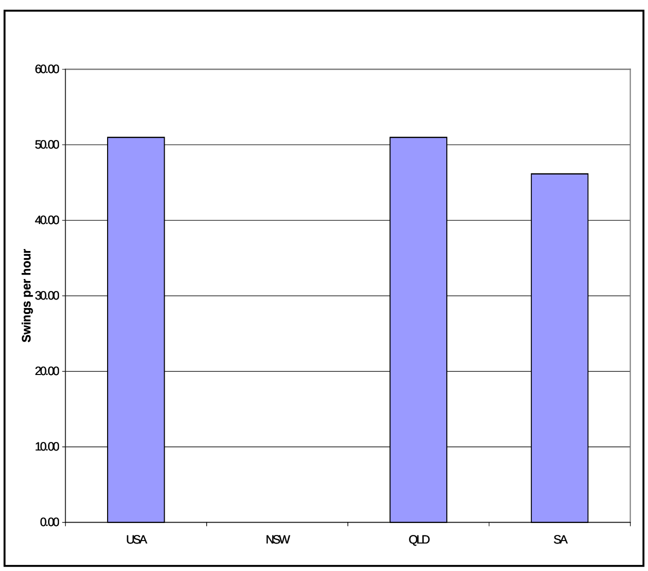


Figure 4.5.1.g: Dragline swings

The average South African dragline utilisation was on par with that of NSW but lower than the Queensland and USA reported utilization (Figure 4.5.1.b). However, some individual South

African dragline operations were found to be outperforming the international benchmark mines and were once more setting a world-class performance standard (see Appendix 1 – Figure 6).

4.6 Operating expenditure

Mines found it difficult to report on the operating expenditure as requested in the benchmarking checklist. Their financial systems did not provide for stripping activity-based costing. The mines were then requested to provide a mining operating expenditure (OPEX) per ROM coal delivered to the tip (Figure 4.6a)

However, the mining OPEX per ROM coal was not meaningful. The mining cost data were therefore recalculated and a mining cost per total BCM moved was produced (Figure 4.6b).

Due to the difficulty in obtaining the mining operating expenditure and the amount of manual manipulation required, the project team decided to exclude these data from the evaluation process.

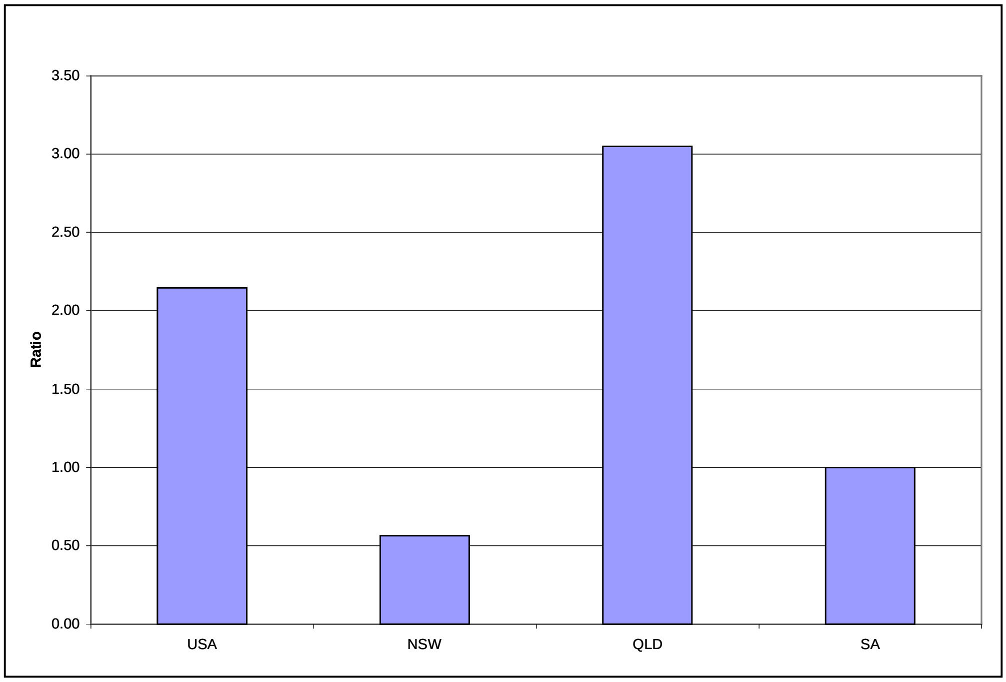


Figure 4.6a: Mining operating expenditure per ROM ton

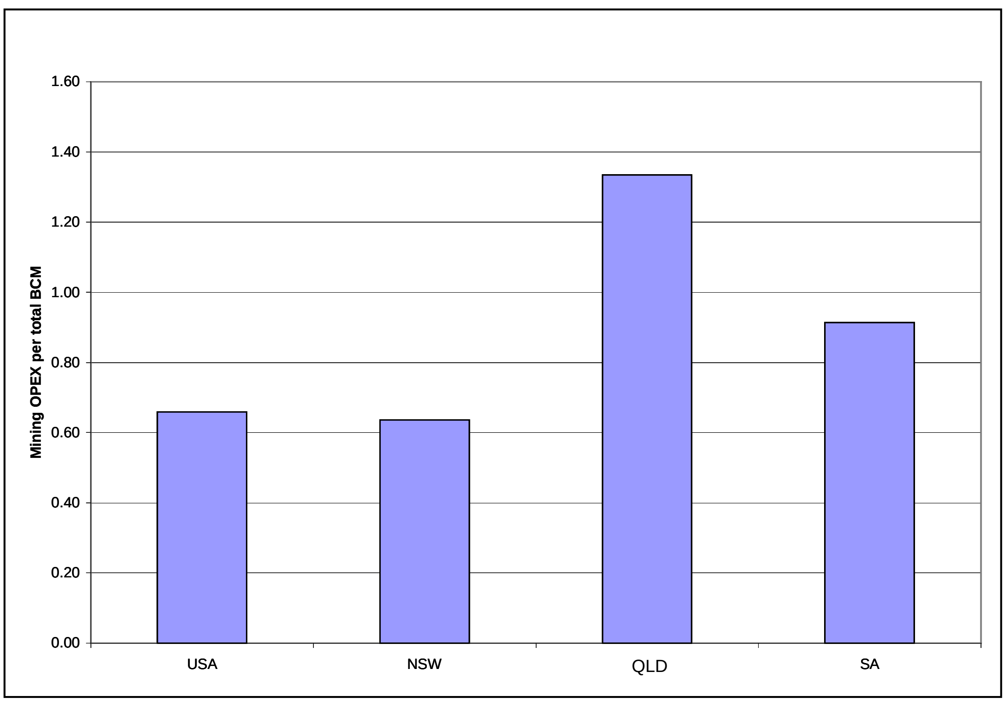


Figure 4.6b: Mining operating expenditure per total BCM moved

4.7 Productivity factor

Productivity was measured by expressing the outputs as a ratio of the inputs used. The productivity factor measures the total output relative to the inputs used. Output can be increased by using more inputs, making better use of the current level of inputs, through technological improvements and by exploiting the scale of economics. The productivity factor indicates the impact mine labour, mining capital invested and operating expenditure had on the output (tons) of the surveyed mines.

Thus, the productivity factor (Figure 4.7) gives an indication of the stripping productivity performance of the countries surveyed in terms of total BCMs moved, capital invested, labour operating expenditure.

The survey found that NSW had the best-performing operations, although the geological conditions were not favourable.

Overstaffing, poor operating practices and low capital utilisation on the South African surface coal mines were the most common reasons for the moderate productivity levels achieved. (The South African mines' productivity factors in summarised in Appendix 1 – Figure 6)

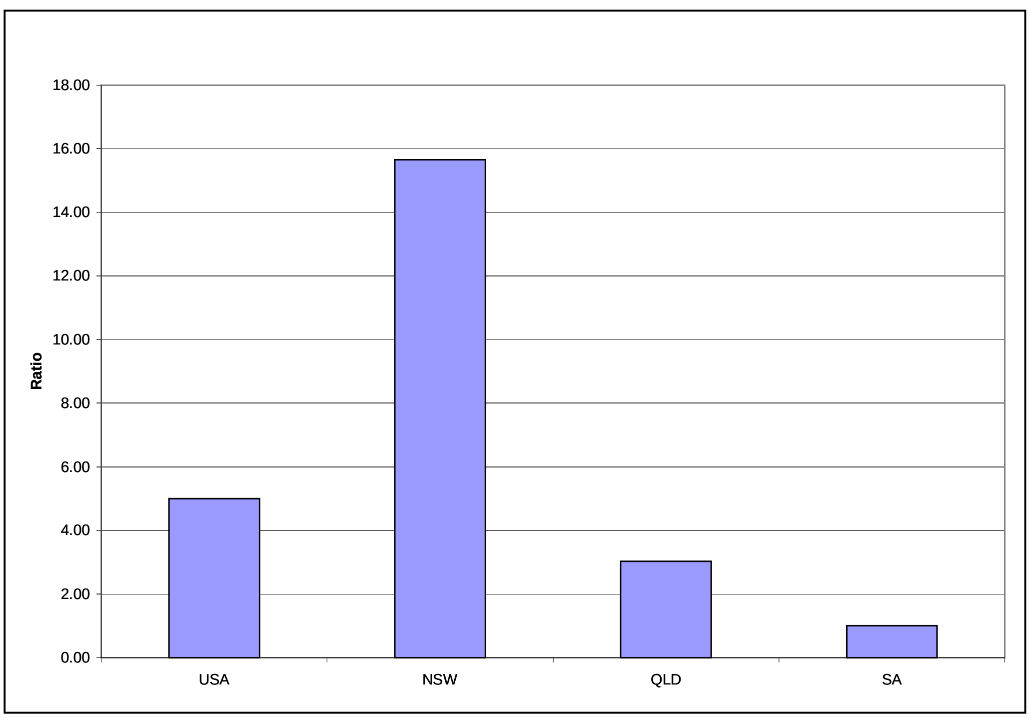


Figure 4.7: Productivity factors for mining countries surveyed

5. CONCLUSIONS

The South African surface coal mining industry recorded the lowest stripping productivity performance when compared with the survey results from the mines in the USA, NSW and Queensland. This below-benchmark productivity performance was mainly the result of low labour and capital productivity performance levels.

The labour productivity indicators contributing to the South African surface coal mining industry's low labour productivity performance were:

- Large percentage of contractors employed on local mines, but not directly involved in mining operations
- Work practices i.e.
- Labour-intensive mining operations
- Large percentage of mine labour not directly involved with mining i.e. support staff. (Socio-economic responsibilities of SA mines)
- Work culture of local work force
- Production incentive schemes.

The capital productivity indicators contributing to the South African surface coal mining industry's low capital productivity performance were:

- Truck-and-shovel performances
- Dragline performances.

The low truck-and-shovel productivity performance can mainly be attributed to:

- Labour practices
- Moderate truck-and-shovel utilization
- Long haulage distances and
- Not capitalising on the economies of scale associated with large mining equipment.

The dragline productivity performance can be mainly attributed to:

- Labour practices
- Under utilisation of excess digging capacity.

However, some individual South African dragline operations were found to be outperforming the international benchmark mines and were setting a world-class performance standard. Key performance indicators, implemented by management to track the performance of the draglines assisted these mines in achieving world-class standards.

Very few mines planned and scheduled cast-blasting as the primary method of moving overburden. In general, mine management agreed that cast-blasting had great potential as an cost effective stripping method and it was not fully utilised on most mines.

Due to the difficulty in obtaining the operating expenditure from the mines and the amount of subjective manual manipulation required these results were not used for evaluation purposes. Coal exposure rate analysis was also not considered an appropriate productivity performance measure due to the difficulty in interpreting those results.

6 RECOMMENDATIONS

During 1998, the current international oversupply of coal continued with a 3,7 % decrease in world coal demand and an increase in production in the USA (5,9 %), Australia (1,2 %), South Africa (2,8 %) and Indonesia (8,3 %) (Minerals Bureau, 1999). This resulted in the continuation of the downward trend in world coal prices which started in 1996 with coal prices dropping by another US$5,8 (13,8 %) (Minerals Bureau, 1999). With no immediate market improvements in the foreseeable future, the South African surface coal mining industry will come under severe pressure to improve its labour and capital productivity levels and its operating costs in order to maintain its competitive edge.

The current state of the South African economy will also not make these improvements an easy task. With the labour sector putting more pressure on government to protect job opportunities in an industry that has long been known as one of the greatest providers of employment in South Africa, low economic growth rates and an ever-increasing trend towards globalisation, the surface coal mines will be hard-pressed to remain competitive and economically sustainable well into the 21st century.

The following recommendations are aimed at assisting the South African surface coal mining industry and Coaltech 2020 in achieving these objectives.

6.1 Improve labour productivity

With profit margins becoming marginal, the future value of coal is locked up in volume and costs. Those mines that manage to increase coal output at marginal cost levels through mergers, acquisitions and re-engineering will benefit. Other labour-improvement initiatives such as restructuring of the organisation, mechanisation of mining-related processes and outsourcing of non-core activities could also improve labour productivity performances.

6.2 Improve capital productivity

6.2.1 Labour practices.

Investigating and implementing a production performance management scheme that will foster improved labour productivity, practices and efficiency without sacrificing mine health and safety could also improve labour productivity and ultimately capital productivity.

6.2.2 Equipment utilisation

In order to improve equipment utilisation it is recommended that mines:

- Work on a **full calendar year** and thus reducing unproductive time to an absolute minimum. Some South African dragline operations are already setting the standards in this regard.
- Either fully utilise or permanently removed **excess mining equipment** and digging capacity from mines. This will lead to better utilisation of the available mining equipment.

6.2.3 Mine planning (Haulage distances)

Mine planning and production decisions should aim at optimising the current stripping activities and practices by:

- Optimising truck hauling distances to tips and dump sites.

6.2.4 Economies of scale

When current mining equipment is due for replacement, the mine must consider the latest proven technologies in mining equipment. Especially the latest truck and shovel generations will improve the economies of scale of the mining operations. Example: the tons hauled per truck cycle on SA mines could be improved by up to 80% if SA mines changes the existing truck fleets with the latest 360t haulers. However it is important to have an optimal truck-and-shovel match as a sub-optimal match will influence the truck loading times and ultimately the capital productivity of surface mining operations.

6.2.5 Key Performance indicators

Key Performance Indicators (KPI) can be of great help to management for managing and improving a mines productivity performance. KPI for the measurement and management of material transportation, i.e. truck spotting times, dragline swings per hour, truck loading times, loading and hauling and dumping parameters, could be implemented, tracked and monitored against the international benchmark on a regular basis.

6.2.6 Cast-blasting

Very few mines planned and scheduled cast-blasting as the primary method of moving overburden. In general, mine management agreed that cast-blasting had great potential as an cost effective stripping method and it was not fully utilised on most surface mines. The possible benefits of cast-blasting should be established for every overburden blast. The South African explosive suppliers provide this service to their customers free of charge.

6.3 Measure results against newly planned surface coal mines

As this study outlines the capital and labour investments on international best practice operations it is also recommended that the findings of this study be used to measure the capital and labour investment on newly planned surface coal mines. The outcome could be used to update and improve the study results and the plans of the new mines.

6.4 Extend the survey to other surface mining operations

By extending this benchmark study to other surface mining operations, the exceptional best practices at these surface mines could be documented and transferred to South Africa's surface coal mines to further improve their current productivity performance.

6.5 Re-evaluate the South African coal surface mines on a yearly basis

The findings of the study reflect the productivity performance of South Africa's surface coal mines at a certain point in time. Due to the external and internal changes affecting the industry, its productivity performance will certainly change. In order to remain competitive and sustainable, it is important to know what the impact of these changes will be or has been on the industry. By monitoring the impacts of these changes, management could use the information collected for decision-making to achieve best practices.

References

Bensa. Benchmarking South Africa (Pty) Ltd, 1999. New Company Profile, Pretoria, South Africa.

Caterpillar Inc, 1999. Equipment brochures.

Gilewicz, P., 1999. U.S. Dragline Census. Surface mining – Coal Age.

Hitachi Mining, 1999. Equipment brochures.

Komatso Mining Systems, 1999. Equipment brochures.

Louw T., 2000. Cast Blasting Survey. Coaltech task 3.14.1 survey, Pretoria, South Africa.

Minerals Bureau, 1998. South African Minerals Industry 1997/98. Department of Minerals and Energy, Pretoria, South Africa.

Minerals Bureau, 1999. South African Minerals Industry 1998/99. Department of Minerals and Energy, Pretoria, South Africa.

Moolman, C.J., Lok, G. and van Zyl, F.J.. 2000. Benchmarking, Report number ESH 00-0146, CSIR Miningtek, Johannesburg, South Africa.

P&H Mining, 1999. Equipment brochures.

Popowich, J.L. and Clarke, H.S., 1993. Shovel and Truck Mining in Oil Sands. Paper presented at the 95th CIM Annual General Meeting, Calgary, Alberta, Canada, May 9-12, 1993.

Tasman Asia Pacific (Pty) Ltd, 1997. The scope for productivity improvement in Australia's open-cut black coal industry.

Tasman Asia Pacific (Pty) Ltd, 1998. Benchmarking the productivity of Australia's black coal industry.

Appendix 1

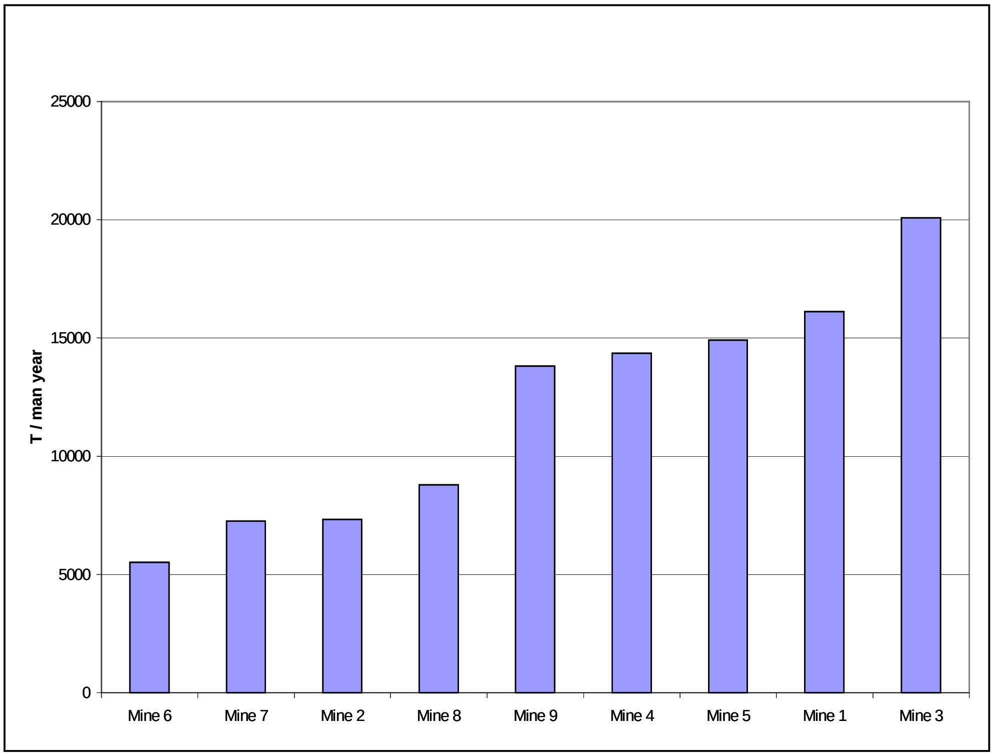


Figure 1: SA ROM tons per man-year excluding contractors

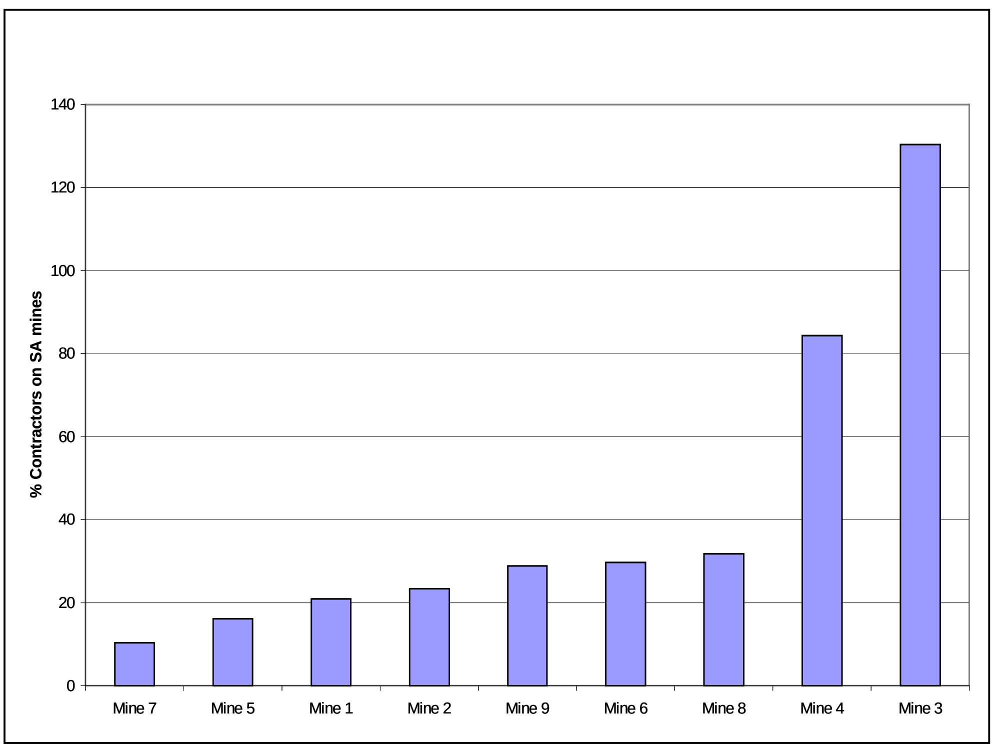


Figure 2: Contractors as a % of mine employees working on SA mines

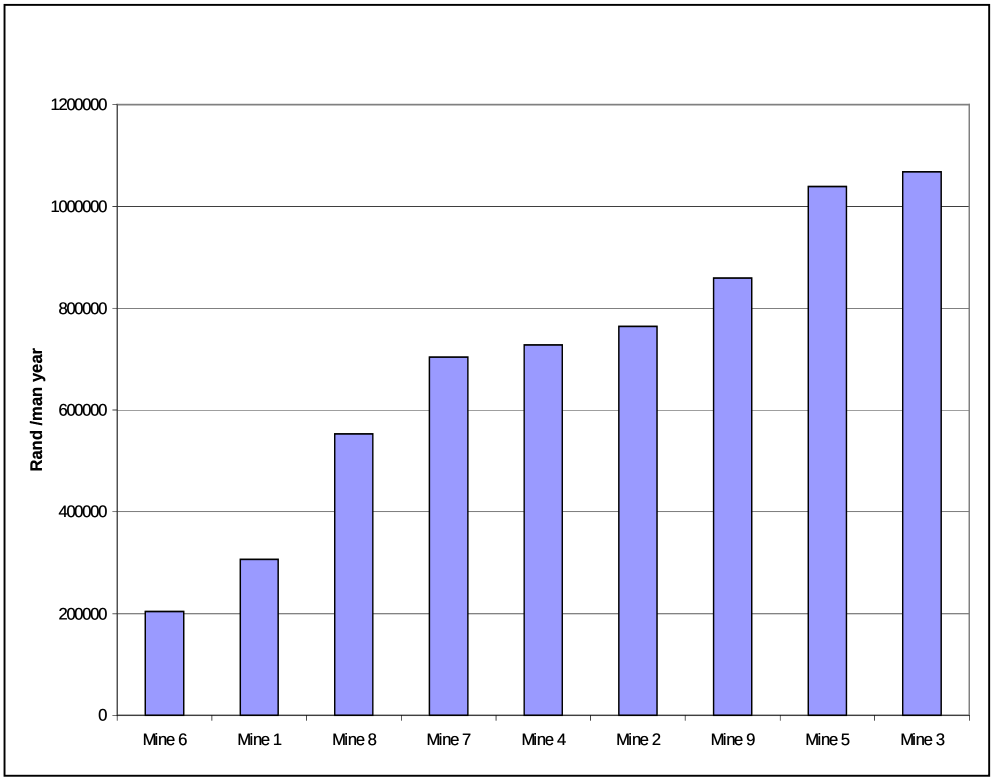


Figure 3: SA Mining CAPEX per mine employee, including contractors

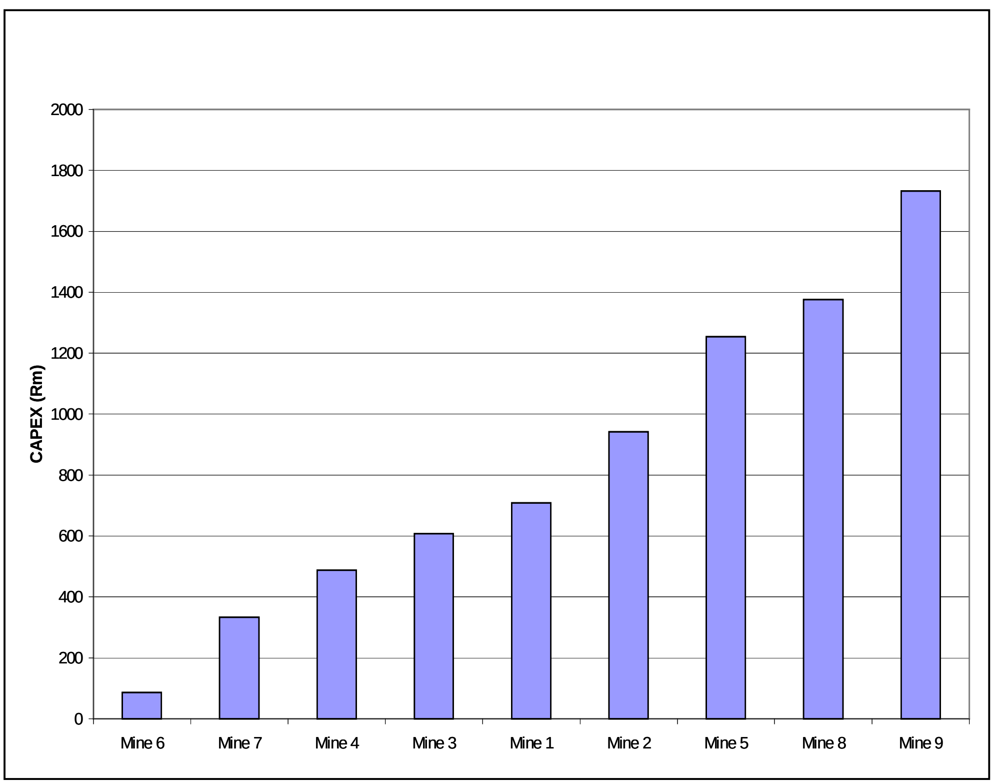


Figure 4: Capital invested on SA mines

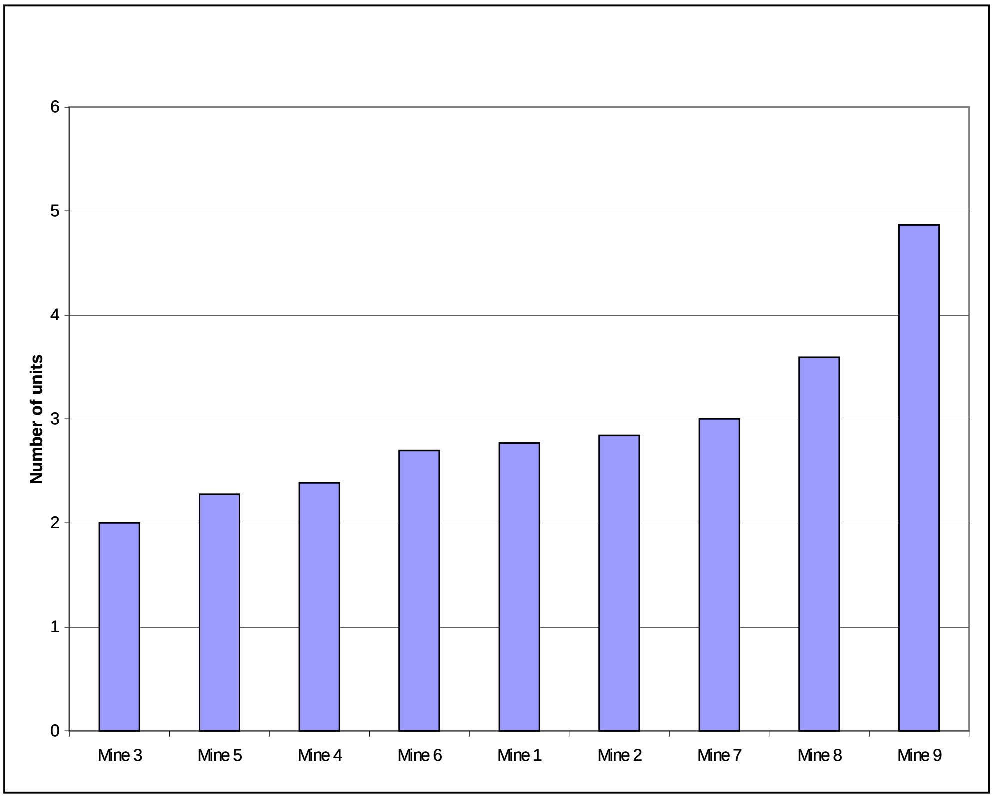


Figure 5: Number of primary equipment units per ancillary unit on SA mines

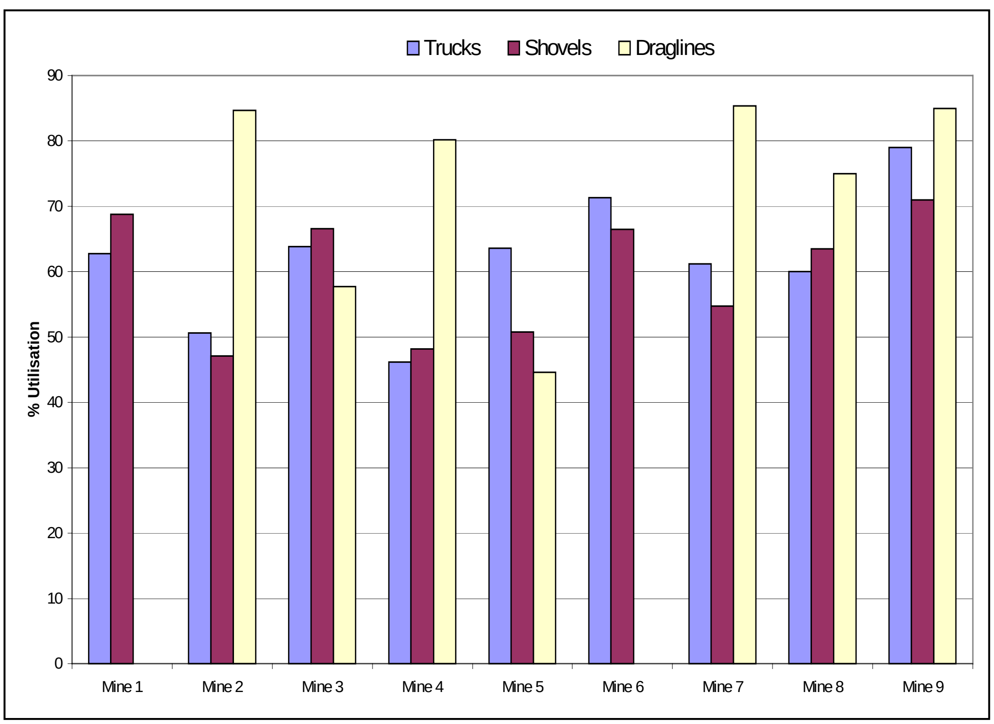


Figure 6: Equipment utilisation on SA mines

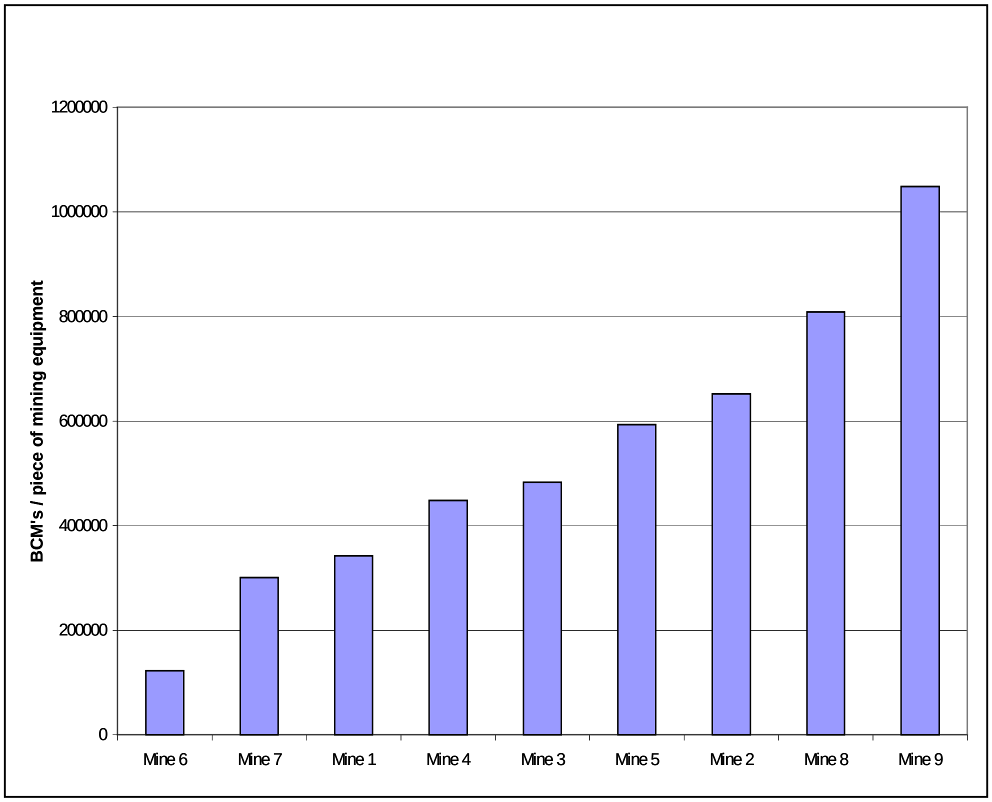


Figure 7: BCM's moved per mining equipment unit on SA mines

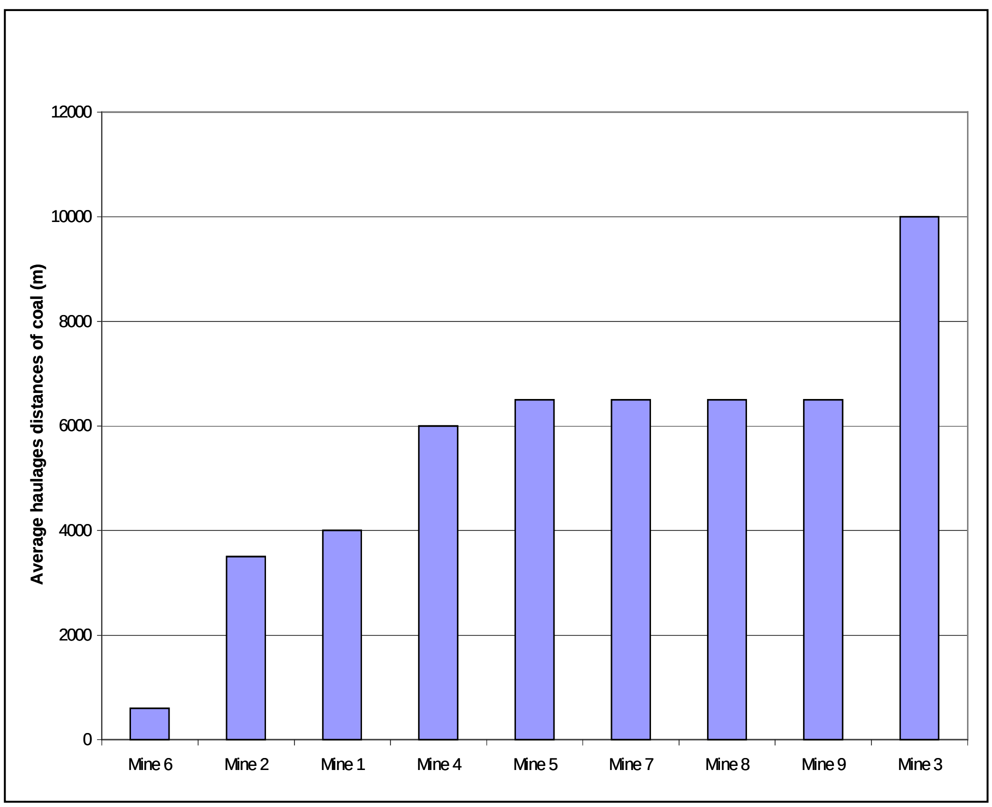


Figure 8: Average overburden haulage distances on SA mines

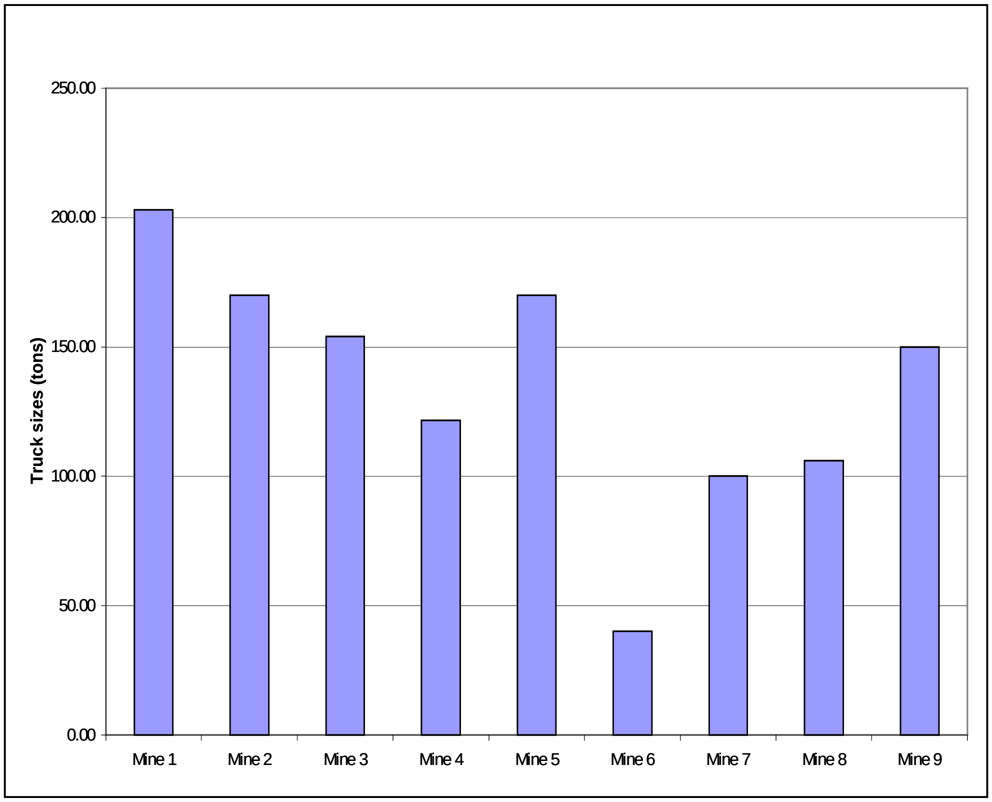


Figure 9: Sizes of haul tucks working on SA mines

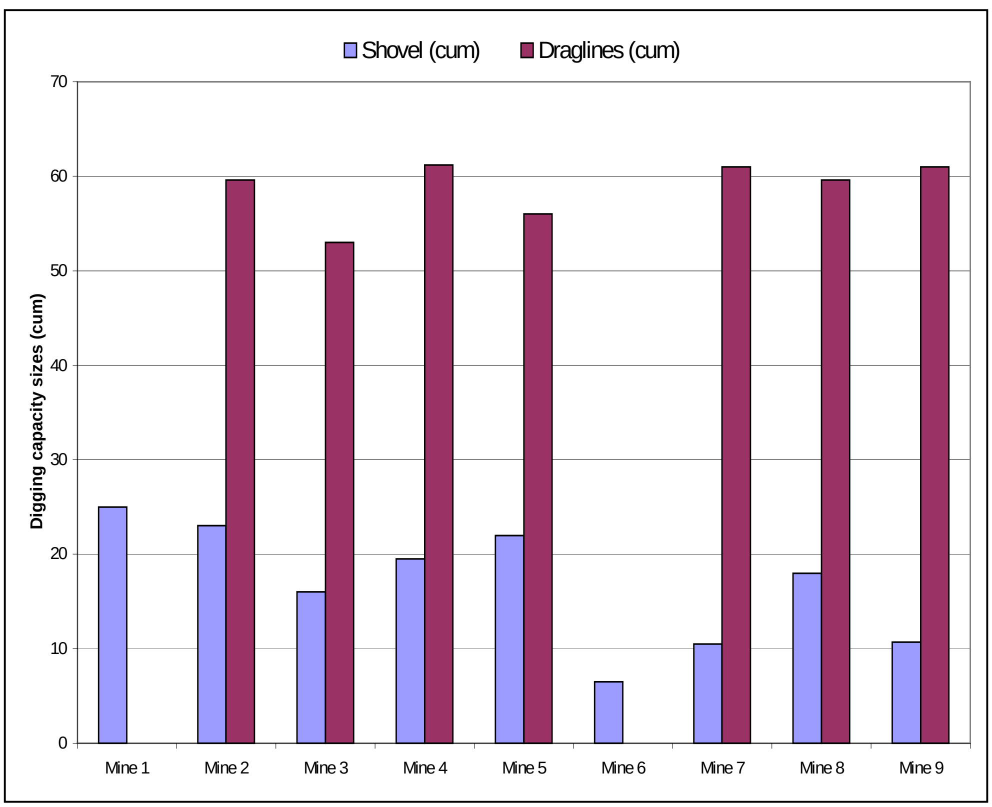


Figure 9: Digging capacity of shovels and draglines on SA mines

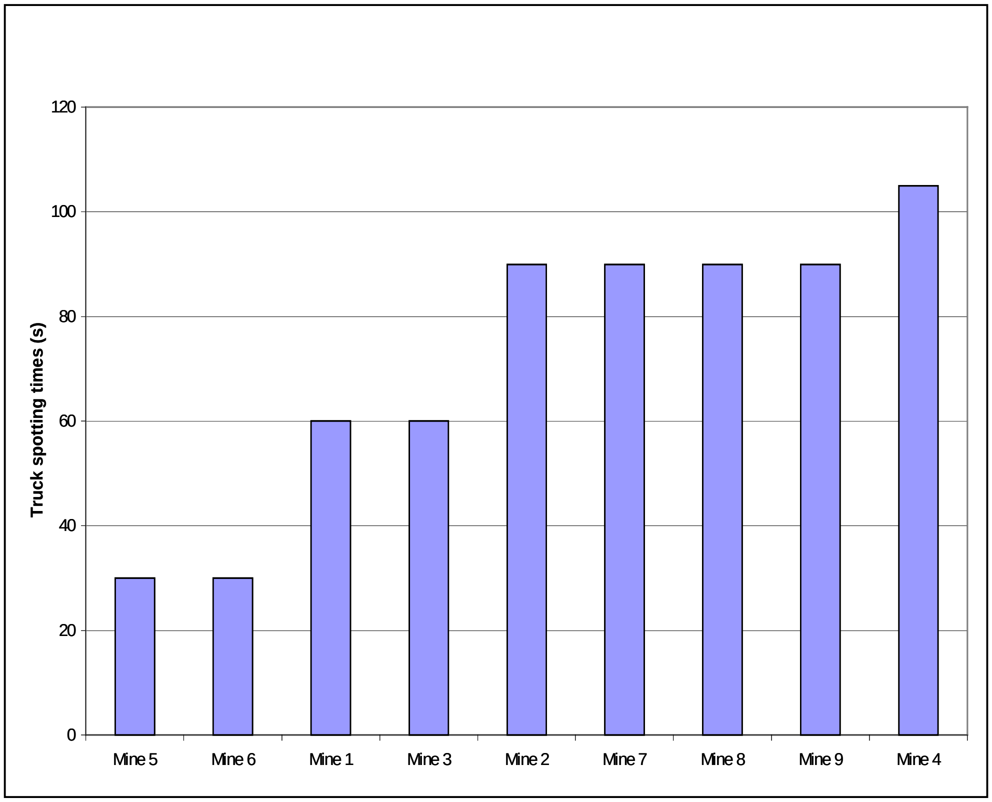


Figure 10: Truck spotting times on SA mines

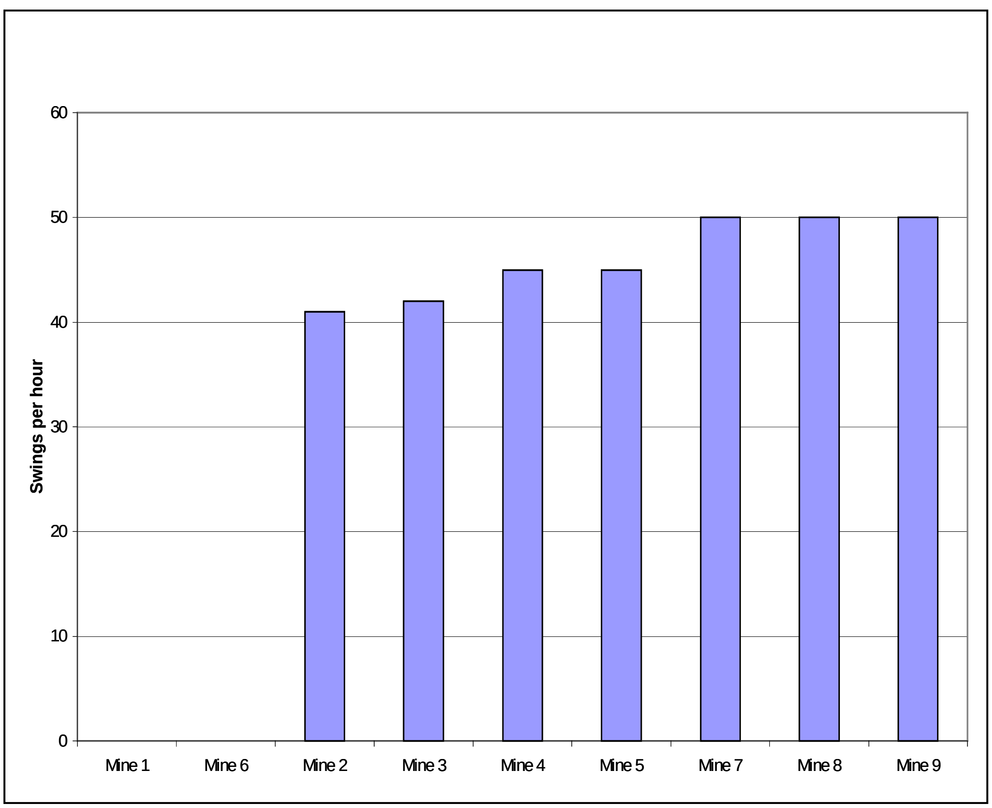


Figure 11: Dragline swing per hour on SA mines

Appendix 2

1. Units of measure and assumptions

1.1 Units of measure

Each mine is known to have its own units of measure. Standardized units of measure were created as a means of measuring the different strip-mining operations in South Africa and internationally. In order to determine what to measure, performance measures and assumptions were created. Using the known performance measures with the assumptions made fixed, the units of measure were finalised and the evaluation checklist was constructed.

From the literature study and industry workshop, it was decided that the following units of measure would be used in this study:

- All **volumetric** and **linear units** will be measured in metric units and not imperial units of measure.
- **Stripping rates** will be measured in BCMs per clock (calendar) hour and per digging hour.
- **Stripping ratios** will be all the material moved from the original ground location (OGL) status versus an in situ ton of coal.
- **Labour** will include all employees and will be split into various activities.
- The **work in progress cost** must be included in the initial capital expenditure.
- For the **pit length index** and some form of activities index per unit pit length, a standard unit length of 1 km will be used.
- **Operating expenditure** (Opex) and **capital expenditure** (Capex) will be reported per activity.
- **The total Opex and Capex** per square metre of coal exposed per activity group and activity method will be measured.
- **The Opex** will not include provision for rehabilitation or overheads or repair and replacement costs.
- **The Capex** will include repair and replacement, rehabilitation and overhead costs.
- **The seam dip** must be less than 10^{o}.

1.2 Assumptions made and fixed

For this study the following assumptions were made and fixed:

- Stripping evaluation will be based on the number of square metres of coal exposed per time frame.
- Processing costs must be dealt with as a separate issue.
- The cost curve should reflect Opex per square metre of coal exposed.
- Direct Opex should be used. This should exclude provision for rehabilitation and any other off-mine overheads. It must, however include the provision made for repair and replacement (R&R).
- The capital cost for a stripping activity will be equal to the replacement value of that equipment. Thus the total capital deployed for a stripping activity will be equal to the sum of all the equipment-replacement costs for that activity.

Appendix 3

1. Previous research work

In October 1997 the Industry Commission of Australia contracted Tasman Asia Pacific to undertake a benchmarking study of the productivity performance of Australia's black coal mines. Tasman benchmarked Australia's black coal industry against best-practice world coal mines and best-practice Australian metalliferous mines. They benchmarked 44 separate mine operations in 1996, and 22 truck-and-shovel and 13 dragline operations in the first nine months of 1997.

The coal mines selected in the United States included a number of mines that had been nominated by industry experts as better-practice operations, as well as mines that were affiliates of Australian mining companies. Responses were received from 20 Australian coal mines; eight United States coal mines and four Australian metalliferous mines. The coal production from the responding Australian coal mines is equal to nearly 40 per cent of Australia's raw coal production.

Tasman's benchmarking is based on TPF measures (which measure total output relative to all inputs used) and supported by partial productivity measures to identify the drivers of productivity differences between mines. This is in contrast to the coal exposure rate per time unit to be used in our benchmarking study. The benchmarking analysis is focusing on the main components of the mining process. However, it does not cover all mine inputs nor does it cover development work (e.g. setting up mine offices, developing access roads). The items excluded are washeries and mine overheads, basically all the maintenance activities and some materials used in production.

1.2 Truck-and-shovel benchmark

Truck-and-shovel mines remove both overburden and coal primarily by means of trucks and shovels. Tasman's benchmarking results indicate that in 1996 to 1997, the total productivity factor of the participating NSW and Queensland truck-and-shovel coal operations was, on average, well below best practice (Figure 1.2a).

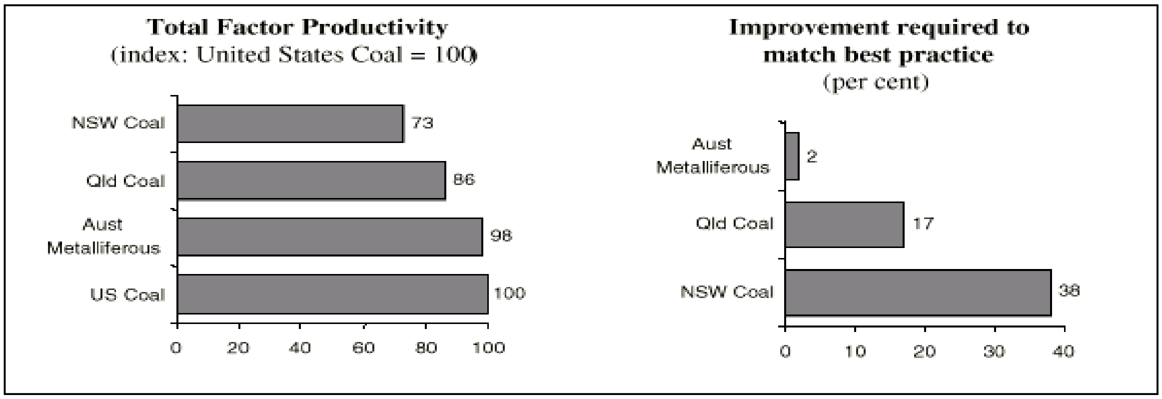


Figure 1.2a: Total factor productivity of truck-and-shovel operations

Source: Survey undertaken by Tasman Asia Pacific (1998).

To match the best-practice productivity levels of United States coal mines, NSW and Queensland coal mines needed to increase their productivity by 38 and 17 per cent respectively. Increases in average productivity of 35 and 14 per cent respectively were required for these mines to match the average productivity of the Australian metalliferous mines covered by the survey. As a whole, the Australian coal mines in the sample needed to increase productivity by about 30 per cent to match the performance of the United States coal mines and Australian metalliferous mines.

Geological conditions, such as thinner coal seams and a greater number of them in the NSW mine category, were just one of a number of factors influencing the productivity outcomes. The main factors adversely affecting productivity were over-staffing, over-capitalization of equipment and poor work practices. These were reflected in relatively low labour and truck productivity in the NSW and Queensland coal mines. Labour and truck productivity both needed to increase by around 70 per cent in the NSW coal mines to match the performance of the United States coal mines. Queensland coal mines needed a corresponding 40 per cent increase on average.

Tables 1.2a and 1.2b outline the key characteristics of the “frontier” and moderately performing Australian truck-and-shovel operations. A number of Australian truck-and-shovel operations are at the frontier of efficient operation, achieving productivity levels more than 50 per cent higher than those of many other Australian mines. These characteristics indicate ways for the poorer-performing mines to improve their efficiency and unit operating costs.

Table 1.2a indicates that over-staffing and over-capitalization are common causes of lower productivity in Australia compared with their American counterparts. Often the moderately performing mines have more equipment than they need. This results in low equipment utilization and productivity, and additional staff. In these mines, excess staff are also often apparent in areas such as operating non-core equipment (e.g. supporting equipment or services) and in general duties.

Table 1.2a: Work practices of typical best-practice and moderately performing Australian truck-and-shovel coal mines

	Best practice operation	**Moderately performing mine**
Total productivity	100	60
3 Resource levels		
Staffing levels: ratio of labour hours worked to equipment hours worked	1,5	2,1
Work time in shifts: time excludes leaving and joining shifts, meal and other breaks (per cent)	92	85
Utilization of truck fleet: hours operated as a percentage of total available hours	45	40
Utilization of major digging equipment: hours operated as a percentage of total available hours	50	40
Work practices		
Hot-seat changes	Yes	Yes
Meal breaks in the field	Yes	No
Staggered meal breaks	Yes	No
Operators move between equipment within shifts	Yes	Rarely
Haulage equipment fuelled during breaks	Yes	No
Clean-up equipment does not impede production	Yes	No

Source: Survey undertaken by Tasman Asia Pacific (1998).

Work practices are more efficient in the high-performing mines in the sample, resulting in a higher or improved productivity. In efficient mines, staff use effective hot-seat changes, take meal breaks on machines, stagger meal breaks to ensure that core equipment continues to operate, move between pieces of equipment within shifts where necessary, fuel haulage equipment during breaks and ensure that clean-up equipment does not impede production. Generally, the poorer-performing mines in the sample implement only a few of these good practices.

Table 1.2b: Key attributes of typical best-practice and moderately performing Australian truck-and-shovel coal mines

	Best-practice mine	**Moderately performing mine**
Efficient truck-loading practices: incidence of double-sided or other efficient truck-loading method (per cent)	>50	0
Stopping time of trucks under shovels (seconds)	35	65
Truck loads per shovel per eight-hour shift	185	135
Industrial disputes: days lost per thousand hours worked	0	20
Safety: lost time injuries per million man hours	20	50

Source: Survey undertaken by Tasman Asia Pacific (1998).

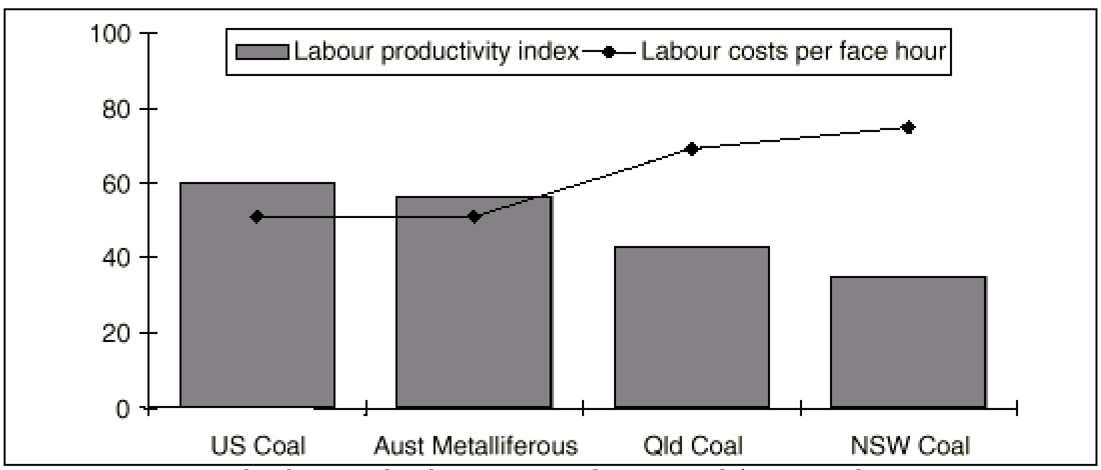
Highly productive truck-and-shovel operations often use shovel techniques such as double-sided loading of trucks. Double-sided loading imposes an extra dimension of care to maintain safety standards. It allows substantially more excavation per shift and improves truck productivity. For example, based on this sample, stopping times for trucks at shovels are often around 35 seconds with double-sided loading, compared with 65 seconds with single-sided loading.

Better-performing mines invariably had fewer industrial disputes and also seemed to have a better safety record.

Tasman’s analysis showed that the cost of material extraction and transport to stockpiles in NSW and Queensland truck-and-shovel operations was around 50 per cent higher than in the United States coal mines and 30 per cent higher than in the Australian metalliferous mines. Most of this was due to a low difference in productivity, while about 30 per cent of the cost difference between the United States and NSW mines was due to high unit costs such as the cost of labour.

As shown in Figure 1.2b, the average cost per hour worked in the sample mines was considerably higher in the NSW and Queensland coal mines than in the Australian metalliferous and United States coal mines. These higher labour costs are in sharp contrast to the poor labour productivity achieved in these mines.

In general, the labour-related problems experienced by the Australian surface-mining industry and highlighted by Tasman's survey, support the South African mining industries' belief that local labour has similar results on the South African productivity levels. This survey will not focus on labour relations and labour practices. It will, however, highlight the hours worked per stripping activity and mining method. It will thus be possible to draw comparisons between South African and international labour productivities.



(Index: United States coal = 60 and $A costs)

Figure 1.2: Labour productivity and cost in truck-and-shovel operations

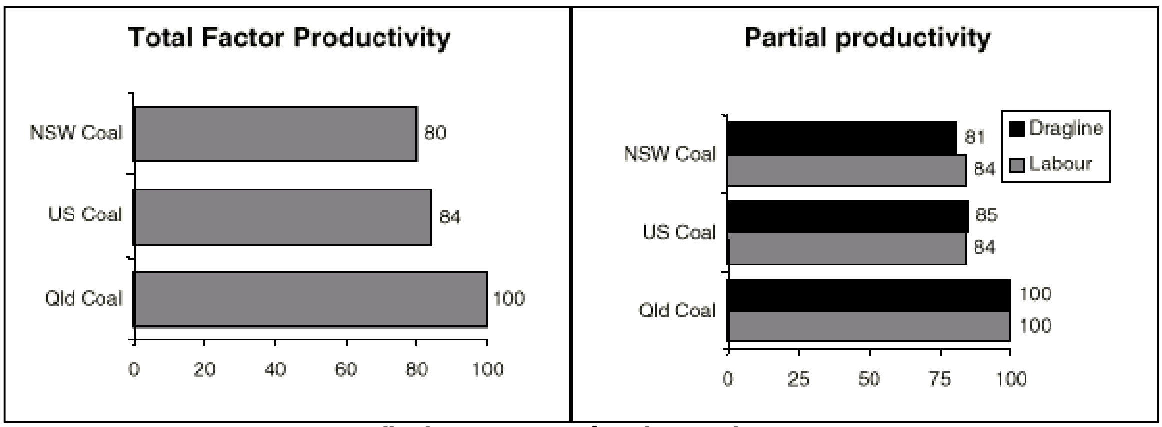
Source: Survey undertaken by Tasman Asia Pacific (1998).

1.3 Dragline benchmarks

Tasman's estimates of dragline productivity focused on overburden removal in 13 strip coal mines located in NSW, Queensland and the United States. The results of this benchmarking identified Queensland mines as the most efficient performers in 1996 to 1997 (Figure 1.3).

NSW and United States producers in the sample needed to improve their total productivity by an average of 25 and 19 per cent respectively to equal the Queensland mines' performance. High dragline and labour productivity helped the sample of Queensland mines achieve this best-practice result. Several factors contributed to the observed differences in productivity, including:

- high dragline capacity utilization, coupled with operational efficiency of draglines in Queensland mines
- low dragline operational productivity in NSW mines
- low blasting requirements in Queensland mines due to the geology of the overburden.



(index: Queensland = 100)

Figure 1.3: Total factor productivity and key partial productivity of dragline operations

Source: Survey undertaken by Tasman Asia Pacific (1998).

Table 1.3 shows that the Queensland mine category achieved the highest operational efficiency with 47 full dragline bucket equivalents per hour, compared with 44 in the United States mines category and only 37 for mines included in the NSW category. The mines in the NSW category were not making effective use of their relatively large draglines. The main reason could be related to the average number of swings per hour. It appears that a number of these NSW mines achieved high dragline bucket factors.

Based on Tasman's sample, labour productivity in Queensland dragline operations exceeded that in NSW and United States mines by about 20 per cent. Much of this difference stemmed from the greater operational efficiency of the Queensland draglines and fewer staff being required for drilling and blasting activities.

Despite the good productivity performance of many of the Australian dragline operations in the sample, they achieved cost levels well above that of their United States counterparts. For example, the total costs of removing overburden in participating Queensland mines were 23 per cent higher than in participating United States mines, even though productivity was 19 per cent higher in the Queensland mines. The higher input costs in the Australian sample mines were largely due to the high cost of labour and explosives.

Table 1.3: Productivity performance of dragline operations

	***Dragline output per hour* (BCM)**	***Bucket factor* (%)**	***Swings per hour* (number)**	***Bucket capacity* (LCM)**	***Equivalent dragline bucketfuls* (number / h)**
Queensland coal	1 901	92	51	41	47
United States coal	2 074	88	50	47	44
NSW coal	1 910	95	39	51	37

Source: Survey undertaken by Tasman Asia Pacific (1998).

Tasman's analysis suggests that a number of Australian strip mines that have problems with over-staffing and inefficient work practices in their truck-and-shovel operations are able to achieve much higher relative productivity in their less labour-intensive dragline operations.

Although Tasman's TPF factor gives a relative indication of the productivity efficiency of a strip mine, it does not measure or report on the effectiveness of overburden removal. Since the biggest portion of a surface mine's mining cost is reflected in the removal of overburden, the more focused benchmarking evaluation of this Coaltech study will indicate the direction or trends in international overburden removal.

1.4 Comment on international results

Tasman's results on the black coal mine benchmarking indicates a very mixed productivity performance by Australian black coal mines. In each mining technology examined (truck-and-shovel and draglines), Australia can boast a number of mines that are at or very close to world best-practice performance levels. The problem for the Australian coal industry is the large number of moderate and poorly performing mines. South Africa is most probably in a similar situation.

Australia's truck-and-shovel mines need to improve productivity by an average of around 30 per cent to match better-practice United States coal mines and Australian metalliferous mines. A large proportion of Australian truck-and-shovel operations in Tasman's sample needed to improve total productivity by over 50 per cent to match their "best-practice" neighbours. The poor-productivity mines typically suffered from over-staffing, over-capitalization and poor working practices.

Queensland's dragline operations were identified as best practice, operating at productivity levels of around 20 to 25 per cent higher than similar mines in the United States and NSW. The productivity performance was achieved consistently in the Queensland operations and appeared to be due to good engineering, management and labour practices.

Tasman's benchmarking study suggests that the performance of mines in the Australian black coal industry is mixed. The varying levels of performance are now mainly due to problems at the company or mine levels, rather than industry level.

This study is focusing only on stripping activities. It is, however, important to remember that the competitiveness of strip mining is also very dependent on the in situ quality and geometry of the coal seams, the downstream cost of getting the coal to the final product market and the final price received for the coal. This is something we must take note of, though many people will be inclined to hope that the final report devotes more attention to the contestability of the terms of strip mining. Many will also disregard the findings of the study due to the differences in local and international geological conditions.

Irrespective of the queries made after any benchmarking study, the findings will reflect the current situation. As the Tasman results suggest, Australian truck-and-shovel mines lag far behind their United States counterparts in productivity and mining costs, equipment is clearly over-manned, truck utilization is poor, turnaround times are slow and idle time is excessive. Does South Africa suffer from the same "diseases"?

The quality and usefulness of the productivity comparisons is dependent on the selection of benchmarking partners whose operations are reasonably similar and on co-operation between them over time to ensure consistency of terminology, classification and measurement. Some of the better-performing Australian and American mines will be very useful benchmarking partners for their South African counterparts.

Appendix 4

Benchmarking: Code of Conduct (BENSA 1999)

Keep it legal Be willing to give what you get Respect confidentiality Keep information internal Use benchmarking contacts Don't refer without permission

1. Principle of ***legality***. Avoid discussions or actions that might lead to or imply an interest in restraint of trade, market or customer allocation schemes, price fixing, dealing arrangements, bid rigging, bribery or misappropriation. Do not discuss costs with competitors if costs are an element of pricing.

2. Principle of ***exchange***. Be willing to provide the same level of information that you request in a benchmarking exchange.

3. Principle of ***confidentiality***. Treat benchmarking interchange as confidential to the individuals and organizations involved. Information that is obtained must not be communicated outside the partnering organizations without the prior consent of participating benchmarking partners. The fact that an organization is participating in a study should not be communicated externally without its permission.

4. Principle of ***use***. Use the information obtained through benchmarking partnering only for the purpose of improving operations within the partnering organizations. External use or communication of a benchmarking partner's name with their data or observed practices requires permission from that partner. Do not, as a consultant or client, extend one organization's benchmarking findings to another without the first organization's permission.

5. Principle of ***first party contact***. Initiate contact, whenever possible, through a benchmarking contact designated by the partner organization.

6. Principle of ***third party contact***. Obtain an organization's permission before providing its name in response to a contact request.

Principle of **preparation**. Demonstrate commitment to the efficiency and effectiveness of the benchmarking process with adequate preparation at each process step, particularly at initial partnering contact.

Appendix 5

5.1 Additional information

Site visit: 1999- -

General and Truck & Shovel

Table 3.4.1a Work practices South African truck and shovel coal mines

	Practice
Total productivity	
4 Resource levels	
Staffing levels: ratio of labour hours worked to Equipment hours worked	
Work time in shifts: time excluding leaving and joining shifts, meal and other breaks (per cent)	
Utilisation of truck fleet: hours operated as a Percentage of total available hours	
Utilisation of major digging equipment: hours operated as a percentage of total available hours	
Work practices	
Hot seat changes	
Meal breaks in the field	
Staggered meal breaks	
Operators move between equipment within shifts	
Haulage equipment fuelled in breaks	
Clean-up equipment does not impede production	

Table 3.4.1b Key attributes of South African truck and shovel coal mines

	Practice mine
Efficient truck loading practices: incidence of double-sided or other efficient truck loading method (per cent)	
Spotting time of trucks under shovels (seconds)	
Truck loads per shovel per 8-hour shift	
Industrial disputes: days lost per thousand hours worked	
Safety: lost time injuries per million man hours	
Reportable per million man hours	
Dressing station per million man hours	
Fatality per million man hours	
5 General information	
Average Round trip (m)	
Bonus scheme (no, bad or good)	

Dragline

Table 2.4.2: Productivity performance of dragline operations

	***Dragline output per hour* (BCM)**	***Bucket factor* (%)**	***Swings per hour* (number)**	***Bucket capacity* (LCM)**	***Equivalent dragline bucketfuls* (number / h)**
Queensland coal	1 901	92	51	41	47

5.2 The stripping activity checklist

Step 1

	Asset register for stripping operation								
	Equipment type, make and name : **Drills**	**Hole Size (mm)**	**No. of units**	**Length of drill steel (m)**	**No. of passes per drill hole**		**Design capacity (m/hr)**	**Actual Operating capacity (m/hr)**	**Operating cost (R/hr)**
1	e.g. Drill: O&K Drillteck 25 KS	170mm hole	2	10	1.8		100	80	150
2									
3									
4									
5									
	Trucks	**Size (t)**	**No. of units**	**Dump Body size (cu m)**	**Power of truck (Kilo watt)**	**Diesel rate (Liter / hour)**	**Design capacity (cu m /hr)**	**Actual Operating capacity (cu m/hr)**	**Operating cost (R/hr)**
1									
2									
3									
4									
5									
	Shovels	**Size (SAE cu m)**	**No. of units**	**Digging force (Kw)**	**Brake out force (KW)**	**Diesel or electric**	**Design capacity in BCM (cu m/hr)**	**Actual Operating capacity in BCM (cu m/hr)**	**Operating cost (R/hr)**
1									
2									
3									
4									
5									
	Draglines	**Size**	**No. of units**	**Bucket size (SAE cu m)**	**Boom Length (m)**	**Boom Angle (°)**	**Design capacity (cu m/hr)**	**Actual operating capacity (cu m/hr)**	**Operating cost (R/hr)**
1									
2									
3									
4									
5									

	Dozers	Size	No. of units	Blade capasity (m²)	Blade type (universal, straight/tilt, angle ect.)	Blade capacity (SAE cu m)	Design capacity (cu m/hr)	Actual Operating capacity and doze distance (cu m/hr & m)	Operating cost (R/hr)
1									
2									
3									
4									
5									
	Ancillary	**Size**	**No. of units**	**Bucket size**	**Primary Function**		**Design capacity (Units/hr)**	**Actual Operating capacity (Units/hr)**	**Operating cost (R/hr)**
1									
2									
3									
4									
5									
6									
7									
8									

Step 2. Drills

	Drilling Equipment Utilization on stripping operation							
		% of time spend by equipment type as listed in Step 1 on stripping activity						
		e.g. O&K Drillteck 25 KS						
1	**Stripping activity**	-						
	Bush clearing	-						
	Top soil removal	-						
	Sub soil removal	-						
	Highwall control	-						
	Blasting	-						
	Pre-stripping	15						
	Primary stripping	60						
	Coaling	5						
	Parting	15						
	Rehabilitation							
	Other	5						
2	**Total time on activity**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
3	**Annual hours lost / equipment to:**							
	Shift change							
	Maintenance Planned							
	Maintenance Unplanned							
	Dead headings							
	Pad preparation							
	Relocation of equipment							
	Blasting							
	Other							
4	**Total annual hours lost per equipment**							
5	**Annual additional operating hours**							
	Sundays							
	Holidays							

Step 2. Trucks

	Truck Equipment Utilization on stripping operation							
		% of time spend by equipment type as listed in Step 1 on stripping activity						
		e.g. CAT 777 (85t)						
1	**Stripping activity**							
	Bush clearing							
	Top soil removal	10						
	Sub soil removal	60						
	Highwall control							
	Blasting							
	Pre-stripping							
	Primary stripping							
	Coaling							
	Parting							
	Rehabilitation							
	Other	30						
2	**Total time on activity**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
3	**Annual hours lost / equipment to:**							
	Shift change	100						
	Maintenance Planned	1000						
	Maintenance Unplanned	250						
	Dead headings	0						
	Pad preparation	0						
	Relocation of equipment	0						
	Blasting	500						
	Other	120						
4	**Total annual hours lost per equipment**	1970						
5	**Annual additional operating hours**							
	Sundays	0						
	Holidays	0						

Step 2. Shovels

	Equipment Utilization on stripping operation							
		% of time spend by equipment type as listed in Step 1 on stripping activity						
		e.g. Cat 994 (20m3)						
1	**Stripping activity**	-						
	Bush clearing	-						
	Top soil removal	-						
	Sub soil removal	-						
	Highwall control	-						
	Blasting	-						
	Pre-stripping	-						
	Primary stripping	-						
	Coaling	80						
	Parting	15						
	Rehabilitation							
	Other	5						
2	**Total time on activity**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
3	**Annual hours lost / equipment to:**							
	Shift change	100						
	Maintenance Planned	1200						
	Maintenance Unplanned	300						
	Dead headings	0						
	Pad preparation	0						
	Relocation of equipment	0						
	Blasting	1000						
	Other	100						
4	**Total annual hours lost per equipment**	2700						
5	**Annual additional operating hours**							
	Sundays	500						
	Holidays	120						

Step 2. Draglines

	Equipment Utilization on stripping operation							
		% of time spend by equipment type as listed in Step 1 on stripping activity						
		e.g. Dragline						
1	**Stripping activity**							
	Bush clearing							
	Top soil removal							
	Sub soil removal							
	Highwall control							
	Blasting							
	Pre-stripping							
	Primary stripping	100						
	Coaling							
	Parting							
	Rehabilitation							
	Other							
2	**Total time on activity**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
3	**Annual hours lost / equipment to:**							
	Shift change	50						
	Maintenance Planned	500						
	Maintenance Unplanned	100						
	Dead headings	70						
	Pad preparation	50						
	Relocation of equipment	150						
	Blasting	200						
	Other	0						
4	**Total annual hours lost per equipment**	1120						
5	**Annual additional operating hours**							
	Sundays	600						
	Holidays	288						

Step 2. Dozers

	Equipment Utilization on stripping operation							
		% of time spend by equipment type as listed in Step 1 on stripping activity						
		e.g. Dozer						
1	**Stripping activity**							
	Bush clearing	20						
	Top soil removal	40						
	Sub soil removal							
	Highwall control							
	Blasting							
	Pre-stripping							
	Primary stripping							
	Coaling							
	Parting							
	Rehabilitation	40						
	Other							
2	**Total time on activity**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
3	**Annual hours lost / equipment to:**							
	Shift change	200						
	Maintenance Planned	1000						
	Maintenance Unplanned	500						
	Dead headings	0						
	Pad preparation	0						
	Relocation of equipment	0						
	Blasting	0						
	Other	100						
4	**Total annual hours lost per equipment**	1800						
5	**Annual additional operating hours**							
	Sundays	0						
	Holidays	0						

Step 2. Ancillary

	Equipment Utilization on stripping operation							
		% of time spend by equipment type as listed in Step 1 on stripping activity						
		e.g. Watercar						
1	**Stripping activity**	-						
	Bush clearing	-						
	Top soil removal	-						
	Sub soil removal	-						
	Highwall control	-						
	Blasting	-						
	Pre-stripping	-						
	Primary stripping							
	Coaling	70						
	Parting	20						
	Rehabilitation							
	Other	10						
2	**Total time on activity**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
3	**Annual hours lost / equipment to:**							
	Shift change	120						
	Maintenance Planned	1000						
	Maintenance Unplanned	200						
	Dead headings	0						
	Pad preparation	0						
	Relocation of equipment	0						
	Blasting	0						
	Other	50						
4	**Total annual hours lost per equipment**	1370						
5	**Annual additional operating hours**							
	Sundays	0						
	Holidays	0						

Step 3

	Labour sheet	
1	**Time**	*Annual hours*
	Annual available hours	8760
	- Annual external hours lost:	
	Sundays	
	Holidays	
	Weather	
	Other	
2	**Annual hours available for production**	
3	**Labour**	**Number of people**
	Total Labour component on mine	
	Management	
	Plant Labour	
	Human Resource Labour	
	Plant Maintenance Labour	
	Mining Maintenance Labour	
	Admin. Labour	
	Services Labour	
	Non mining Contractors	
	Other	
	Total Labour in Mining	
	+ Bush clearing	
	+ Top soil removal	
	+ Sub soil removal	
	+ Pre-stripping	
	+ Highwall control	
	+ Drilling	
	+ Blasting	
	+ Primary stripping	
	+ Coaling	
	+ Parting	
	+ General Labour(Pump, Road crew etc)	
	Mining Contractors	

Step 4

	Production sheet							
1	**Production activity**	**Area cleaned / annum (m2/annum)**	**BCM moved / annum (cu m)**	**TCM Moved per annum**	**% Rehandle (as % of BCM moved)**	**% Blast gain (as % of BCM moved)**	**Powder factor (kg/m3)**	**Total Cost / annum**
	Bush clearing							
	Top soil removal							
	Sub soil removal							
	Highwall control							
	Blasting							
	Pre-stripping							
	Primary stripping							
	Coaling							
	Parting removal							
	Rehabilitation							
	Survey method							
2	**Total production**							
		Length (m)	**Width (m)**					
3	**Pit 1**							
	2							
	3							
	4							
4	**Total length of pit mined per annum (m)**							

***Please complete a production sheet for each stripping operation.**

Step 5

	Geology sheet					
1	**Coal seam**					
	Name	**Thickness (m)**	**Effective stripping ratio**	**Depth below surface (m)**	**m2 coal exposed / annum**	**Actual stripping ratio**
	1					
	2					
	3					
	4					
	5					
	6					
2	**Information**	**Material Thickness (m)**	**Bench height (m)**	**In-situ density(t/m3)**	**Compressive Strength (MPA)**	**Blasted or Free digging**
	Bush clearing					
	Top soil: Softs					
	Hards		---			
	Sub soils: Softs					
	Hards		---			
	Pre-stripping: Softs					
	Hards		---			
	Primary stripping: Softs					
	Hards		---			
	Coal seam 1					
	Coal seam 2					
	Coal seam 3					
	Coal seam 4					
	Coal seam 5					
	Parting 1					
	Parting 2					
	Parting 3					
	Parting 4					
	Parting 5					

Step 1

This step involves listing the capital equipment needed to do the stripping of overburden, coal and interburden material for the last financial year. This is done by:

1.1 Listing all the equipment involved with the stripping operation. For each piece of equipment:

- Give its full name and description as outlined by the equipment supplier.
- Describe the equipment size in carrying capacity, full size, blade size, etc.
- Describe the bucket size of the dump body, bucket, etc. in volumetric unites (m^3) and push blades of dozer in cubic metres (m^2).
- The amount or number of the same units in operation or active in the stripping process.
- Give the design capacity of the equipment as the equipment supplier in BCM, meters, ect. per operating hour indicates it.
- Give the operating capacity of the equipment by obtaining the BCM moved or meters drilled by the equipment per annum and dividing that with its annual total hours obtained from Step 2.

- Adding all the fixed and variable cost per hour associated with the equipment will result in the total cost per hour. This cost figure should include associated labour, maintenance, fuel, electricity costs and provision for repair and overhaul cost. It should exclude overhead and replacement costs.

Step 2

This step involves listing for each piece of equipment its annual time in hours spent on each stripping activity and annual time in hours lost to internal stoppages for the last financial year. Each equipment group listed in Step 1 has its own Step 2 form.

2.1 The time spent on each activity is done by:

- Listing each equipment type in the equipment row.
- Determining the percentage of time each equipment spends on the associated stripping activity as a percentage of its total operating hours (no time allowed for time losses).

2.2 The sum of each equipment's time spent on each mining activity must be 100% .

2.3 The annual internal hours per equipment type lost to shift change, maintenance planned, maintenance unplanned, dead headings, pad preparation, relocation of equipment, blasting and other hours lost is expressed in annual hours and is obtained by the record keeping system on or of each machine type.

2.5 Adding the equipment operating hours for public holidays and Sundays will result in the additional hours per annum spent operational.

Step 3

This step involves listing the time available for production, the labour component on the mine that was involved in each department for the last financial year.

3.1 The time calculation is done by:

- Using the annual calendar hours (Calendar hours = 8 760).
- Deducting the annual external hours lost will result in the annual hours available for production.
- Adding the time in hours lost to Sundays, holidays, weather conditions will result in the annual external hours lost.

3.2 The labour calculations is done by:

- Listing the labour component for each department on the mine.
- Adding the number of people listed in each department row will result in the total labour on the mine.
- Dividing the mining labour into the number of labour associate with each stripping activity will result in the associated number of people of labour employed per activity.

Step 4

This step involves listing the annual square meters of area cleared, the BCM moved, percentage re-handle, % blast gain and total cost for each mining activity and the powder factor realized by blasting for each associated activity active during the previous financial year.

4.1 The production activity projections are done by:

- Multiplying the width of the cut by the total length of material cleared per annum for each stripping activity will result in the area cleared by annum.

- Multiplying the area cleared per annum by the associated total thickness will result in the BCM moved per annum for each stripping activity.
- Total cubic metres (TCM) is the total volume of BCM moved by the equipment.
- Dividing the BCM re-handled by the total amount of BCM moved per annum will result in % of BCM re-handled.
- Dividing the BCM moved by blasting by the total amount of BCM moved per annum will result in % blast gain.
- Dividing the kilograms of explosives used by the associated BCM will results in the powder factor.
- Adding all the total fixed and total variable costs associated with each activity will result in the total cost per annum. This cost figure should include associated labour, maintenance, fuel, electricity costs and provision for repair and overhaul cost. It should exclude overhead and replacement costs.

Step 5

This step involves listing the geological conditions present on the mine during the last financial year.

5.1 The information projections for the coal seams are done by:

- Listing all the coal seams present in each stripping operation and listing each one's associated thickness in meters.
- To calculate the effective stripping ratio of each coal seam see Figure 1. The effective stripping ratio is derived from dividing a coal seam overlaying waste material thickness in meters by the coal seam thickness in meters
- List the depth from surface to the top of each coal for the depth below surface.
- Multiplying the width of the cut by the total length of a coal seam exposed per annum will result in the m^2 coal exposed/annum.
- To calculate the actual stripping ratio of each coal seam mined see figure 1. The actual stripping ratio is derived from dividing the BCM's by the in situ mineable coal tons available in that pit.

Stripping ratio