

# 1. Introduction

## 1.1 Background

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 market improvements foreseeable in the immediate 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 (Runge, 1998), the surface coal mines will be hard-pressed to remain competitive and economically sustainable (O'Conye & Thomas, 1993) well into the 21<sup>st</sup> century. As part of the Coaltech 2020 research initiative into the sustainable exploitation of the Witbank coalfield, this study focused on the different overburden stripping techniques used in South African surface coal mines and evaluated their efficiencies in terms of capital invested, labour productivity, production outputs, operational expenditures and other productivity measures.

## 1.2 Geology

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

- Springbok Flats
- Waterberg
- Limpopo
- Pafuri
- Soutpansberg

Figure 1.1: South African coalfields

The second, 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



**Figure 1.1:** Mining South African coalfields

The second, 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.

The third is the Molteno Formation, which contains the Molteno Indwe coalfield. The latter is 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 700 km from north to south and 500 km from west to east (Minerals Bureau, 1998), as illustrated in Figure 1.1 (Pinheiro, 1999). Coal mining activities take place primarily within the province of Mpumalanga, which produces 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, 0,9% by longwalling, 10,6% by pillar recovery (stooping) and 44,5% by opencast mining methods. (Minerals Bureau, 1999).

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. Surface mining methods are therefore an ideal option for most of the available mineable reserves. For this reason there are a large number of opencast mining operations 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 specific research to be undertaken, hence this study.

### **1.3 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 differ from one mining operation to another, depending on the size of the operation, the prevailing geological conditions and the type of mining equipment selected.

The primary objectives of this study 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.

## 1.4 Outline of the study

Section 1 provides the background, problem statement and the objectives of this thesis. The research methodology is outlined in Section 2 which also discusses the benchmarking process that formed the basis for the data collection and evaluation.

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 apply research findings that will enable the South African coal industry to remain competitive and sustainable well into the 21st century.

After the Coaltech Management Committee had approved Task 3.14.1, *Evaluation of stripping techniques*, in March 1999, the study on which this thesis is based 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. It was decided to follow the internationally 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 and the confidentiality agreement had been signed, the South African survey commenced. This 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 were collected during the site visit. The local site visits were followed by international site visits 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 utilisation 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 activities and mining methods that would form the basic structure of the checklist
- Identify mining supply companies that would be able to provide information relevant to the evaluation and identification of available methods and international benchmark sites
- Determine future mining methods and 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 involves performing a comparative study of specific processes in an industry that are considered to hold some potential for improvement. In *The Benchmarking Book* (Spendolini, 1992), Michael Spendolini 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 organisational improvement".*

An internal benchmarking approach was first used to collect and compare mine performance data on 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.

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 subsets of strip mining activities: subsoil removal, pre-stripping, primary stripping, parting and coal removal. Various productivity measures were used to evaluate these activities.

### 2.2.1 Productivity measures

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 organisations' experience base, assisted in employee development and stimulated teamwork.

According to Wiebmer (1999) the winning mines will be ones which manage their operations so that they stay in the bottom third of the lowest quarter of the cost curve compared with their competitors. This desire to measure where mines stand on the cost curve is driving an intense amount of benchmarking activity in the industry. This has led to some fairly consistent world-class standards by which operations can measure themselves.

## 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 through the use of a given quantity of inputs. Mines use a range of inputs including labour, machines, fuel, materials and services. If a 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 organisational 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. 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 various 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 currently 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, both local and international. 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 was 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 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 seems 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 (see Appendix 3). This provided a structure and an international standard by which the benchmarking study was conducted.

## 2.2.4 Current performance levels

### 2.2.4.1 South African survey

This is the first collaborative evaluation study of overburden removal in South Africa. In fact, this is the first study that the author is 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 whole mining operation in terms of run-of-mine (ROM) coal or saleable coal tons. This reporting is in line with the core business of the coal mines. Measuring the efficiency of

overburden removal was not the main purpose of publishing the results 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 (Industry Commission (Australia), 1998). Tasman benchmarked Australia's black coal industry against best-practice world coal mines and best-practice Australian metalliferous mines. They benchmarked 44 separate mining operations in 1996, and 22 truck-and-shovel and 13 dragline operations in the first nine months of 1997 (Tasman, 1997). See Section 3 for more detail.

## 2.3 Benchmarking partners

Most of the South African surface coal mines were already part of the study through the Coaltech 2020 initiative.

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, Ingwe, 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 African survey

From the 12 possible South African surface mines identified, a total of nine data sets were received. Checklists were received for evaluation from two truck-and-shovel operations, and eight 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			Data not received
	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
<b>Total</b>	<b>3</b>	<b>9</b>	<b>12</b>	<b>3</b>

### 2.3.2 International survey

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 <sup>1</sup>	1	2	3	2
NSW, Aus <sup>2</sup>	3	0	3	2
QLD, Aus <sup>3</sup>	0	3	3	2
<b>Total</b>	<b>4</b>	<b>5</b>	<b>9</b>	<b>6</b>

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 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 coal production from the top 100 Australian coal mines is equal to nearly 40% of the total production. The mines used as benchmarks are internationally known for their high mining productivity performances (Australian Coal, 1999). One mine surveyed in NSW was judged as the most productive mine in Australia during 1998 (Tasman, 1998).

## **3. Data collection**

### **3.1 Introduction**

In this part of the project, the available data for South Africa and the world were collected and evaluated 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 methods and equipment trends.

### **3.2 Previous research work**

In 1998 the Industry Commission of Australia expressed the opinion that the Australia coal producers must use their workforces and capital more efficiently than in the past (Tasman, 1998). In April 1998 the Commission released Australia's first draft report on the benchmarking study, undertaken by Tasman Asia Pacific, into the productivity performance of Australia's black coal mines. As stated before in Sub-section 2.2.4, Tasman benchmarked Australia's black coal industry against best-practice world coal mines and best-practice Australian metalliferous mines. In 1996, 44 mining operations were benchmarked and in 1997, 22 truck-and-shovel and 13 dragline operations.

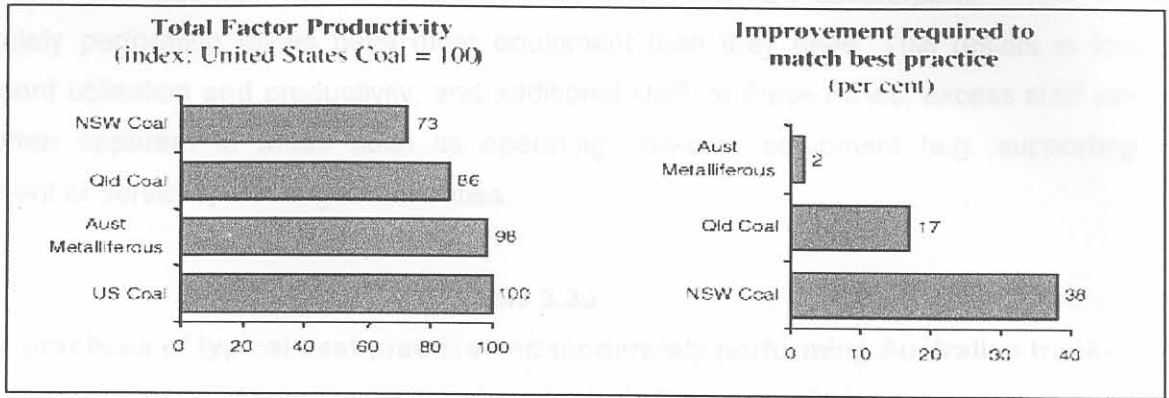
The coal mines surveyed by Tasman (Tasman, 1997) in the United States included a number of mines that had been nominated by industry experts as best-practice operations, as well as mines that were affiliates of Australian mining companies. Responses were received from 20 Australian coal mines, eight United States coal mines and four Australian metalliferous mines.

The coal production from the responding Australian coal mines is equal to nearly 40% 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 used in this benchmarking study. As in Tasman's study, this benchmarking analysis focused 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.

### 3.3 Truck-and-shovel benchmark

Truck-and-shovel mines remove both overburden and coal primarily by means of trucks and shovels. Tasman's benchmarking results indicated that in 1996 to 1997, the total productivity factors of the participating NSW and Queensland truck-and-shovel coal operations were, on average, well below best practice (Figure 3.3a).



**Figure 3.3a: Total factor productivity of truck-and-shovel operations, (Tasman, 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% respectively. Increases in average productivity of 35 and 14% 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% 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-capitalisation 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% in the NSW coal mines to match the performance of the United States coal mines. Queensland coal mines needed a corresponding 40% increase on average.

Tables 3.3a and 3.3b outline the key characteristics of the 'frontier' and moderately performing Australian truck-and-shovel operations. These characteristics indicate ways for the poorer-performing mines to improve their efficiency and unit operating costs.

Table 3.3a indicates that over-staffing and over-capitalisation are common causes of lower productivity on Australian mines compared with their American counterparts. Often the moderately performing mines have more equipment than they need. This results in low equipment utilisation 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 3.3a**

**Work practices of typical best-practice and moderately performing Australian truck- and-shovel coal mines (Tasman, 1998).**

	<b>Best practice operation</b>	<b>Moderately performing mine</b>
Total productivity	100	60
<b>Resource levels</b>		
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 (%)	92	85
Utilisation of truck fleet: hours operated as a percentage of total available hours	45	40
Utilisation of major digging equipment: hours operated as a percentage of total available hours	50	40
<b>Work practices</b>		
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

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 units 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 3.3b**

**Key attributes of typical best-practice and moderately performing Australian truck-and-shovel coal mines (Tasman, 1998).**

	<b>Best-practice mine</b>	<b>Moderately performing mine</b>
Efficient truck-loading practices: incidence of double-sided or other efficient truck-loading method (%)	>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

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 time 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.

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

### **3.3.1 International trends for trucks and shovels**

The competitive nature of opencast mining forces mine operators to adhere to one simple bottom-line mentality: moving the largest amount of material for the least amount of money. The growth in the capacity of trucks and shovels during the last 15 years has enabled mines to achieve these goals.

The trend for the last 15 years in the surface mining business has been simply towards larger and larger. Wiseda (now owned by Liebherr Mining Equipment) was the first company to



introduce a 220-ton haul truck during 1984 at the Black Thunder mine. Dresser (now Komatsu Mining Systems) followed suit shortly thereafter, and Caterpillar (CAT) introduced its 220-ton hauler in 1991 (Fisher, 1999).

The capacity of loading tools has caught up with and surpassed that of the 220-ton haulers. The P&H 4100 is capable of loading a 290-ton truck in four passes. The new P&H 4100XPB will be able to load a 330-ton haul truck in three to four passes (Caterpillar, 1999).

Komatsu Mining Systems (KMS) launched the 290-ton 930E haul truck at MINExpo '96 in Las Vegas, Nevada, USA, and production went into high gear during 1997 and 1998. Although KMS have sold only three 930Es in the coal industry, they have sold almost 100 in the hard rock mining industry, thus setting the standard for the development of the new ultra-heavy off-highway trucks (Fisher, 1999).

Liebherr Mining Equipment Co. (Liebherr) introduced the 330-ton T282 during October 1998. "This is the first truck in this size range and is a two-axle, six-tire configuration, using proven structural and mechanical concepts," said Bill Lewis, Liebherr's Vice President Engineering (Fisher, 1999).

CAT recently announced its intention to build the 360-ton CAT 797 haul truck. With a more conservative bent, Pete Holman, CAT's Sales Manager - Corporate Mining Group, said to Fisher (Fisher, 1999), "CAT takes a total systems approach, and we do what makes the most sense to create a more cost-effective mining system."

For a long time the hard rock mining industry led the way with large truck-and-shovel fleets and was followed by the oil sand operations in North America (Caterpillar Inc, 1999; *et al*). It is only recently that the USA coalfields have started upgrading their truck-and-shovel fleets. The Australian and Indonesian coal mines are also preparing to follow the USA trend and will soon start upgrading to large equipment. The Douglas pillar project introduced Caterpillar's proven 793s with Demag's 655 face shovel into the South African coal industry in 1999. The motivation for larger trucks and shovels was to take advantage of the economies of scale offered by the new larger equipment, as can be seen from Figure 3.3.1a, but it was clear that South Africa was not following this trend vigorously (Komatsu Mining Systems, 1999 & Gove *et al.*, 1994).

### Mining Truck Cost/Ton Trend

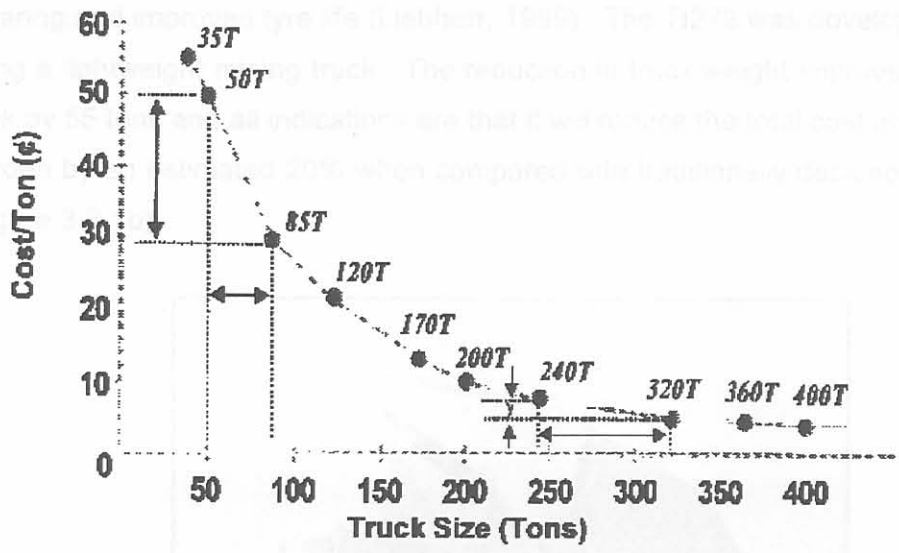
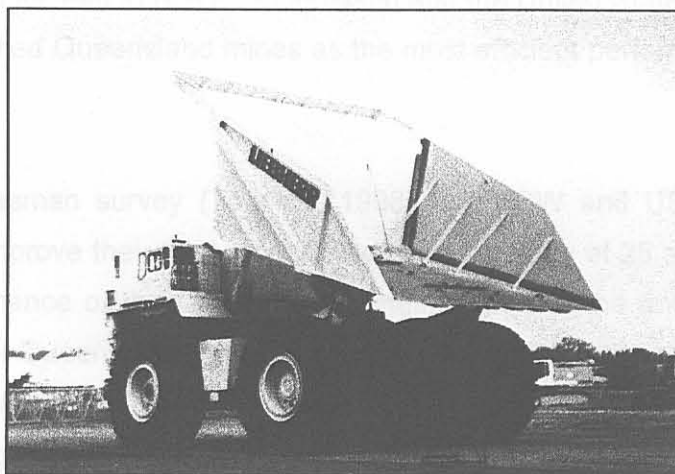


Figure 3.3.1a: Truck size cost (Komatsu Mining Systems, 1999)

According to Fisher (1999), truck selection is site-specific. Mines that have large quantities of material to move can use the larger trucks better and more efficiently. The projected life-time of a project, however, is critical to justifying the investment. Site infrastructure, the size of the loading equipment, the size of the maintenance facilities and the haulage roads also play an important role when considering upgrading to larger trucks and shovels. The 300-ton haulers will be more than 20% wider than the 220-ton trucks. The weight and braking of these heavy haulers have an impact as deep as 5 m below the surface and therefore the dynamics of haulage road design must change accordingly.

The rate of increase in truck and shovel sizes cannot continue forever as tyre and horsepower limitations are already slowing down the next generation of trucks and shovels (Lightfoot, 1999 & Ellis, 1994). The increase in research and development, building and transportation costs associated with the larger trucks and shovels will put pressure on the economic viability of this larger equipment (Holman, 1994). Figure 3.3.1a gives an indication of one original equipment manufacturer's (OEM) estimates of the economies of scale associated with larger haul trucks.

Liebherr recently introduced the 270-ton TI272 hauler with innovative design changes. The dump body provides torsional rigidity for the frame and eliminates the rear cross-member. The dump body is supported only at the rear and front, which reduces the frame weight. Each set of rear dual tyres oscillates about the truck's longitudinal axis, which allows improved load-sharing and improved tyre life (Liebherr, 1999). The TI272 was developed with the idea of having a lightweight mining truck. The reduction in truck weight improved the payload of the truck by 55 tons and all indications are that it will reduce the total cost of moving coal and overburden by an estimated 20% when compared with traditionally designed haulage trucks (see Figure 3.3.1b).



**Figure 3.3.1b: Liebherr's TI 272 (Liebherr, 1999)**

During the past ten years there has been a significant improvement in truck design. The life of major components such as engines and drive trains has increased from 7 000 hours to 12 000 hours. Computer-assisted diagnostics are standard on all large trucks. One microprocessor can monitor more than 90 vital factors controlling the truck's operation. These systems allow continuous statistical data recording, which improves truck availability and lowers operating cost. Most OEMs agree that, with appropriate rebuilds, a mine can get up to 100 000 hours out of a haul truck (or 12 to 15 years). Availability is also improving. Availabilities of 7 000 to 8 000 operating hours per year are routinely achieved whereas ten years ago, 4 000 hours was accepted (Ellis, 1994). These improvements in truck design and diagnostics are expected to continue in future and will further reduce the cost of moving material (Caterpillar, 1999; Lightfoot, 1999).

The trucks of the future will depend heavily on innovative designs, such as Liebherr's TI272, and to what extent Global Positioning Systems (GPS) (Schaidle, 1994) and Information

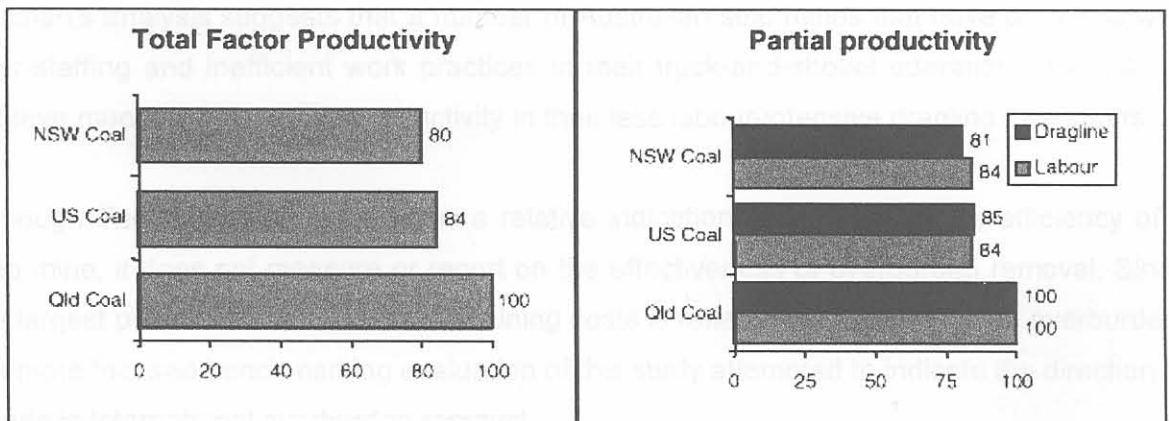
Technology (IT) will revolutionise the surface mining industry, (Kral, 1997). There is already talk of autonomous trucks and the continuous growth in environmental pressures is reshaping the business environment, but for the time being preventative maintenance, improved availability and the drive for higher productivity will remain the mainstays of coal mining operations (Caterpillar, 1999).

### 3.4 Dragline benchmarks

Tasman's estimates (Tasman, 1998) 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 3.4).

According to the Tasman survey (Tasman, 1998), the NSW and USA producers in the sample needed to improve their total productivity by an average of 25 and 19% respectively to equal the performance of the Queensland mines. High dragline and labour productivity helped the sample of Queensland mines to achieve this best-practice result. Several factors contributed to the observed differences in productivity, including:

- high dragline-capacity utilisation, coupled with the 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 3.4: Total factor productivity and key partial productivity of dragline operations (Tasman, 1998).**

Table 3.4 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 the United States mines by about 20%. Much of this difference stemmed from the greater operational efficiency of the Queensland draglines and fewer staff being required for drilling and blasting activities.

**Table 3.4**  
**Productivity performance of dragline operations (Tasman, 1998)**

	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

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 largest portion of a surface mine's mining costs is reflected in the removal of overburden, the more focused benchmarking evaluation of this study attempted to indicate the direction or trends in international overburden removal.

### 3.4.1 International trends

Large walking draglines were found to be the primary method for moving overburden in the South African coal strip mines (SAIMM, 1987). Despite the dragline's cost advantages and the growing overburden-removal requirements at most mines, the USA coal industry's demand for new walking draglines diminished substantially in the 1990s. In fact, the last new machine commissioned was the Bucyrus International (B-I) 2570WS at Thunder Basin Coal's Black Thunder Mine in 1993 (Gilewicz, 1999). The last dragline commissioned in South Africa was a Marion 8200S at Sasol's Syferfontein Mine in June 1997.

Since the start-up of the B-I 2570 at Black Thunder, at least six used machines have been decommissioned, relocated and put into service; in mid-1999, three more machines were relocated and put into service (Gilewicz, 1999).

Even among these giants, the trend is towards the use of larger machines, with nearly 75% of America's total dragline capacity falling in the 61 m<sup>3</sup> and larger range (Gilewicz, 1999). Since machines are matched to mines' total overburden requirements, digging depths and other size-related characteristics, the dominance of larger machines reflects a shift towards larger mines.

The capital cost of large walking draglines, along with the relative inflexibility of their application, combine to make individual purchases a major investment decision for even the largest coal mine operators (Fair *et al.*, 1997). Traditionally, dragline machines were destined for a mine where they would work for decades until retired, but changing market conditions have forced the premature closing of many operations.

### 3.4.2 Mining deeper from surface

In order for mines to mine deeper with the current technology used at surface coal mines, the productivity must be improved with the currently available resources (Herbar, 1991). Once the productivity limit has been reached, technical improvements will produce further improvements in operating cost and consequently in the depth of mining (Ross, undated).

Since draglines are the cheapest method of moving overburden on South African surface coal mines, they work under very strict operating conditions. More and more overburden

material will have to be moved which will be impractical for the draglines currently operating on the coal mines in the Witbank coalfield.

The developments in the oil sands industry and the Powder River Basin could be used to give some insight into the possibilities of future operating techniques for the South African surface coal industry.

Two of the main economic advantages of the truck-and-shovel system for a new mine application are the lower capital cost and high service factors. Comparative data for dragline and truck-and-shovel systems are summarised in Table 3.4.2. The capital costs of support equipment for each system have not been included. The capital cost per annual ton of capacity for the dragline is more than double that of a truck-and-shovel system.

**Table 3.4.2**

**Economic comparison of draglines vs. truck-and-shovel operations in the oil sands in Canada (Caterpillar, 1999)**

<b>Mining system</b>	<b>Capacity tons/year (1 000's)</b>	<b>Capital cost (US\$ 1 000's)</b>	<b>Capital cost per ton (US\$ 1000's)</b>	<b>Service factor %</b>	<b>Operating hours per year</b>
Dragline	25 400	138 000	5,43	51	4 500
Truck-and-shovel	25 400	60 000	2,36	66	5 800

There are a large number of technical advantages associated with the truck-and-shovel mining system (Hartung & Rosenberg, 1998), with the importance of each advantage being dependent on the geology of the ore body proposed for development. Some of these advantages can have a major impact on both capital cost and operating costs (Popowich and Clarke, 1993). The main technical benefits as compared with existing strip mining techniques are listed below:

- Flexible mine plans
- Reduced working area per ton of capacity
- Delayed overburden stripping
- Less technical support needed
- Ease of linking the mining system to new transportation or extraction technologies

- Interchangeability of trucks and shovels on overburden stripping and coaling equipment
- Reduced rehabilitation efforts and cost.

### 3.4.3 Application of truck-and-shovel technology

The future of the surface coal mining industry is dependent on the cost-effective exploitation of new and current coal reserves. In particular, existing operations will require the development of off-site reserves to replace or expand existing capacity. This can be accomplished by linking truck-and-shovel mining with remote extraction (Ingle, 1992).

Truck-and-shovel mining offers excellent opportunities to add value and increase the opportunity for economic development of the coal reserves (Fair *et al.*, 1997). In this respect the main conclusions are summarised below:

- Existing mines that adopt truck-and-shovel technology will have lower operating costs in the future
- Truck-and-shovel technology will continue to improve in the future when the next generation of larger shovels and trucks is developed
- It will be possible to exploit small and remote coal reserves economically with truck-and-shovel mining plus new extraction technology.

## 3.5 Data collection

In order to lend 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 the baseline since 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 (see Appendix 5).



The checklist was also used to capture the geological characteristics of each surveyed surface coal mine, i.e. factors such as the seam thickness, hardness and specific gravity of rocks which affect the explosive requirements and the digging and loading components of the mining cycle (Wayland & Chenne, 1996). These data were required to determine the effects that mine-specific geology had on each mine's performance.

### 3.6 Comment on previous research work

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 is the whole overburden stripping activity evaluated.

Tasman's results (Tasman, 1998) on the black coal mine benchmarking exercise 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 Americans were found to be the leaders in truck-and-shovel productivity.

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

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 (Moolman *et al.*, 1999). Some of the better-performing Australian and American mines will be very useful benchmarking partners for comparison with their South African counterparts.