Longwall mining, with particular reference to its implementation in South African collieries*

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SYNOPSIS

This paper considers the introduction of large-scale longwall mining into South African coal mining, instead of the conventional mechanized bord-and-pillar mining that is widely practised at present. The two methods are compared, and longwall mining is found to have the advantage in several respects in some seams. The most cogent reasons for the introduction of the longwall method in some seams are associated with safety, strata control, and increased labour costs.

SAMEVATTING

Hierdie referaat handel oor die lewensvatbaarheid van grootskaalse gemeganiseerde strookafbou in die Suid-Afrikaanse steenkoolbedryf. Dié metode word met die konvensionele gemeganiseerde pilaarafboumetode vergelyk. Die bevinding is dat strookafbou in verskeie opsigte, in sekere some, die voordeligste metode is. Die belangrikste voordele is geleë in die veiligheids-, stratabeheer- en arbeidskoste-aspekte.

Introduction

The Republic of South Africa is rapidly becoming an industrial country with ever-increasing energy requirements. There are four important reasons for the investigation of high-extraction methods of coal mining in this country. Firstly, with the prospect of increasing energy demand and unsettled oil supplies, it is clearly a sensible policy for countries to concentrate on developing their own indigenous fuel resources. Secondly, it is in the national interest that finite reserves of coal should be utilized to the best advantage, and a comparison of mining methods would help to identify the safest and most viable method of mining the coal. The energy crisis emphasizes the need to conserve and utilize indigenous coal reserves to the best advantage, and conservation implies *inter alia* a much higher extraction percentage of existing reserves. Thirdly, the changing labour pattern in South Africa will play a major role in the choice of mining method. Almost 80 per cent of the unskilled labour employed in South Africa comes from sources outside the Republic. Recent events in Malawi, Mocambique, and Lesotho have shown the risk involved in depending on external sources of supply, and the labour-intensive systems at present employed must therefore be made more productive or must be replaced by systems of higher productivity. Fourthly, the application of high-extraction methods reduces the geographic expansion of a mine, resulting in reduced expenditure on services such as the transportation of coal.

The object of this paper is to examine longwall coal-mining in comparison with the mechanized bord-and-pillar system, and to ascertain the viability or otherwise of large-scale longwall coalmining in South Africa.

Utilization of Resources

Coal Reserves

In the mining of any coal deposit, there are unavoidable losses, e.g., haulage and barrier pillars, geological losses, and surface restrictions. The following average percentage extractions were calculated for the two methods, the details being given in Table II:

Longwall mining	84 per cent
Bord-and-pillar mining	55 per cent.

Labour

There is a severe shortage of both skilled and unskilled labour in South Africa, and one solution might be to increase the productivity per man shift by increased mechanization, better training of existing manpower, and the creation of conditions in which higher productivity can be achieved.

The following are productivity figures for longwall and bord-and-pillar sections, examples being drawn from various mines over the world.

Bord and pillar

A single bord-and-pillar mechanized section normally has a complement of 25 to 28 unskilled labourers and 1 skilled worker. At 14 blasts per shift, giving 50 to 70 t per cut, this results in an average production of 700 to 980 t per shift. This gives an average of 30 t per manshift.

Longwall

The average complement per longwall face is 12 men.

Average tonnage per hour	230
Average tonnage per 8-hour shift	1610 (7 hours operating time)
	134 t per manshift

Strata Control

Depth

An analysis based on a research programme conducted by the Research Laboratories, Chamber of Mines of South Africa, showed that, at depths of less than 60 m, the loss of reserves in conventional bord-and-pillar mining is small, and no other type of extraction (with the possible exception of opencast) is likely to compete with this system.

Longwall mining cannot be used at very shallow depths for three reasons:

the possibility of severe surface damage,

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the risk of fires as a result of spontaneous combustion, the disruption of mine ventilation.

The last two arise from cracks propagated at the surface.

Experience at Coalbrook and overseas has indicated that bord-and-pillar mining is not efficient or safe below 200 m in depth. The following is the average depth below the surface of coal measures in South Africa:

Northern Free State coal field

No. 1 seam 190-240 m, average 215 m

No. 2 seam 180-235 m, average 207 m

No. 3 seam 160-200 m, average 180 m.

Natal coal fields

From outcrop to 300 m.

Transvaal Highveld coal fields

From 30-100 m.

From the preceding it is apparent that there is much scope for longwall mining, particularly in the Northern Free State and Natal coal fields.

Length of Face

In bord-and-pillar workings, the most important restricting factor with respect to face length is perhaps the legal requirement that a ganger must be able to visit all his working places within a period of 40 minutes and, in the case of gassy seams, that no more than 6 working places may be worked per section.

In longwall mining, the length of face required to cause collapse of the dolerite sill that overlies most of the South African coal measures would be a decisive factor.

Geology

A geological investigation into the various fields indicates that roof and floor conditions in the Natal and Free State fields are particularly advantageous for longwall mining. The weak shale roof in these areas militates against the use of the bord-and-pillar method. The undulations and thinning out of seams in the Natal field can be accommodated with present technology in this field, e.g., ranging shearer and double telescopic chocks. The geological conditions in the Free State result in very low extractions (sometimes of the order of 13 per cent) with the bord-and-pillar method. One of the main geological conditions in the Transvaal field militating against longwall mining is the presence of multiple seams. Judicious selection of mining sequences and the possibility of ash-fill may overcome this problem, but it is doubtful whether the additional costs will justify the wide implementation of ash-fill in these shallow seams.

Extensive subsidence with subsequent restoration is an added cost. It can thus be concluded that the Natal and Free State fields lend themselves readily to the implementation of the longwall method, while problems could arise in the Transvaal field.

Experiments conducted by the Chamber of Mines indicate that the dolerite still overlying most of South Africa's fields could not pose a serious threat to the safety and operational features of the longwall method.

Safety

It must be emphasized that safety is primarily dependent on good housekeeping, through training, friability of the surrounding rock, and other related factors, irrespective of the mining method used.

The enquiry following the Coalbrook disaster revealed that no reliable scientific or practical method was available for the design of bord-and-pillar workings. In view of this fact and to improve safety in general, the Coal Mining Research Controlling Council was formed. As a result, pillars are now designed for specific underground conditions. However, there is still a constant danger of roof and overhang falls, especially because of the handling and blasting of explosives, which are used in this mining method.

The South African coal measures are normally overlain by a thick dolerite sill (0 to 30 m thick). Rock mechanics investigations had originally indicated some uncertainty about adverse sill behaviour, which could have caused longwall mining to be hazardous, but experience gained at Sigma and Durnacol has eliminated these doubts.

With more coal coming from fewer faces, there is bound to be a reduction in the number of areas of greatest danger underground. In the field of health and safety, the longwall system has had to provide solutions to the problems of methane, dust, heat, and spontaneous combustion, all of which are potentially severe in various parts of our coalfields. While there are still some undesirable features to be eliminated from the mining systems, the safety of the men and the underground environment have improved immeasurably. A great deal of research has been carried out by the National Coal Board and the manufacturers of longwall equipment to develop further acceptable improvements, including the following.

(a) Exhaustive scientific studies have shown that, by the use of fewer and larger cutting bits in shearer drums, the amount of dust can be reduced and the methane released can be significantly lessened.

(b) Advances in drum design have now alleviated the problem of floating dust by the flushing of water on the bits. Drum ventilation has improved the dispersal of methane.

(c) The safety features of the longwall system were especially enhanced with the advent of powered face supports. It is noteworthy that, over the past ten years in the U.K., as the use of powered supports increased, fatalities due to roof falls were reduced from 100 to 18 per annum, and serious accidents from 465 to 126 per annum. In addition to the safety advantages of more efficient ventilation and handling of floating dust, present longwall installations almost completely eliminate injuries and fatalities due to roof fall. Once the face is established and starts advancing or retreating, the men working on it are in a 'ring of steel' and consequently are almost completely protected.

A well-known longwall authority, Mr Carman of the Eastern Associated Coal Corporation, states that longwall installations appear to be safer than conventional, and this is borne out by experience at Durnacol and Sigma collieries.

At Durnacol, longwall mining has proved to be a far safer operation than pillar extraction, particularly with regard to accidents from roof falls. The few accidents that have occurred resulted mainly in minor injuries to fingers and hands that were sustained during the handling of material. The chocks have yielded once. Similarly, at Sigma, longwall operations have proved to be considerably safer than conventional bord-and-pillar methods. Since the commencement of operations, the lowest accident rate at the mine has been consistently achieved by the longwall unit. Improved roof control, better safety training, the concentration of operations and supervision, have all contributed to the safety level attained.

Surface Subsidence

Surface subsidence used to be one of the most important factors to be taken into account in the planning of a longwall- or pillar-extraction layout. Disputes may arise between farmers and mining companies as to the degree of interference with farming activities and the corresponding compensation.

During longwall operations at Sigma, surface cracks developed along the edge of the surface being lowered as the dolerite was deflecting downwards. The first noticeable cracks appeared on the surface when the face had advanced 154 m. Initially, the cracks were small and almost vertically above the perimeter of the mined-out area. The following conclusions were reached.

(a) There is no reason why the surface cannot be used for the normal agricultural applications in the area. For example, the cultivation of maize could take place in the depression and over the cracks, which will soon fill or close. Surface and underground operations can take place simultaneously.
(b) If necessary, the cracks can be easily filled up to prevent animals or persons breaking limbs.
(c) If longwalling is done systematically within a large area (e.g., 50 hectares), the surface within this area will settle fairly evenly and all initial cracks, except those round the perimeter of the excavated area, can be filled in and the whole area made safer for farming activities.
(d) The natural groundwater will be lost. The extent to which this will take place depends on the nature of the natural and induced underground fissures and the reconsolidation of the subsided area.
(e) Surface objects, such as buildings and pipelines, will be damaged if undermined.
(f) No indication is available as to when the surface will be stable enough to permit the erection of permanent structures.

Geographic Expansion

Associated with the low extraction at depth of the bord-and-pillar method is the problem of widespread mining activities, with longer roadways to be maintained and higher transport costs than for a concentrated longwall production of comparable output.

Ventilation

Compared with the supply of air to the face of the ordinary bord-and-pillar section, the ventilation of a longwall face is a straightforward operation not requiring daily changes as the face advances or retreats. Longwall mining does not require ventilation brattice lines and ventilation piping, except when the necessary entries are being driven. Also, it is easy in longwall mining to increase the quantity of ventilating air as conditions require it.

Economic Appraisal

A hypothetical coal body was taken for the purposes of comparison, and a required annual output of 3 million tons was assumed (Table I). The height of the seam had to be specified because the equipment and capital costs for longwall mining vary largely with the working height. As the average seam height in South African fields is 2,4 m, this height was assumed for the hypothetical coal body. The mineable reserves (based on percentage extraction) were then calculated and are given in Table II.

The outputs for both types of mining were obtained from operating collieries overseas and from manufacturers of equipment (Table III). From these data, the number of production sections and shifts (Table IV) and the labour complement (Table V) were established, based on the following assumptions:

(1) that longwall mining is a three-shift operation because of the problems that can occur due to transfer of mass, especially at the gate ends, when the face is stopped for any length of time;

TABLE I
DETAILS OF HYPOTHETICAL COAL BODY ON WHICH FINANCIAL APPRAISAL IS BASED

Coal body		250×10^6 t
Seam height		2,4 m
Annual output required		3×10^6 t
Monthly output required		250 000 t
Available for exploitation:		
	Longwall	167×10^6 t
	Bord and pillar	102×10^6 t
Life of mine:	Longwall	56 years
	Bord and pillar	34 years

TABLE II
CALCULATION OF MINEABLE RESERVES

	Longwall %	Bord and pillar %
Total in situ reserves	100	100
Less geographical restraints (dykes, faults, etc.)	5	5
Less market restraints (quality)	4	4
Less major surface restraints (dams)	2	2
Mineable in situ reserves	89	89
Less mining method limitation (% extraction)	1	30
Less mine design (shaft and barrier pillars)	3	3
Less surface restrictions (railway lines)	1	1
Extractable reserves	84	55
Less mining losses (unmineable triangles, panel corners)	4	1
Less market quality restraints (washing plant yields)	13	13
Saleable reserves	67	41

Note: Averages are considered here.

TABLE III
RELATIVE OUTPUTS ON LONGWALL FACES OVERSEAS

Mine	Country	Mining height m	Face length m	Production at face t/h	Labour							
					Shearer	Supports	Main-gate	Tail-gate	Stage loader	Mechanics	Face boss	Total
A	Japan	2,20	100	130	2	3	3	1	1	2	1	13
B	Japan	2,30	70	175	2	3	3	1	1	2	1	13
C	U.S.A.	1,85	122	171	2	3	1	1	1	1	1	10
D	U.S.A.	2,29	137	200	1	2	1	1	0	1	1	7
E	U.S.A.	1,33	183	205	1	4	2	1	0	2	1	11
F	Britain	1,60	91	158	1	2	1	1	1	2	1	9
G	Britain	2,80	114	85	2	2	2	1	0	2	1	10
H	Britain	2,14	159	216	Not available							
I	France	2,60	150	294	1	4	3	2	0	2	1	13
J	West Germany	2,40	280	350	3	2	2	2	2	3	1	15
K	West Germany	2,40	175	103	2	2	2	2	1	2	1	10
L	West Germany	2,20	250	329	Not available							
M	West Germany	2,60	250	583	4	4	4	4	0	2	2	20
N	West Germany	2,70	250	New face	Not available							
O	West Germany	3,35	220	228	Not available							

TABLE IV
NUMBER OF SECTIONS AND SHIFTS PER DAY REQUIRED BY LONGWALL AND BORD-AND-PILLAR MECHANIZED MINING

Monthly output required 250 000 t
Daily output required (26-day month) 9615 t, i.e. approximately 10 000 t

	Longwall		Bord-and-pillar mechanized
	Maximum	Minimum	
Output per unit per shift, t	1 500	3 000	600
Number of shifts per day	3	2	2
Output per section per day, t	4 500	9 000	1 200
Output required per day, t	10 000	10 000	10 000
Number of units per section required	2	1	9
Continuous miner for longwall development	1	1	—
Total number of shifts per day	6	3	18

(2) that the panel lengths are 1600 m;
(3) that there is an additional output of 1000 t/d for the continuous miner, which is used for longwall development.

Tables IV and V give maximum and minimum costs for longwalling. Figures for actual installations of similar output in South Africa are few or non-existent, and, as

TABLE V
LABOUR COMPLEMENT PER SECTION PER SHIFT FOR LONGWALL AND MECHANIZED BORD-AND-PILLAR MINING*

Job	Longwall		Bord-and-pillar mechanized
	Minimum	Maximum	
Miner Section	1	1	1
Developing	1	1	
Artisan	1	1	1
	3	3	2
Labourer			
Cutting			
Blasting			6
Loading			3
Barring			3
Sweeping			3
Drilling			2†
Tamping			1
Shuttlecars			2
Roofbolts			6
Water			1
Supervisor	1	1	1
Chocks	3	4	
Face conveyor	1	1	
Shearer operator	1	1	
Maingate	2	2	
Tailgate	1	2	
Cables, etc.	1	1	
Engineering aides	1	2	
Development	10	17	
Sub-total	21	31	30
Total	24	34	32

*It must be noted that the average of that found in practice has been taken.
†Drill rig is used.

TABLE VI

SECTION CAPITAL COSTS FOR CONVENTIONAL MECHANIZED BORD-AND-PILLAR MINING

Section Equipment	
1 coalcutter	R60 000
1 loader	60 000
2 shuttlecars	80 000
1 drill rig	65 000
Fans, cables, and switchgear	60 000
	R325 000
Total for 9 sections	R2 925 000
Housing	
Skilled, 2 at R25 000	50 000
Unskilled, 30 at R1000	30 000
	R80 000
Total for 18 shifts per day	R1 440 000
Total section capital cost	R4 365 000

TABLE VII

SECTION CAPITAL COSTS FOR LONGWALL MINING

	Cost			
	Minimum		Maximum	
	Cost R	Life t × 10^6	Cost R	Life t × 10^6
Equipment				
Mining				
Chocks*	1 400 000	15	2 800 000	10
Single props.	15 000	10	19 000	8
Power packs	12 000	15	13 000	10
AFC† motors	80 000	15	100 000	10
Pans, etc.	200 000	3	220 000	3
Chains	40 000	1,5	50 000	1
Stageloader:				
Motors	30 000	15	35 000	15
Pans, etc.	18 000	15	24 000	12
Chains	6 000	7	7 000	5
Breaker	60 000	3	70 000	1,5
Motor	9 000	15	10 000	15
Shearer	350 000	9	370 000	9
Face communication	50 000	15	30 000	15
Face lighting	5 000	15	10 000	15
Switchgear	150 000	18	170 000	18
Panel cable	80 000	9	100 000	9
Development				
Continuous miner	200 000	4	230 000	3
Shuttlecars†	120 000	3	120 000	1,5
Roofbolter	20 000	3	20 000	3
Fans, switchgear	50 000	3	50 000	3
Sub-total for 1 Section	2 845 000	—	4 448 000	—
Sub-total for 2 Sections	—	—	8 896 000	—
Housing				
Skilled: at R25 000	225 000	—	75 000	—
Unskilled: at R10 000	72 000	—	132 000	—
Sub-total for 1 Section	297 000	—	207 000	—
Sub-total for 2 Sections	—	—	414 000	—
Total for 1 Section‡	3 142 000	—		
Total for 2 Sections §	—	—	8 890 000	

*Chocks R1 400 000
Chock shields R2 800 000
†Armoured face conveyor
‡Extremes taken.
§Only one continuous miner used for both sections.

TABLE VIII

SECTION WORKING COSTS FOR CONVENTIONAL MECHANIZED BORD-AND-PILLAR MINING

Labour			
18 miners at R750/month		R13 500	
18 artisans at R900/month		R16 200	
		R29 700	i.e. 11,88 c/t
540 mining labourers at R100/month		R54 000	
36 engineering labourers at R100/month		R3 600	
		R57 600	i.e. 23,04 c/t
Stores, c/t			
Mining: Support*	19,30		
Blasting	9,30		
Picks	0,20		
Bits	2,03		
Ventilation	2,73		
Stonedust	1,00		
	34,56		i.e. 34,56 c/t
Engineering (operating), c/t			
Coalcutters	11,40		
Loaders	6,70		
Shuttlecars	9,00		
Cables, power, etc.	5,40		
	32,50		i.e. 32,50 c/t
Overhaul costs, c/t			
Coalcutters at 880 000 t	0,75		
Loaders at 800 000 t	1,00		
Shuttlecars at 500 000 t	1,50		
	3,25		i.e. 3,25 c/t

*Figures taken from operating mines.

TABLE IX

SECTION WORKING COSTS FOR LONGWALL MINING

Labour			
3 miners (longwall) at R750/mth		R2 250	
3 miners (development) at R750/mth		R2 250	
3 artisans at R900/mth		R2 700	
Minimum (1 longwall, 1 development unit)		R7 150, i.e.	2,86 c/t
Maximum (2 longwall, 1 development unit)		R12 150, i.e.	2,86 c/t
Minimum 126 labourers at R100/month		R12 600, i.e.	5,06 c/t
Maximum 181 labourers at R100/month		R18 100, i.e.	7,26 c/t
Stores, c/t			
Longwall: mining, engineering, overhaul		37,41 c/t*	
Development:			
Mining:			
Support	19,30=	1,93†	
Picks	5,70=	0,57	
Ventilation	2,73=	0,27	
Stonedust	1,00=	0,10	
Engineering:			
Cont. miners	21,20=	2,12	
Shuttlecars	9,00=	0,90	
Cables, power	6,70=	0,67	
		6,56	i.e. 43,97 c/t
Overhaul costs, c/t			
Longwall: Included in stores.			
Development: Cont. miner (at 1×10^6 t)	8,00=	0,80	
2 shuttlecars (at $\frac{1}{2} \times 10^6$ t)	1,50=	0,15	
		0,95	i.e. 0,95 c/t

*Obtained from U.S.A. reports.
†Continuous miner contributes 1/10 of total production.

a compromise, the figures and experience quoted by overseas manufacturers were extrapolated.

The present-day capital costs (equipment and housing) for both types of mining were then estimated (Tables VI and VII). The section conveying equipment joining the main transport system was assumed to be the same for bord-and-pillar as for longwall mining, and was therefore omitted. The most costly components, e.g. chock shields, were assumed to be used in longwall mining, and the capital and section costs of the continuous miner and other equipment used for longwall development were included as part of the longwall cost.

The section working costs are given in Tables VIII and IX. These are not the total costs of producing 1 ton of coal; they do not include the costs of all the installations and activities outside the sections, which, for the purpose of these calculations, were assumed to be the same for both systems. Similarly, they do not include the costs of conveyor-belt structures and belting in the sections, which were also assumed to be the same in both methods.

The total costs per ton in the respective sections were then converted to total annual costs, and discounted cash flows were computed for both types of mining (Tables X and XI). This was done for approximately 30 years so that the replacement of major equipment could be included. The annual cost per ton was obtained from the product of the calculated cost per ton and the annual tonnage previously calculated.

The inflation and discount rates were calculated as follows. It was assumed that the unskilled labourers' wages would increase annually at 50 per cent for 1976 and 1977, and at 19 per cent after that; and that the wages of the other workers and the remainder of the working costs would increase at 15 per cent. An inflation factor of 15 per cent was therefore applied to these latter costs and 19 per cent to the labourers' wages. For both methods of mining, the costs were discounted at 15 per cent, which was assumed to be a reasonable profit level.

Conclusions

From the conservation point of view, the longwall method (environmental and geological factors permitting) offers a higher extraction than the mechanized bord-and-pillar method. However, the financial appraisal of the two methods indicates that the future escalation of labour costs may be the decisive factor in any choice between these two methods.

Opencasting and pillar extraction are other methods offering high extraction, but depth and stripping ratio may preclude the first whereas pillar extraction as a secondary operation loses some of the benefits gained from an initial operation, e.g., geographic expansion. The productivity, both machine and labour, in pillar extraction is also lower than in the longwall, bord-and-pillar, or opencast methods.

The following conclusions are drawn.

(1) It is essential to conserve and utilize South Africa's strategic coal reserves. This calls for the maximum possible extraction. Financial, geological, strata-control, and operational factors permitting, at depth longwall mining fulfils this requirement.

(2) South Africa's vulnerable labour structure at present, in which migratory and high-cost labour patterns play increasingly large roles, can be made more stable by the employment of a mining method that requires fewer personnel for a similar output. Longwall mining can be considered preferable in this respect because of its high productivity and low labour requirements. The financial appraisal showed that this factor may be decisive in the choice of method. It has been shown that the labour force in South African coal mining has declined steadily since 1968, while salaries and wages have increased constantly. If these trends continue, a method of high productivity and low labour force will be of vital importance. It has been shown that the longwall method increases the labour productivity by 400 per cent.

(3) The bord-and-pillar method at a depth of less than, say, 60 m remains competitive, and at these shallow depths numerous difficulties have to be overcome with longwall implementation. With increasing depth, however, the longwall method becomes more attractive with respect to safety, percentage extraction, and strata control. An analysis of the various coal fields in South Africa with respect to depth, indicates that the longwall method can be used to its full advantage in the Natal and Northern Free State fields, but that its wide use may be precluded in the relatively shallow Transvaal seams.

(4) A geological investigation into the various fields indicates that roof and floor conditions in the Natal and Free State fields are particularly advantageous with respect to longwall mining.

(5) As proved here and abroad by casualty figures, the longwall method is safer than bord-and-pillar extraction.

(6) Longwall mining normally causes surface damage and subsidence, and restoration costs must be included in the estimates. There may be legal implications, and, where subsidence may occur, due respect must be paid to the relationship between the owners of the surface and the owners of the mineral rights. The Sigma longwall experiment indicates that undermined land can be used for normal agricultural operations after any cracks have been filled in. No problems are foreseen in the filling of these cracks.

(7) The larger rate of geographic expansion in mechanized bord-and-pillar mining is associated with increased costs for transport, stonedusting, and road maintenance.

(8) The ventilation of a longwall section is a straightforward operation, not requiring daily changes as the face advances or retreats.

(9) As shown by the discounted cash flow, the present value of the section working costs including the initial capital and the replacement of capital equipment was lower for both the minimum and maximum cases of the longwall method for the mechanized bord-and-pillar system. A major factor in the near future will be the high rate of escalation of labour costs in any decision between the two

TABLE X

ESTIMATED COSTS FOR CONVENTIONAL MECHANIZED BORD-AND-PILLAR MINING (IN RANDS)

	Present value	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Labour																
Skilled	2 755 616	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400
Unskilled	13 231 389	1 691 200	1 036 800	1 555 200	1 617 408	1 602 104	1 749 388	1 819 364	1 892 138	1 967 824	2 046 537	2 128 398	2 213 398	2 302 075	2 394 158	2 489 925
Stores																
Mining	7 844 429	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800
Engineering	7 376 850	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000
Overhaul Costs	737 685	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500
Capital Cost	4 365 000	4 365 000														
Replacement Cost																
9 coalcutters at 3 × 10^6 t	240 948									540 000						
9 loaders at 2 × 10^6 t	465 804						540 000						540 000			
18 shuttlecars at 1,5 × 10^6 t	321 264									720 000						
9 drill rigs at 6 × 10^6 t	54 346															
	37 393 331															

	Present value	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Labour																	
Skilled	2 755 616	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400	356 400
Unskilled	13 231 389	2 589 522	2 693 103	2 800 827	2 912 800	3 029 374	3 150 549	3 276 571	3 407 634	3 543 940	3 685 697	3 833 125	3 986 450	4 145 908	4 311 745	4 484 214	4 663 583
Stores																	
Mining	7 844 429	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800	1 036 800
Engineering	7 376 850	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000	975 000
Overhaul Costs	737 685	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500	97 500
Capital Cost	4 365 000																
Replacement Cost																	
9 coalcutters at 3 × 10^6 t	240 948			540 000									540 000				
9 loaders at 2 × 10^6 t	465 804			540 000						540 000						540 000	
18 shuttlecars at 1,5 × 10^6 t	321 264			720 000									720 000				
9 drill rigs at 6 × 10^6 t	54 346			585 000													
	37 393 331																

TABLE XI

ESTIMATED COSTS FOR LONGWALL MINING (IN RANDS)

	Present value	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Labour																
Skilled	1 103 123	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800
	(649 163)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)
Unskilled	4 154 540	217 200	325 800	488 700	508 248	528 578	549 721	571 709	594 578	618 361	643 095	668 819	695 572	723 395	752 331	782 424
	(2 880 500)	(151 200)	(226 800)	(340 200)	(353 808)	(367 960)	(382 678)	(397 985)	(413 905)	(430 461)	(447 680)	(465 587)	(484 210)	(503 579)	(523 722)	(544 671)
Stores	9 980 310	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100
Overhaul Costs	215 631	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500
Capital Costs	8 890 000	8 890 000														
	(3 142 000)	(3 143 000)														
Replacement Cost																
A. Mining																
Chocks	2 684 640						2 800 000					2 800 000				
	(1 342 320)						(1 400 000)					(1 400 000)				
Single props	35 638				19 000			19 000			19 000			19 000		
	(28 135)				(15 000)			(15 000)			(15 000)			(15 000)		
Power packs	12 946						13 000				13 000					
	(11 951)						(12 000)				(12 000)					
AFC O. head mtrs	95 880						100 000					100 000				
	(76 704)						(80 000)					(80 000)				
AFC pans	1 444 320		220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000
	(1 313 200)		(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)
AFC chains	984 900		150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000
	(525 280)		(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)
Stage-loader drive head	65 835				35 000			35 000			35 000			35 000		
motors	(56 271)				(30 000)			(30 000)			(30 000)			(30 000)		
Stage-loader pans	31 610					24 000				24 000				24 000		
	(19 176)						(20 000)					(20 000)				
Stage-loader chains	24 918			7 000		7 000	7 000		7 000		7 000	7 000		7 000		7 000
	(14 379)				(6 000)		(6 000)		(6 000)			(6 000)		(6 000)		(6 000)
Breaker assembly	919 240		140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000
	(393 960)		(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)
Motor (B.A.)	9 739						10 000					10 000				
	(8 765)						(9 000)					(9 000)				
Shearer	701 557				370 000			370 000			370 000			370 000		
	(661 780)				(350 000)			(350 000)			(350 000)			(350 000)		
Face communication	29 217						30 000					30 000				
	(4 869)						(5 000)					(5 000)				
Face lighting	9 739						10 000					10 000				
	(4 869)						(5 000)					(5 000)				
Switchgear	127 500							170 000						170 000		
	(112 500)							(150 000)						(150 000)		
Panel cable	189 420				100 000			100 000			100 000			100 000		
	(151 264)				(80 000)			(80 000)			(80 000)			(80 000)		
B. Development																
Continuous miner	1 510 180		230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000
	(1 313 200)		(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)
Shuttlecars	1 575 840		240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000
	(787 920)		(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)
Roofbolter	131 320		20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Fans, switchgear	328 300		50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000
Maximum	35 256 543															
Minimum	(24 153 767)															

	Present value	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Labour																	
Skilled	1 103 123	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800	145 800
	(649 163)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)	(85 800)
Unskilled	4 154 540	813 721	846 270	880 121	915 325	951 938	990 016	1 029 617	1 070 801	1 113 633	1 158 179	1 204 506	1 252 686	1 302 794	1 354 905	1 409 102	1 465 466
	(2 880 500)	(566 458)	(589 116)	(612 681)	(637 188)	(662 675)	(689 182)	(716 750)	(745 420)	(775 236)	(806 246)	(838 496)	(872 036)	(906 917)	(943 194)	(980 921)	(1 020 158)
Stores	9 980 310	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100	1 319 100
Overhaul Costs	215 631	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500	28 500
Capital Costs	8 890 000																
	(3 142 000)																
Replacement Cost																	
A. Mining																	
Chocks	2 684 640	2 800 000					2 800 000					2 800 000					
	(1 342 320)	(1 400 000)					(1 400 000)					(1 400 000)					
Single props	35 638	19 000			19 000			19 000			19 000			19 000			
	(28 135)	(15 000)			(15 000)			(15 000)			(15 000)			(15 000)			
Power packs	12 946	13 000					13 000					13 000					
	(11 951)	(12 000)					(12 000)					(12 000)					
AFC O. head mtrs	95 880	100 000					100 000					100 000					
	(76 704)	(80 000)					(80 000)					(80 000)					
AFC pans	1 444 320	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000	220 000
	(1 313 200)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)
AFC chains	984 900	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000	150 000
	(525 280)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)	(80 000)
Stage-loader drive head	65 835	35 000			35 000			35 000			35 000			35 000			35 000
motors	(56 271)	(30 000)			(30 000)			(30 000)			(30 000)			(30 000)			
Stage-loader pans	31 610		24 000				24 000				24 000				24 000		
	(19 176)	(20 000)					(20 000)					(20 000)					
Stage-loader chains	24 918	7 000		7 000		7 000	7 000		7 000		7 000	7 000		7 000		7 000	
	(14 379)			(6 000)		(6 000)		(6 000)			(6 000)		(6 000)		(6 000)		
Breaker assembly	919 240	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000
	(393 960)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)	(60 000)
Motor (B.A.)	9 739	10 000					10 000					10 000					10 000
	(8 765)	(9 000)					(9 000)					(9 000)					(9 000)
Shearer	701 557	370 000			370 000			370 000			370 000			370 000			370 000
	(661 780)	(350 000)			(350 000)			(350 000)			(350 000)			(350 000)			(350 000)
Face communication	29 217	30 000					30 000					30 000					30 000
	(4 869)	(5 000)					(5 000)					(5 000)					(5 000)
Face lighting	9 739	10 000					10 000					10 000					10 000
	(4 869)	(5 000)					(5 000)					(5 000)					(5 000)
Switchgear	127 500				170 000						170 000						170 000
	(112 500)				(150 000)						(150 000)						(150 000)
Panel cable	189 420	100 000			100 000			100 000			100 000			100 000			100 000
	(151 264)	(80 000)			(80 000)			(80 000)			(80 000)			(80 000)			(80 000)
B. Development																	
Continuous miner	1 510 180	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000	230 000
	(1 313 200)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)	(200 000)
Shuttlecars	1 575 840	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000	240 000
	(787 920)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(120 000)	(200 000)
Roofbolter	131 320	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Fans, switchgear	328 300	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000
Maximum	35 256 543																
Minimum	(24 153 767)																

methods. Increasing unskilled wages and the necessity to conserve South Africa's coal resources are now off-setting the advantages gained by bord-and-pillar mining, viz lower initial capital cost and flexibility.

(10) The longwall-mining method is destined to become a widely practised method in coal mines in South Africa. This does not imply that it can be implemented on all mines under all conditions. However, it will be a practical proposition (if not an economic one) in many mines.

(11) Maximum benefits are to be gained from longwall mining where adverse roof conditions are encountered.

(12) The introduction of the longwall mining method in South Africa is recent, and its application has so far been limited to thin seams of high-grade coking coal and to a thick seam in very adverse conditions. In both cases, longwall mining was implemented after the bord-and-pillar technique had proved of limited application.

(13) It must be noted that a relatively new system such as longwall mining can be costly unless expert guidance and thorough training techniques are implemented. Such guidance and training are available from United Kingdom mining engineers who developed the British mechanized longwall equipment and have long experience in its use, and from the manufacturers of longwall equipment, e.g., Eickhoff, Dowty, Anderson Mavor and Gullick.

In summary, the most cogent reasons (technical and economic) for the introduction of longwall mining in some seams are associated with strata control and increased labour costs. Other reasons include simplified and improved ventilation, reduced production of coal dust, higher productivity, and higher percentage recovery.

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