Manpower utilisation in South Africa with special reference to the mining industry

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Introductory remarks by author

When Mr R. C. J. Goode suggested preparation of a paper in the area of manpower utilization in South Africa, I was, while keen to accept his invitation, somewhat hesitant for two reasons. Firstly, I recognized the great difficulty of making a factual contribution, because of the lack of really relevant statistical information available, the fact that much of it is out of date, and the difficulty of researching and co-ordinating it and of evaluating a statistically sound resultant viewpoint. Experience in the actual preparation of this paper has done nothing to change my view in this respect.

Secondly, it is obvious that a paper presented to a meeting of this Institute, by a member of it, would be expected to devote considerable attention to the subject in the mining industry. I am not directly employed by the mining industry, although my company has carried out extensive assignments for various sectors of it both in this country and in other parts of the world, since the 1939-45 war. I am more conscious than most of the tremendous technical and managerial skills at the disposal of the industry in this country, and consequently am equally conscious of the hazards of publishing facts and figures which might be taken to indicate any criticism of performance.

I am aware that some of the information that I am about to present may indeed generate comment, and possibly even critical comment. I would like to be regarded therefore in presenting this information, as a member of the group, rather than an external critic. Under these circumstances, comment can only be constructive, and this is my earnest hope.

The contribution of my paper, if contribution there is, will I hope be in the area of assessing labour productivity in mining, and in secondary industry in such a way that the performance of each against its own past results is comparable. This task has not for the present been to my knowledge attempted, and in advance I wish to take out authors' insurance against legitimate criticism from professional economists and others, by stating that I am well aware of possible short-comings in the arguments. Nevertheless I believe that under the circumstances I have, with the important assistance of several people, been able to take the subject further than has been the case in the past. Finally, I have related productivity in the mining industry and in secondary industry to a target of productivity in the Republic of South Africa.

I was fortunate recently in being able to attend a series of lectures by a prominent economist in America. He introduced his subject by calling it 'A broad survey of macro-economics'. Perhaps I might be permitted to describe my paper, in the same idiom, as 'The macro-management of labour'.

Discussion

W. H. Keeley*: Mr McGregor's paper is stimulating and provocative. He has lifted this problem of efficiency in the gold mines out of its usual mundane and isolated setting by attempting not only a comparison with manufacturing, but by an examination of the problem in relation to that contemporary obsession, national growth.

A great deal has been attempted in this paper and it is a pity that so many themes have received only a cursory examination. This particularly applies to his assessment of improved efficiencies for the whole economy and for manufacturing and construction industries.

The estimated improvement in national output per worker per annum of 2.8 per cent is a useful basic figure. There will, of course, be considerable variation in the rates achieved by individual sectors of the economy, but I cannot agree that this variation can be used as a merit rating for grading the workers and drones. In the last Economic Development Programme covering the period 1968-1973, the projections for each sector give the expected growth rate of output per worker. The arithmetic averages for the 23 sectors comprising manufacturing industry is 3.0 per cent. The lowest is textiles with 1 per cent, clothing and furniture at 1.3 per cent. Basic industrial chemicals heads the list with 6.9 per cent, the ubiquitous miscellaneous manufacturing is second with 4.7 per cent and with wood products and electrical machinery at 4.0 per cent.

The construction industry is a low 0.03 per cent, agriculture 2.5 per cent, coal mining 3.6 per cent, other mining and quarrying which is so much in the news, a mere 1.7 per cent and gold mining 3 per cent.

I wish I could leave the matter there with a nice comforting 3 per cent, the same level as manufacturing. But this 3 per cent is based on the amount of gold and uranium produced and is not the sort of efficiency

Mr McGregor is talking about.

At this stage I must confess that, despite some researching, I am unable to give you the measure of increasing efficiency in gold mining. I have, however, unearthed information which has some bearing on the problem.

The unit of costing in gold mining is by tradition the ton milled. But this choice has led to some distortion with the great increase in the tonnage of waste hoisted in the new areas. The calculation below, based on the actual distribution of tonnage, shows that cost per ton milled in the new areas in comparison with the old areas exaggerates the real difference by about 25 per cent. Milling and hoisting costs are each about 10 per cent of total costs.

TABLE I

COST PER TON BROKEN

		Old areas		New areas	
	True cost per ton	Distribution of tons broken	Total cost	Distribution of tons broken	Total cost
	(a)	(b)	axb	(c)	axc
Tons milled	100	79	7 900	61	6 100
Waste packed ug.	80	9	720	11	880
Waste sorted on surface	90	7	630	5	450
Waste hoisted	90	5	450	23	2 070
		100	9 700	100	9 500
Actual cost per ton milled			100		100
Cost per ton if total cost allocated to tons milled			123		156
to tons broken			97		95

I have, therefore, chosen to use tons broken as the measure of output. This measure, like any other factor of tonnage, has one major demerit in that the resources required to extract each ton of rock vary so greatly not only between mines but within the same mine. This variation in the difficulty of extraction I refer to as the 'Mining Factor'. This factor is taken to increase with a greater degree of mining difficulty. A satisfactory unit of output is essential to measure productivity. My ideal unit would be tons handled multiplied by the Mining Factor. It would appear that the factor generally increases throughout the working life of a mine as a result of distance, depth, heat and other problems and the new mining areas generally have a higher Mining Factor than the old areas. Efficiency is, therefore, defined in terms of tons broken times the Mining Factor.

I have referred to old and new areas which seem to naturally divide into:

Old Mining Areas

Area 1. Old Witwatersrand—production started before 1906.

Area 2. East Rand Basin—Mines started 1908-1924.

Area 3. Post Gold Standard 1932-1942—Mostly East Rand.

New Mining Areas

Area 4. Far West (includes two post gold standard mines).
Area 5. Klerksdorp.
Area 6. O.F.S.
Area 7. Evander.

The analysis deals separately with each of the elements of working costs and with capital.

The resources covered by working costs may be broadly classified:

1. Non-White Labour
2. White Labour
3. Materials

The relationship between the elements which make up working costs have not changed much over the last thirty years. Roughly the proportions are:

1. Non-White Labour 25%
2. White 30%
3. Stores and Power 40%
4. Other 5%

Labour costs include fringe benefits. Non-White labour costs include White labour and stores used to provide Bantu housing and feeding.

Bantu Labour

Mr McGregor's conclusion that the gold mining industry has shown a disappointing level of improvement in manpower productivity is based largely on his analysis of the output of Bantu workers. I have devoted a large part of my enquiries to this one aspect.

As a first approximation the number of tons broken per Bantu at work underground (referred to as the tonnage duty) has been calculated for the years 1937 to 1969. I have taken this part of the analysis back to 1937, because a convenient statistical series started in that year and the period is long enough to give trends unhampered by badly chosen base periods.

If the figures are plotted, they are found to conform closely to a straight line on the linear scale. This is most unusual in that the growth of efficiency more usually progresses as an exponential function. The line of best fit shows tonnage duty to have improved at 1¼ per cent per annum simple interest.

But an average is no better than its constituents. In an attempt to interpret the significance of the progression of a mere 1¼ per cent per annum simple interest, tonnage duties for individual companies were examined and the figures were plotted to determine 'lines of best fit'.

These 'lines of best fit' generally fall into one of four patterns:

(a) Rise in tonnage duty, followed by fall ∧.
(b) Fall in tonnage duty, followed by rise ∨.
(c) Steady rise in tonnage duty /.
(d) Steady fall in tonnage duty \.

A cursory examination of Table 2 will convince one that the regular improvement of 1¼ per cent per annum for the industry as a whole is merely the fortuitous result of adding together a number of unrelated positive and negative trends and by itself is valueless as a measure of improving efficiency. Lines of best fit have been plotted for each company. From an analysis of these trend lines, certain basic patterns emerge.

TABLE II

PATTERN OF LINE OF BEST FIT–NUMBER OF MINES

Area	Λ	V	/	\	Other
I Old Witwatersrand	6	1	4	5	2
II East Rand Basin	6		–	3	2
III Post Gold Standard	9		1		1
IV Far West Rand	2	1	1	3	
V Klerksdorp		1	4	1	
VI O.F.S.	1	2	4	3	
VII Evander			2	1	
Total	24	5	16	16	5

A few mines (about 8 per cent) show either a combination of (a) and (b), or no trend at all.

The pattern of each mine in the old area is virtually established, but in the new areas a proportion of the mines can be expected later to develop divergent trends. Thus, a number of mines with simple up or down trends may develop the familiar V or inverted V pattern.

The trends of each mine generally persist for long enough to establish their secularity, that is the trends are not due to temporary extraneous influences such as the supply of Bantu labour. The question arises, why do trends arise in this form?

There is a continuity of management and personnel in each mine which must tend to ensure the maintenance of achieved standards of efficiency while the competitive atmosphere of any industrial unit surely ensures a more or less continuous striving towards greater efficiency.

The changes in Bantu tonnage duty for any mine in my opinion is no indication of changes in efficiency, because this crude measure of productivity is very much influenced by what I have described as the Mining Factor.

To carry this point further, the mines have been analyzed according to the angle and duration of trend lines in Table III. Angles are calculated at simple interest based on the initial observation for each mine.

Upward slopes must indicate an efficiency growth greater than the growth rate of the Mining Factor. Downward slopes indicate the contrary position.

The positive and negative sides of the table roughly balance and the median in both cases is about 2½ per cent. Thus, one quarter of the mines at one stage of their growth were able to achieve increases in productivity exceeding 2½ per cent per annum, a high rate of improvement. One quarter of the mines in the period when their productivity was improving, achieved only a moderate rate. While one half of the mines are climbing the remainder are on a downward trend, half above and half below minus 2½ per cent per annum.

Bearing in mind the continuity of management and personnel and the controls exercised by the mining groups, variations in the growth of efficiency of this magnitude seem impossible especially in view of the comparatively long period for which these trends persist.

It seems apparent that the Mining Factor not only plays a major role in determining the level of productivity, but it is often large enough to override the efficiency factor and produce in mines growth rate in productivity.

Presumably the Mining Factor can be positively small or could be less than unity. The change of trend, shown by those mines falling into the V pattern, possibly implies a major change in the Mining Factor from a large positive figure to a small positive or even a negative value.

Some preliminary enquiries were started to attempt some explanation of these changes in trend both for the V and inverted V patterns but with little success. It is obvious that a fairly extensive analysis is required. The most puzzling feature of these changes in trend is the sharpness with which trends change direction. In one case it was clear that an upward trend which turned sharply downwards was due mainly to switch over from a reef with 100 per cent extraction to a poorer reef necessitating selective mining. A gradual change in direction would have been expected as the change was effected over a period of years. But relatively large tonnages easily gained from pillar extraction coinciding with the first half of the switch over, served to maintain the upward trend for a few years.

A more direct analysis of the mechanics of the Mining Factor can be achieved only on the basis of case studies of individual mines, but mine records are generally inadequate for this purpose. Until a more factual analysis is prepared, the problem of assessing the Mining Factor must remain the missing link in efficiency studies.

Before leaving the question of labour productivity, I thought it worthwhile to take a broader look at average trends for underground Bantu on the different mining districts for a longer period. I have also used the same crude trends to examine the productivity of surface Bantu and White labour, both surface and

TABLE III

ANALYSIS OF ANGLE AND DURATION OF TRENDS

	Upward Trends											Downward Trends											Level Trend
	10% or more	9	8	7	6	5	4	3	2	1	Less than 1%	Less than 1%	1	2	3	4	5	6	7	8	9	10% or more	
Up to 4 years				1													1				1		
4-8	1		1	2				4		3	2	1	1	3	2	2	1	1				1	
9-12						2	1	2	3	2	2	1	3	3	4	1							1
13-16					1		1	1	7	4	1	3	6	4	2	1							1
17-20								1	2	1	1	1					1						
21-24													1										
More than 24										1	2	3	1										2
	1		1	3	1	2	2	8	12	11	8	9	12	10	8	4	3	1			1	1	4
						24				25			26					23					

underground. The limited application of these crude trends will be appreciated.

The productivity for underground Bantu showed a long upward trend for the two oldest areas, followed by a downward trend from 1954 on. Otherwise this comparison of district totals is much the same as the picture shown by Table II for individual mines.

Productivity for surface Bantu has dropped slowly in the old areas but has shown a fast rise in the new areas.

Productivity for Whites has generally increased at a faster rate than for Bantu and the new areas are better than the old areas. The productivity of Whites is a study in itself. Some of the improvement must be due to substitution but, of course, the increase in underground officials to provide better supervision will increase Bantu productivity but has the contrary effect on White output.

The combined improvement in productivity for all classes of labour (each class weighted according to total cost), was + ½ per cent and + 1.5 per cent in the old areas, 1937-1953 and 1954-1969 respectively, and + 4 per cent in the new areas from 1954 to 1969.

Cost of Stores

The cost of stores, expressed as the cost per ton broken at the 1910 level of costs, indicate that costs do not seem to change very much. The main point to be noted is that costs in the new areas are about 10 cents higher than in the old areas.

Working Costs per ton handled

Working costs on the old areas corrected to 1910 values have a steady downward trend of about minus 0.4 per cent. The costs of new areas, starting at a very high level, are now about 10c per ton above the old areas.

Capital

The cost of capital per ton broken at 1910 values was about 12c in the old areas and 30c in the new areas. If these amounts are added to Working Costs, it will be seen that costs in the new areas are now a little higher than costs in the old areas in 1910.

Sixty years of mining experience have not succeeded in altering costs. The obvious conclusion is that increases in efficiency have almost exactly balanced increases in the Mining Factor.

Conclusion

Superficially the old areas seem to present a rather stodgy picture of moderate increases in labour productivity and careful husbandry of stores.

I have tried to show that these apparently moderate achievements cover a respectably high achievement when considered against the continually increasing Mining Factor.

In contrast, the new areas present a picture of labour productivity increasing at a high rate. This is possibly the result of greater mechanization as evidenced by higher stores costs and capital costs 2½ as great as in the old areas.

But the large increase in capital costs must be attributed mainly to the great increase in the Mining Factor.

*Mine Mechanisation Consultant.

T. Watt*: We have had the privilege of reading and listening to a lucid and challenging paper by Mr MacGregor on Manpower Utilization.

Manpower productivity is one means of following the trends in mining and manufacture so the conclusions reached by Mr McGregor from his statistical data appear to leave little doubt as to the perilous downward trend of the gold industry. Those within the industry will be the first to admit that on the factual data submitted and in spite of their prodigious efforts to improve productivity the progress is anything but spectacular. They may also admit that no radical change for the better is likely to materialise in the near future from within the industry.

Mr McGregor has rendered a service to the mines and to South Africa by drawing attention to Professor Black's original suggestion that a research institute be formed consisting of two parts which he placed in logical sequence. The question arises as to why the essential first part, the creation of an operations research team, was never implemented. The industry may have been relying on its research committee members to provide the necessary directives for research by the laboratories. If this was the case it would appear that an operations research team will have to be located outside the industry if any useful purpose is to be served.

The task of the team seems simple enough; that of testing new methods and equipment in the field and in the process analyzing problems in production with a view to eliminating bottlenecks, in fact a separate company may serve this purpose to perfection.

The use of computers was mentioned in the discussions but their system of control is such that the output is governed by the input so that no ideas are likely to materialize from their use.

The research team may or may not be capable of inventing new equipment or developing new mining methods, so a suggestion box comes to mind as a possible source of new developments. The Chamber night start now with a postal suggestion scheme. It would have to be run on an entirely secret basis so that contributors might with confidence submit their ideas without fear of ridicule or possible victimization.

Again, many manufacturing companies would be only too pleased to pass on to the team some of their patented products for test and further development.

It is reported that a director of research, who is not a mining man, has been appointed by one of the groups. This is a bold and promising step since he will not be inhibited by existing equipment or systems of mining.

Most producing mines have a struggle to maintain their outputs so that scientific or other research workers on the property may prove to be an added burden and as such not too welcome. If a non-producing but maintained mine was made available to the operations research team it might be ideal for most of the field testing and development tasks.

The introduction into the actual field of the tested equipment or method of working might necessitate the training of personnel for the task so that the team would have to be able to give the required instructions and training to mining men at all official levels.

The interest engendered by Mr McGregor's paper is indicative of the value of the Mining and Metallurgical Institute for publicity and discussion purposes so that nothing but benefits should result if all progress reports

by the operations research team were tables for perusal and discussion in this Institute.

Mr McGregor stated that it was difficult to see avenues for substantial future reductions in personnel or ways in which the mining industry could achieve the productivity increases required to meet and possibly continue to aid the national economy. The trend shown by his statistics give him good grounds for such pessimism.

The writer, on the other hand, drawing on half a century of close contact with mine mechanization developments, views the future with optimism provided the mining industry accepts the challenge from Mr McGregor to implement fully Professor Black's suggestion by creating an independent operations research team. Such a team would provide a sure but narrow way into the industry for thoroughly tested new equipment and methods of working.

*Mine Mechanisation Consultant.

J. M. Pike: Mr McGregor's paper will form a valuable reference work for many years to come, when productivity in the mining industry is being studied. Are we correct in assuming, however, that an increase in Bantu productivity is a primarily desirable objective in all circumstances?

In fact, given that the industry's average 'factory site' has moved deeper and further from main shafts during the period in question, would not a decrease have been expected, but for efforts to counter this? The supply and use of Bantu labour by the mining industry is a complex matter. There are political, social and even ecological considerations; so that the industry operates in an environment which it can attempt to manipulate but cannot positively control.

Some of these implications are:

1. Investment in capital equipment designed to improve Bantu productivity is seldom justified on purely economic grounds. The 'present value' of a Bantu labourer (that is the sum that can be spent to displace him) over 10 years at current interest rates is some R2 000. This does not go far on modern equipment—especially as part or all may be absorbed by maintenance costs.

   Improvement in European workers' productivity on the other hand (where the present value for a skilled worker ranges up to R50 000) is good business—a fact fully recognized by the industry as Mr McGregor has shown.

2. Improvements in Bantu productivity have been achieved for other than purely economic reasons. Some of these reasons are:

   (a) Insufficient labour is available when required; either in a particular locality or throughout the industry.

   An example of this type occurred at the world's deepest mine, East Rand Proprietary Mines Limited. Bantu productivity was falling sharply until 1960—due largely to increases in depth and the need for more elaborate underground layouts. This led to a higher proportion of labour being required for capital and other construction work.

   Shaft and compound capacities could not cope with a higher complement (even if labour were available). Thus the mine's future rested on a mechanization programme.

   This was successful in improving production without increasing the labour force. Tons milled per Bantu per month increased from 14 tons in 1960 to 17 tons in 1965, with an even greater increase in European productivity. An important feature of this programme was the introduction of mechanical traction in footwall drives.

   As will be seen from the graph, European workers' productivity increased even more steeply during this period. This was due largely to the adoption of a staff rationalization programme; though mechanization also played its part.

   (b) The possibility (so far only realized to a limited extent) that political considerations inside and outside the Republic may reduce the supply of labour.

   (c) The use of machinery where speed is essential and cannot be achieved by manual means—shaft sinking, and high speed development being typical examples.

   (d) Working conditions are unsuitable for manual labour.

   (e) A saving in Bantu labour has been a by-product of a reduction in European strength.

3. What is likely to happen in the future?

   (a) If the supply of Bantu labour diminishes sharply for any reason, South African mining engineers are only too eager to meet the challenge. Professional pride has, in the past, in fact, often been unable to resist the temptation to mechanize uneconomically.

   (b) The optimum use of large rock handling units is hampered in most South African gold mines by narrow mining widths. A sharp rise in the demand for gold, uranium and shingle for construction purposes might lead to increased mining activity near the surface. In this event such equipment might be used to better advantage, with beneficial results on Bantu productivity.

   The sharp jumps in productivity of base metal mines shown in the paper may well be due to the high proportion of open cast and cavern mining associated with the working of such minerals.

4. Improved Bantu productivity in the mining industry cannot improve living standards if it merely increases the number of unemployed or un-industrialized Bantu in Southern Africa.

   Productivity in the mining industry is therefore linked with the growth of the whole economy.

E. W. Thiel: We must thank the author for drawing attention to the important question of improving productivity, something which has never ceased to exercise the minds of all mining engineers and industrialists.

In his conclusions he finds that in the gold mining industry White productivity has improved reasonably satisfactorily but this cannot be said for Bantu productivity. We can hardly refute this finding but some comments in mitigation of this state of affairs would not be out of place.

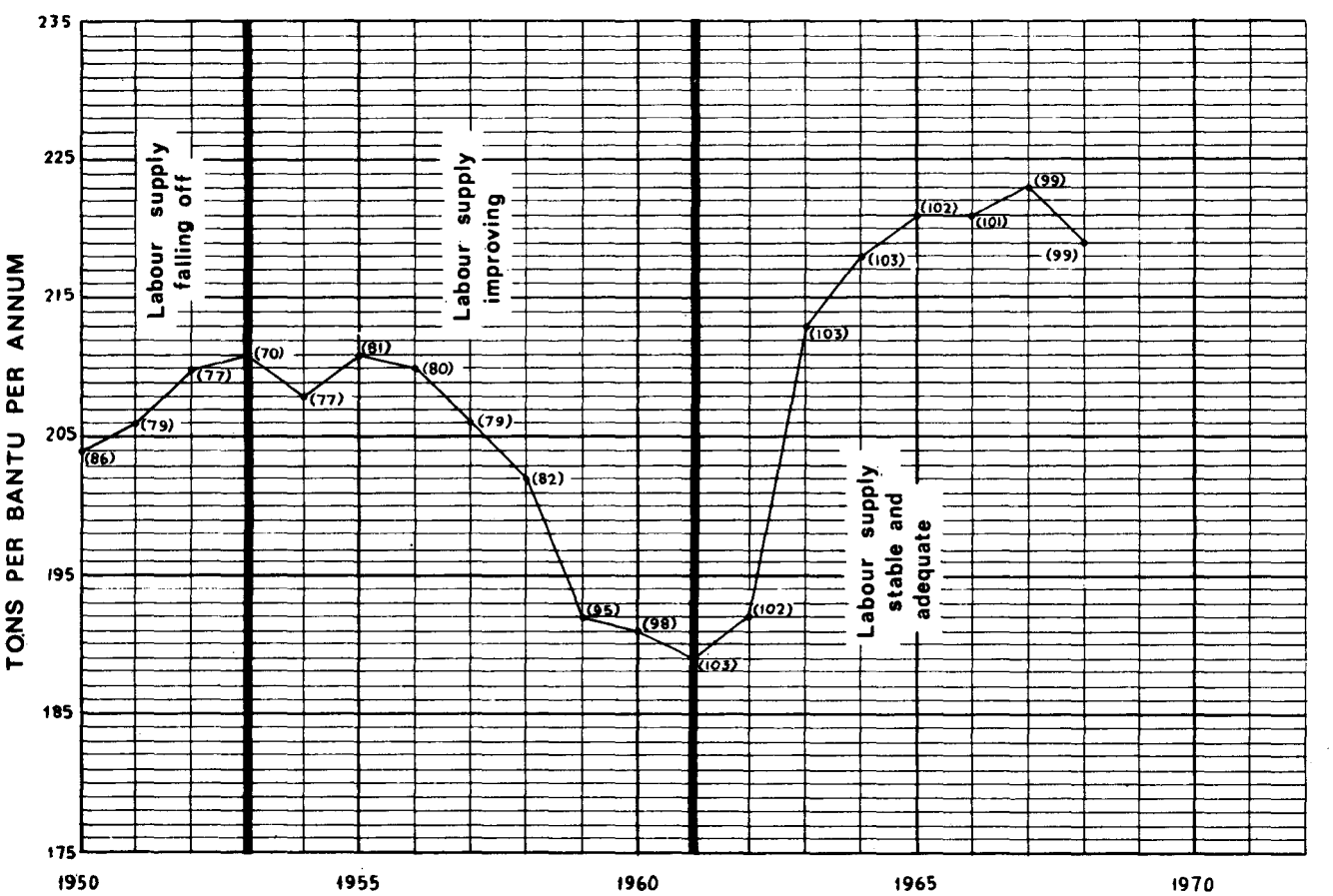
It is necessary to look at the Bantu labour supply during the two years under comparison. In 1958 the industry was experiencing a shortage of Bantu labour, and was only able to fill some 81 to 84 per cent of complements. Admittedly some and probably most of these complements were deliberately inflated to get a 'fair' share of the supply, but the fact remains that a shortage existed. On the other hand Bantu labour was in relatively free supply during 1968 when more realistic requirements were filled adequately with percentages varying between 97 and 105 per cent. It is possible that Bantu productivity during 1958 would have been lower if labour had been in freer supply and consequently the improvement shown by the 1968 figures could have been higher. This is more clearly illustrated in the attached graph. Three separate and distinct periods become evident. In the first period 1950-53 the percentage of complements filled had a decreasing tendency with attendant increases in productivity. In the second period 1954-1960 the complements percentage increased with a marked decrease in productivity. In the last period labour supplies were adequate and under these stable conditions productivity improved considerably. I feel the author would have been better advised to measure the improvement between the years 1961 and 1968. It shows an increase of some 16 per cent over the seven years or just over 2 per cent per annum, a much more satisfactory rate.

In Table III of the paper the combined improvement White and Bantu is given as 1¼ per cent per annum for the most recent period. This is accepted but it does not reflect the picture if costs of labour are introduced. If we accept the ratio of costs of White to Bantu labour as roughly 15 to 1, and apply such weighing to the respective White and Bantu productivity figures, the overall improvement on a labour cost basis would be 2 per cent. I do not offer this better figure as an excuse for the poor showing in Bantu labour productivity improvement but rather to emphasize the relative importance we are virtually forced to attach to White and Bantu productivity respectively.

The author suggests that the most important reason for the low Bantu productivity improvement centres round the highly capital intensive nature of the gold mines. It probably is a factor but the one single main reason can be found in the almost impossible restrictions imposed on the industry by the colour bar philosophy. Our efforts to improve are thwarted by the Mines and Works Act and Regulations under which only scheduled persons are permitted in so many instances; by the attitudes of the various trade unions where perhaps understandably the laws of the country have to be obeyed and by political pressures which seem to single out the gold mining industry.

The paper shows the phenomenal increase in boss boys over the years, an indication of the concerted efforts devoted to training with the hopes of improving productivity. Commensurate rewards have not flowed because of the restrictions mentioned earlier. We are all aware of the much publicized experiment conducted a few years ago where the boss boy was given greater responsibility. The experiment gave the most promising results but was terminated by Government pressure. One wonders how much better the improvement of 1 per cent in Bantu productivity calculated by the author would have been had the experiment been allowed to flow throughout the industry.

The paper attempts analysis of productivity improvement on a regional basis in Table IV. In many ways this



is meaningless and arguments and conclusions based on it are fallacious. Productivity measured in tons per employee could alter appreciably on a mine by the expansion of milling capacity; by the reduction in milling capacity (last years of a mine's life); by abandoning deeper workings and concentrating work in shallower areas; by milling increasing quantities of surface accumulations; by a reduction in the development programme (major layouts completed) and by the dip of the reef, stoping widths, hanging wall conditions, etc.

None of these factors are taken into account when results are analyzed on a regional basis. In his general conclusions the author cites the Orange Free State district as an example which if followed by the rest of the industry could lead to spectacular results. I can quote one mine in the Free State where during the period 1958 to 1968, White productivity in tons per employee increased from 1 011 to 2 047 (or 102 per cent) ($7\frac{1}{4}$ per cent per annum) and Bantu from 176 to 234 or 33 per cent (3 per cent per annum). This resulted essentially from the doubling of milling capacity, a programme followed by many of the then new mines in the district. The rest of the industry can hardly follow this process, and it illustrates the danger of drawing any conclusions from results analyzed purely on a regional basis.

On the operations research aspect other contributors will deal more fully with the subject, but I would hasten to say that many facets of operations research has been dealt with successfully by the Chamber of Mines Research Organisation and valuable findings of a basic nature are available for application in the industry.

E. Margo*: The author is to be congratulated on presenting to this Institute an excellent paper, which I have read with considerable interest, on the topical subject of manpower utilization with particular reference to the South African mining industry.

It has long been recognized that in an industry which is labour intensive, and the gold mines *are* labour intensive considering that more than 50 per cent of the working costs is made up of wages and salaries, the major source of manpower must be productively employed by providing it with the means to function effectively.

In the limited field of vertical shaft sinking the industry has enjoyed success and its record of achievement has been recognized and acclaimed throughout the world. This, however, cannot be said of the day-to-day production effort where the productivity growth rate is distressingly poor.

Recently I had occasion to investigate the behaviour pattern of productivity in the gold mining industry since 1930. Although tonnage milled has fallen slightly since 1966 and with it the number of persons at work, the productivity growth rate quoted below for the period 1950 to 1965 is indicative of the current trend. The source of the information was the Government Mining Engineer's Annual Reports and the Chamber of Mines Annual Reports.

Tons mined	$+3\frac{1}{4}$% p.a.
Number of Europeans at work underground	$+\frac{3}{4}$%
Number of Bantu at work underground	$+1\frac{3}{4}$%
Total labour force	$+1\frac{3}{4}$%
Tons mined per European shift underground	$+2\frac{1}{2}$%
Tons mined per Bantu shift underground	$+1\frac{1}{2}$%
Tons mined per Total shift underground	$+1\frac{3}{4}$%

The number of persons at work underground per 1 000 tons hoisted per day decreased as follows:

For Transvaal mines	—Europeans	2% p.a.
For Transvaal mines	—Bantu	$1\frac{1}{4}$%
For O.F.S. mines (since 1960)	—Europeans	3%
For O.F.S. mines (since 1960)	—Bantu	$1\frac{1}{2}$%

During the period under review, the ratio of Bantu to each European underground rose from 7.2 to 9.5. This is equivalent to a growth rate of 2 per cent per annum.

Meanwhile, the industry was expending large sums on the mechanization of the underground productive effort. For example, rockdrills in use increased at the rate of $3\frac{3}{4}$ per cent per annum. The tons of tungsten-carbide bits and borers consumed rose sharply from 2 000 tons in 1950 to 4 100 tons in 1955, since when it has fallen steadily and by 1964 the figure was back to 2 000 tons.

However, it was mainly in rock handling and transport that large sums were spent on mechanization. For example, the number of scraper scoops in use increased at the rate of $9\frac{1}{2}$ per cent per annum and mechanical loaders increased at the rate of 20 per cent per annum. The use of diesel locos grew at $9\frac{1}{4}$ per cent per annum and the loco size, measured in HP input, increased at $13\frac{1}{4}$ per cent per annum. The growth rate of scrapers, haulages, loaders and winches in use was 15 per cent per annum.

A special investigation conducted in the principal gold mines, members of the Chamber, showed during the period under review a rate of improvement of only $1\frac{1}{4}$ per cent per annum in the tonnage duty per Bantu at work underground. Even India, which is notoriously poor in the utilization of its labour force, had for the same period an underground manpower productivity growth rate marginally better at 1.8 per cent per annum.

Increased depth together with the worsening climatic conditions underground may well inhibit manpower productivity. However, the marked improvement in air-conditioning engineering, and the systematic planning and control of improved ventilation and cooling plants—particularly the increased use of underground regional cooling plants—have helped to maintain good air conditions with no adverse effects on manpower productivity.

If, as the author points out, South Africa experienced a healthy economy during the past twenty years and the annual increase in the GDP was 2.8 per cent, why then has the labour productivity in our gold mines maintained such a low growth rate? From the statistics quoted above, it can be concluded that substituting a mechanical system for a manual system does not necessarily bring about an improvement in labour productivity. Further, since the ratio of Bantu to Europeans increased at the rate of 2 per cent per annum and the Bantu productivity at $1\frac{1}{2}$ per cent per annum, it would appear to nullify the European contribution towards productivity growth measured in real terms. In other words, the Bantu, because of the nature of his employment and the organisational environment in which he operates, is the only significant measure of labour productivity. If therefore we wish to improve the growth rate, then it is the Bantu in *his* work situation that should be critically examined.

Dr P. I. Riekert, Chairman of the Prime Minister's Economic Advisory Council, pointed out in a recent paper on productivity that there are three elemental resources utilized by the State, namely labour, capital and land. The extent to which labour can be substituted

is a measure of the sophistication in the industry concerned. However, it is the nature of labour, how it is used and the opportunity provided for advancement that is far more indicative of the growth of the industry. The greater the proportion of skilled complement in the total labour force, the greater will be the growth and economic viability. It is apparent that substituting mechanical energy for hand labour is merely a replacement of one form of muscle for another. Growth is obtained through the organizational system which provides the means and opportunity together with training and education, whereby the relevant skills can be developed and practised.

Unfortunately for the mining industry, the unions which control the majority of European workers have vehemently resisted innovations in the work pattern of the overall labour force. This considerable reluctance to change is probably the one single factor which inhibits the labour productivity growth rate. In the manufacturing sector this prejudice has not been manifest with the result that a very satisfactory growth rate has been experienced.

Finally in examining labour productivity, it is imperative to know exactly the areas of shortcomings and where improvement in output can contribute most to growth. To determine efficiency it is necessary to know the degree of utilization of the resources. In the broadest sense this can be viewed as a measure of productivity. Measurement of performance and the determination of the utilization of the manpower resource is essential. In the mining industry this may be efficaciously done by actively sampling and by specific predetermined time systems such as MTM3. It is in this regard that I fully support the view expressed by the author that the mining industry should hasten towards establishing an Institute of productivity.

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Merton Dagut, M.A. (Rand)*: As one involved in some of the calculations behind Mr McGregor's suggested measures of productivity per man in the manufacturing and construction sectors, I hope you will not think it out of turn for me, a visiting economist, to venture some comments, particularly about the former, and to sketch briefly an economist's ideas about manpower utilization other than in mining.

With the statistical sources available to one in South Africa, one is most hesitant to draw any conclusions about labour productivity—for we simply do not know the number of hours worked and often have the utmost difficulty in determining the value of physical output. Mr McGregor was a brave man, indeed, to have attempted to do so. The lines sketched on Fig. 3, therefore, must be taken only as guestimates of what happened to *output per employee*. They leave aside all the important questions of imputation—quite rightly stressed by Mr McGregor. The questions of what produced how much—the man or the machine—are begged. Thus they are not nearly a true measure of productivity changes which must be measured in physical terms as *output per man hour*.

The confusion which can arise could not have been illustrated more clearly than in Table II of Dr Joughin's contribution. In his attempt to produce 'comparable statistics' he offered us a meaningless exercise: the convenient ten-year period chosen unfortunately ended in 1966—a peak year—and showed how important is the careful choice of a base for short-term average comparisons. More fundamental is the point that the contributions to gross domestic product were valued in money terms and therefore agglomerated, at varying levels of prices, the value and quantity of actual gold output, manganese ore, coal, etc. and compared these with the money values of other goods produced by the economy. Despite appearances, like was not being compared with like. Furthermore, total product was divided firstly by the number of White workers and then by the number of Non-whites. The question of who produced what was not asked. As one knows that the number of Whites employed in the mining industry barely grew over the period and therefore that Non-whites were substituted for Whites as units of input, a calculation attributing the increased value output to the factors which did not produce it, is patent statistical nonsense. I offer this comment to stress that productivity must be measured in physical terms per unit of time input if accurate conclusions are to be drawn.

There is, however, a sufficiently high degree of correspondence among the various curves offered by Mr McGregor to make one feel reasonably confident in asserting that they do show something about the effectiveness of how men were employed. That this is so is suggested further by one's knowledge of the behaviour of the profits of listed manufacturing companies. An article we published recently in out *Quarterly Economic and Financial Review* examined profits through the boom years of the sixties. Between 1958 and 1969 before tax profits of these companies grew at an average annual compound rate of 7.8 per cent. Profits of commercial companies by comparison grew by 10.5 per cent compound on average. The difference in these rates is interesting and the relatively less good (although in itself excellent) performance of industrial profits must have been brought about because industry, as compared with commerce, is more sensitive to changes in the availability and prices of raw materials and capital equipment, to import competition and to labour bottlenecks. Even more significant, though, is the fact that *most* of this growth in profits occurred between 1961/2 and 1964/5—that is, exactly the period during which Mr McGregor's curve number seven moved upwards most rapidly. Profits then grew far more slowly as the growth of output per man curve flattened out and, significantly, perked up again to mid 1969 as the plotting of later figures have pulled up the curve on the graph. Thus one has strong evidence to suggest again the relationship between profitability and more full utilization of resources or inputs. A simple fact, but a very true one.

The second set of comments is to suggest a slightly different way of looking at the reasons offered by Mr McGregor for the relationship between the decline in the rate of increase of output per man and the decline in the rate of increase of gross investment and the absolute fall in its level in 1968. One could argue cogently, I think, that as gross fixed investment is itself a large component of domestic output and that it is, in the main, itself the result of output of capital intensive industries, we have a sort of automatic causality or auto-correlation problem. Investment outlays grew at an extraordinarily rapid pace between 1962 and the mid-sixties and this may have brought automatic increases in aggregate output per man. As these outlays began to grow less rapidly the structure of total *output* and hence of *employment* changed from slightly less to slightly more labour intensive activities. This is in terms of the assumption that consumer goods industries, like services, tend to be more labour intensive than capital goods industries. This slight shift to an

emphasis on more tertiary industrial activity—which was in response to the consumption led boom enjoyed by the country—may have itself helped flatten the curve between 1965 and 1968. The reasons underlying this phenomenon are of importance to industries other than manufacturing.

It is useful also, perhaps, to look at the increases in employment in manufacturing industry which occurred over the eight years. Between 1961 and 1965 manufacturing employment grew by 7.8 per cent compound per year, the corresponding figure for the next four years, 1965-1969, was only 4.4 per cent. So not only was growth in the output of each employee falling—from 3.0 per cent in 1961-1965 to 2.4 per cent in 1965-1969—but also the increase in the number of bodies employed was falling. Incidentally, but of importance, is the fact that the number of registered unemployed Whites, Coloureds and Asiatics which, quite high for South Africa at 30 381 in 1961, fell by more than 50 per cent to 11 653 in 1965 and has since fallen to only just under 11 000 people. Thus not only does it seem that the bottom of the barrel is being scraped but also that most of the new employees must be African.

I would not like these statements to convey the impression that I believe that new African employees of necessity must contribute less to the growth of output per man than new other employees. It is quite possible to argue that as the rate of growth of overall money demand in the country (as measured by gross domestic expenditure) fell by almost 23 per cent in 1965-1969 as compared with the 1961-1965 period, but that the rate of growth of real satisfied demand (i.e. G.D.E. deflated to correct for price changes) fell by almost 44 per cent comparing the two periods, it was the appearance of a series of bottlenecks in manufacturing industry which halted the increases in output per man—not the fact that the new employees were African. I believe that these bottlenecks, in main, can be attributed to a shortage of *labour made available*—not an absolute shortage but a shortage of skilled workers who may be employed.

It seems to me that the figures for 1969 bear out these several contentions. Of a total of 69 800 additional manufacturing employees taken in that year 58 900 were not White and the proportion of Whites to the total fell from 25.2 per cent of the previous year to 24.5 per cent. In that year too, output per employee increased by 3.3 per cent.

N. C. Joughin, (Member), **N. G. W. Cook,** (Visitor): There are two main reasons why we feel obliged to comment on this paper.

The first, and less important, of the two reasons is that since some of the statistics quoted in the paper were obtained from the Statistical Department of the Chamber of Mines, readers may erroneously form the impression that the views expressed in the paper are officially endorsed by the Chamber of Mines. The Chamber of Mines recognizes a need to improve labour productivity in the mines, mainly because of the general shortage of manpower.

The second, and most important, reason is that the analysis in the paper makes use of a number of questionable assumptions which result in errors and conclusions which divert attention from the most important problems confronting the gold mining industry by representing manpower productivity as the major problem.

Mr McGregor uses the ratio of the Real Gross Domestic Product and the total population as an index for 'general standard of living' and as an index for 'manpower productivity'. While this may be a useful indicator in a highly industrialized country with a uniform population, it is a very bad indicator in South Africa which has a complex, very heterogeneous population where the Whites, forming about 20 per cent of the economically active population, can be classified as 'industrialized' and the Non-Whites can be classified as 'developing'; to use the jargon of international relations. The ratio reflects neither the standard of living and productivity of the Whites nor that of the Non-Whites. Its significance is obscure since the ratio of economically active Whites to Non-Whites varies from 0.07 tp 4 in the different productive sectors of the economy.

The rate of change of the real G.D.P. per capita needs to be treated with extreme circumspection. Firstly, the contribution to the G.D.P. by each of the productive sectors is changing at very different rates, and secondly, the ratio of Whites to Non-Whites is changing rapidly and at a different rate in each of the productive sectors. Thus, the overall rate of change of 2.8 per cent per annum in the real G.D.P. per capita, as used by Mr McGregor, is not very meaningful as regards productivity, especially when making comparisons with a specific productive sector, such as the mining industry.

Another objection that we have to Mr McGregor's analysis is that totally different criteria, which are corrected for depreciation in different ways, are used as measures of productivity in the different productive sectors. The real G.D.P. per head of total population is used as a measure of national productivity. The tons milled per annum per employee, with differentiation between Whites and Bantu, is used as a measure of productivity in gold mining. The gross and net value of output per employee are used as measures of productivity in manufacturing and construction. The physical volume of production index is also used for manufacturing, and it should be noted that the rate of change of this index differs substantially from the rates of change in the other measures of productivity for manufacturing.

The choice of tons milled per annum per employee in the gold mining industry is particularly unfortunate for the following reasons. Firstly, the tonnage milled does not represent the product or the value of the product from mining. Over the life of the gold mining industry, the grade of ore being mined has more than doubled and the rate of production of by-products has changed substantially. For example, uranium production in 1968 was about half that in 1958; this affects both the value of the products and the number of White employees, without changing the tons milled to a great extent. Secondly, geological conditions affect the tonnages mined and the stoping widths. On a narrow reef, a large tonnage for a given area mined would, in fact, be indicative of inefficiency. It is most significant that the proportion of gold mined from narrow reefs has increased from a few per cent to about 80 per cent in the past 20 years.

It is misleading to claim that the data in Table I of Mr McGregor's paper represent a 'massive expenditure' on machinery which could be expected to improve manpower productivity. Much of this expenditure is associated with the opening of new mines and the problems of mining at greater depths, and is trivial in relation to the total capital investment on the mines. It is of interest to note that the mines in the Evander area have the best performance in terms of tons milled per employee, yet these mines are the least mechanized.

TABLE I

THE CONTRIBUTION TO THE GROSS DOMESTIC PRODUCT BY THE PRODUCTIVE SECTORS OF THE ECONOMY AND THE ECONOMICALLY ACTIVE POPULATION IN THESE SECTORS FOR 1960

Sector	G.D.P. $R10^6$	Whites 10^3	Non-Whites 10^3	G.D.P./ capita	G.D.P./ White	G.D.P./ Non-White	Percentage Whites
All	4 829	1 151	4 570	840	4 190	1 060	25.2
Agriculture	588	119	1 570	350	4 900	375	7.0
Mining	656	61.7	554	1 070	10 600	1 190	10.0
Construction	140*	72.4	203.7	506	1 940†	686	26.2
Manufacturing	916	210.7	433	1 420	4 340	2 110	32.8
Electricity and Water	121	10.5	29.1	3 060	11 500	4 150	26.5
Transport Storage and Communication	493	115.8	89.3	2 400	4 260	5 500	56.4
Commerce and Finance	810	255.6	262.4	1 560	3 180	3 090	49.2
Government and other Services	902	260.3	989.4	914	3 460	722	20.8

*The G.D.P. for Construction is for Contractors only.

†The G.D.P. for Contractors divided by the Economically Active White is R1 940, but the G.D.P. per White Employee is of the order of R5 000.

Virtually all of Mr McGregor's conclusions as regards the changes in productivity in the mining sector and differences in productivity between the different mining areas are in error, for the reasons stated above. It is a simple matter to compare the productivity between the various productive sectors by simply using the contribution to the gross domestic product from each sector and the labour employed in that sector. Tables I and II show data compiled from 'South African statistics 1968' (Bureau of Statistics, Pretoria). Unfortunately, the data are not complete for every sector and they do not cover the same periods, so that an up-to-date analysis cannot be made; but at least they come from one source and have been compiled in a uniform manner. Table I shows the contribution to the G.D.P. and the economically active population in the various sectors. If the ratio of G.D.P. to the economically active population is used as an index for manpower productivity, then the productivity of Whites in mining is more than twice that of Whites in any other sector except electricity, gas and water supply. The G.D.P. per economically active Non-White is highest in those sectors where Whites are in the majority, and is critically dependent on the proportion of Whites active in each sector. Clearly the G.D.P. per Non-White is a poor indicator of Non-White productivity and the G.D.P. per capita is little better.

Table II shows the rate of change in the G.D.P. and in the G.D.P. per employee in those three sectors which Mr McGregor analyzed. The improvement in G.D.P. per employee for both Whites and Non-Whites in mining exceeded that in other sectors. Thus, the data in Tables I and II indicate that the mining industry has, in fact, led the economy in terms of the level of productivity of the Whites and the rates of improvement in productivity of Whites and Non-Whites. This is in direct contradiction with Mr McGregor's conclusions.

TABLE II

CHANGES IN THE G.D.P. AND THE G.D.P. PER EMPLOYEE OVER THE PERIOD 1956 TO 1966

Sector	Change in G.D.P. per annum %	Change in G.D.P. per White employee per annum %	Change in G.D.P. per Non-White employee per annum %
Mining	7.1	7.2	5.4
Manufacturing	8.5	3.8	3.6
Construction	9.7	5.2	2.6

The economic structure of the gold mines is such that the working profit is not very sensitive to changes in productivity. The total working profit for those gold mines that are members of the Chamber of Mines is 41 per cent of the revenue, while the total wages, salaries and allowances for Whites amounts to 16.7 per cent of the revenue and for Bantu to 8.2 per cent of the revenue. Thus, even if it were possible to double the productivity of the Bantu, that is, effect a 100 per cent improvement in productivity without any increase in wages or other costs, the profit would be increased to 45.1 per cent, which is only a 10 per cent improvement. In principle, it is technically feasible to improve the stope Bantu labour productivity by more than a factor of two by increased stope mechanization; however, the mechanized system results in an increased cost of production[1]. The profits are twice as sensitive to changes in White productivity as to changes in Bantu productivity. However, Whites are already at a high level of productivity. A more thorough analysis of avenues open to improving the profitability of mining has shown that only slight improvements in profitability can be attained by substantial improvements in labour productivity[2].

On the other hand, the profits of a mine are extremely sensitive to the grade of ore mined. Thus, as the price of gold has remained fixed and inflationary pressures have pushed up costs, the mines have been able to maintain profits by mining a higher grade of ore. Consequently more and more gold, currently amounting to some 10 million kg, has become unprofitable to mine. The biggest problem facing the industry is that it will come to a premature end if something is not done to enable the ore that may otherwise be left unmined to be mined at a higher profitable grade.

When one examines the distribution of gold in the reef, two important points are apparent. Firstly, most of the remaining gold occurs in reefs very much narrower than typical stoping widths, consequently the possibility exists for upgrading the ore by decreasing the stope tramming width. The Mining Research Laboratory of the Chamber of Mines has been very active in this area and has demonstrated the feasibility of rockcutting[3] as a means for more selective mining of the gold-bearing portion of the reef in thickness. Secondly, the gold distribution is such that on a large scale there are regions of enrichment and, on a small scale, there are small, relatively widely spaced patches of enrichment. With the current methods of evaluating the reef, it is not possible to recognize the enriched regions with sufficient precision so that they

may be mined and the unpayable regions left unmined. As a result, rich and poor regions are mined together yielding a low, often unpayable, average grade of ore. It is feasible that the reef could be demarcated much more accurately with new evaluation methods[4] so that the ore could be upgraded by more selective mining in plan.

We believe that if these methods for mining more selectively can be perfected, the gold mining industry will still have a long and profitable future.

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Dr. W. S. Rapson (Fellow): The scope for continuing increases in the employee productivity of those mines engaged in the recovery of gold from the Witwatersrand series must be considered in the light of a number of significant factors such as:

(a) The increasingly difficult conditions as mining progresses to greater depths. These must inevitably offset a proportion of the productivity increases that are achieved.

(b) The thinness of the reef, and the hard abrasive character of the rock. These make mechanized equipment very difficult to design and operate in these mines.

(c) The restrictions which exist on the uses to which the unskilled and migratory African labour force can be put. These severely limit the benefits which can be derived from increased mechanization, which calls for more skilled labour.

In his failure to take these factors, and particularly (a), into account, the author's treatment of his subject is inadequate. Moreover, in formulating his conclusions based upon this inadequate treatment, the author has failed to inform himself concerning the role and activities of the Chamber's Research Organization, with the result that he has presented these incorrectly, and because of this has been led to misleading and incorrect conclusions.

Prior to the establishment of the Mining and Collieries Research Laboratories of this Organization, and during the first years of their existence, careful consideration was given to the possible benefits to be derived from the application of the techniques of operations research in the industry. As a result it was concluded that operations research as then applied in Europe and America offered limited scope for effecting significant improvements in productivity.

The conclusion reached was that it would be more advantageous to concentrate attention upon a variety of technological problems which were seen as adversely affecting safety, productivity and profitability. Accordingly over the past five years this approach has been followed, and has evolved into a methodical analysis of the complete mining system. This has identified specific scientific and technological problems, solution of which is essential to improving the efficiency of mining.

The beneficial impact of the first of this work is already being felt throughout large parts of the gold and coal mining industry. For example, the layout of stopes and service excavations of most gold mines is now planned to achieve maximum safety and productivity, using computer techniques evolved by the organisation. Improved stope support resulting from a proper understanding of its requirements is also finding widespread application, and also proving of substantial benefit to the mines, in respect of safety, productivity and materials costs. Design and development of new equipment has been a consequence of these activities, and only now, for example, are items of equipment designed and developed by the organisation, in collaboration with manufacturers, being brought into use.

The organisation's work on rockcutting aimed at making possible more selective mining of the gold-bearing reefs has received a great deal of publicity because of the tremendous scope this development offers for increasing the profitability of gold mining. However, it is only too easy to forget that this development is a direct consequence of a logical analysis which identified the weaknesses in the present system of mining which result in a very low ratio of annual revenue to capital used, and create onerous problems of strata and environmental control, which limit the depth to which mining can be pursued.

An exciting feature of this systematic analysis of the mining system is that it has led logically to attempts to simulate mining activities using both digital and analogue methods.

Thus, as is reported in the 1969 *Research Review* of the Chamber, the present state of knowledge of the physics and mechanics of mining is such that it is now possible to consider the construction of a realistic computer model for a complete mining system. Such a computer model for gold mine investigations is currently being built up in stages, from models of each aspect of mining. As each model is built up it is being used to study that particular aspect.

In terms of current planning the gold mining system is being divided conveniently into three basic aspects. These are stope layout, access layout and environmental control, and it is appropriate to say something of each of these in turn.

Firstly, simulation for stope layout incorporates knowledge of the distribution of ore values, strata control limitations, methods of mining, labour utilization, and their effects on production costs. As a first step a computer programme which simulates the stoping activities of drilling, blasting and scraping has been written. It is hoped to present an account of this to the Institute during the course of the next year.

Secondly, access layout includes the disposition and size of shafts, haulages, reef drives, raises and ore passes, and the rockhandling and transport equipment associated with them. The model for this aspect should reveal the behaviour of different access layouts permitted by stope layouts and strata control restraints.

Thirdly, environmental control places important physical and financial constraints on the stope and access layouts. The first step in tackling these problems has been the successful development of computer models for simulating heat pick up in airways and in stopes.

The value of these simulation facilities which are being built up in the Simulation Division of the Mining Research Laboratory lies in the capacity which they provide for effective planning and design of mines, and the experimen-

tal study of mining problems. The usefulness for planning and design is self evident, since plans or designs can be tested well in advance of their execution to determine optimum conditions and to avoid costly mistakes. The usefulness in the study of operating problems is hardly less important, since it enables mine managements to assess the effects of changes in mine practice quickly and effectively without recourse to costly, long drawn out, and often inconclusive underground trials. In fact simulation seems destined to become an increasingly important tool so far as mine development and management is concerned. *Conventional operations research is in our view much less rewarding than this true simulation approach to mining problems.*

These developments are of course being pursued in respect of what is one of the most complex of mining systems. For the less complex conditions of coal mining, parallel developments are also taking place rapidly through the activities of the Mine Planning and Computer Applications Division of the Collieries Research Laboratory.

Thus a recent investigation has shown that computer simulation of the operations in a mechanized coal section is feasible. Very good correlation between actual and predicted productivity was found. Already as a result, such simulation is being applied by collieries to uncover bottlenecks in production in specific operations, and to specify remedial measures. It is also being used to evaluate the operational characteristics of new equipment and mine layouts, and so enable colliery managers to make decisions more quickly and cheaply than has been possible to date.

Another development which is finding extensive application is the computerized evaluation of coal reserves.

One of the first problems of mine planning is the evaluation of exploration data. In order to assess the viability of a proposed project and to plan for optimum extraction, it is essential to determine both the quantity and the quality of mineable coal in the various parts of the field. A suite of computer programmes has been developed to do this task.

First, geometrical and quality data are stored in a master file on the basis of a regular co-ordinate grid. This master file can be up-dated in order to ensure that the most reliable information is stored at any one time.

The data are then processed on the assumption that the bord and pillar method of mining is employed.

The pillar sizes are calculated as a function of depth, seam height and other parameters. In multi-seam situations requirements concerning pillar super-position and minimum parting between seams are taken into account. After these and other basic constraints, such as quality limitations and mining height restrictions have been satisfied, the extractable reserves of a block are maximized by selecting the best combination of seams for mining. On the basis of these selections, quality parameters are compounded over specified portions of the field. Output is presented in the form of detailed tables as well as key plans, indicating the optimum seam combinations in different areas. The computer can be requested also to produce tonnage breakdowns into quality intervals.

In brief, therefore, and in contrast to what has been stated by the author, the Chamber's Research Organisation is as a matter of policy devoting a major portion of its energies to analysis of mining systems, and its primary purpose in so doing is to increase productivity and safety. It is, however, concentrating upon the development of exact simulation techniques for this purpose, because of a conviction that such techniques provide a sounder and more efficient basis for increasing productivity and safety, than the application of conventional operational analysis methods.

A. A. Hazel*: The author is to be congratulated on presenting this paper which shows how little improvement has been achieved in productivity over the last 10 years.

In this contribution the following four points made by the author, are discussed:

1. Improvements in European productivity have resulted mainly from the automation of mechanical equipment and the use of computers to eliminate clerical functions.
2. Stope and development productivity has increased little in spite of considerable mechanization, e.g. an increase of 104 per cent in scrapers, loaders and winches.
3. The 'old fashioned' mining methods still result in the highest overall productivity, viz on the East Rand and the Evander area, where the strike track system is in common use.
4. Bantu productivity has increased less than one per cent per annum over the last 10 years.

It is well known in the gold mining industry that fewer and fewer Europeans are seeking jobs, and the European labour force is gradually dwindling. This has resulted in improvements in productivity by force of circumstances rather than by design. We must expect that as the extent of secondary industry increases, the mines will be compelled to work with still fewer people. In view of this, future productivity increases must be planned, otherwise total production will suffer.

The author has shown that increased mechanization underground has had little effect on the overall productivity. If we cannot depend on mechanization to solve our problems, which path should we follow? I suggest that we look to the development of human potential. Events to date have shown that improvements are possible. How much more can be achieved if only we consciously try to develop this potential. We all know of individuals who have shown considerable improvements in productivity, and we also know of the tremendous gap which exists between the best and the worst. If the reasons for individual success can be found, they can be used to develop the productivity of others. In fact, this is the most fruitful and cheapest solution of all. On the Winkelhaak Gold Mine the average productivity of stopers has been improved by 50 per cent in 12 months by using the following methods:

(a) Allocating stope machines to miners according to their ability.
(b) The placing of miners in stopes where they can realise their full potential.
(c) Monthly planning for optimum machine utilization, in accordance with a carefully planned cycle of operations for each stope.
(d) The teaching of stope organization to those miners at the bottom of the productivity list.
(e) The setting of monthly production objectives, jointly between mine overseers, shift bosses and miners.
(f) The use of weekly measurements of centares and metres as control measures, rather than the number of holes drilled.

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(g) The use of work study to show where and how improvements are possible.

(h) The improvement of the strength of the organization by
   (i) delegating authority
   (ii) concentrating on clear objectives
   (iii) developing the management skills of all mining personnel
   (iv) placing full trust in each level of management

(i) The building up of a stable labour force by:
   (i) improving earnings which must be based on improved productivity
   (ii) engaging miners of proven ability only.

A paper giving full details of these methods is at present being prepared.

With regard to Bantu productivity, recent studies in the Evander area have shown that stoping and development performances lie between 54 and 87 per cent. On the work performance scale, 100 per cent performance can be expected from a suitably trained and motivated person with an 'all out' performance of 125 per cent. The main reasons for low Bantu productivity are:

(a) ineffective European supervision
(b) over complement Bantu, resulting from seasonal fluctuations.

The author implies that the mines set their labour estimates too high as a result of the fluctuations in Bantu labour. This may be so, but a little consideration will show how difficult it is to arrive at the correct estimate. The Bantu labour complement should be assessed in the following way:

1. Decide on the target or call for each of the work tasks, i.e. the number of centares and metres, the number of sweeping centares required, etc. Sweeping should not be the work category which varies with the labour fluctuations.
2. Use work study to determine the present work performance levels and the standard minutes for each unit of production.
3. Set the labour complements for each of the work tasks at the 100 per cent performance level.
4. Introduce an effective bonus scheme based on productivity.
5. Compare mine labour requirements with the known fluctuations in labour supply and set the estimate so as to maintain an average work performance level of about 100 per cent over the year.

In fact, the monthly fluctuations on Winkelhaak Mine are such that the Bantu work performance does not reach 100 per cent. As a result, the cost of the 'over complement' is estimated at R70 000 per year.

Moreover, an efficient labour force should be able to work at 100 per cent performance throughout the year, and at 105 per cent for short periods. If this could be achieved, the labour estimate could be reduced to give an average work performance close to 100 per cent, approaching 105 per cent for perhaps 10 per cent of the time. The saving in labour costs at this higher efficiency would be at least R45 000 per year, and a more satisfied labour force would result due to higher bonus earned.

Labour fluctuations are such that it is extremely difficult fo make correct labour estimates. It is surely worth a great deal of time and effort to devise ways and means of maintaining a more even supply of Bantu labour to the mining industry.

I wish to record my appreciation to the Consulting Engineer, Union Corporation Ltd., for permission to publish this contribution.

J. R. Brett, B.Eng. (Mining) (Member): Mr McGregor is to be congratulated on the presentation of his paper. The facts have been given and the problems set out in a clear and concise manner, with a minimum of data and no clutter of statistics.

This contribution is intended to be complementary to the main paper, which is, in some ways, incomplete. The condition has been diagnosed but no treatment has been recommended.

From the many contributions submitted at the presentation of the main paper, it was obvious that statistics could be produced to show results contrary to those suggested by Mr McGregor. However, the industry stands to gain considerably by improvement of manpower utilization, so why not accept the findings and do something about improving them?

What can be done?

As I see it, there are three steps required in the process of improving manpower utilization. The first step is to assess the existing systems and determine their potential. In other words, what is our performance under existing conditions and by how much can we improve it?

The second step, assuming an improvement is possible, is to find how to obtain the required improvement.

Steps 1 and 2 are required for one of two reasons. If the maximum potential of the present system has already been attained, efforts to improve production will meet with little success. If that potential has yet to be fully attained, we should exploit it to the full before changing the system.

Having completed steps 1 and 2 and achieved what might be called 100 per cent or standard performance using existing systems, we reach a stalemate unless the system is changed or varied to permit further improvement. Determination of changes or variations to permit this further improvement is step 3.

Union Corporation Limited has, to a degree, started on all three steps.

STEP 1: We have recently carried out a series of studies on stoping, developing and sweeping operations which have enabled us to assess the work content of the various operations and so determine the present operating efficiency. We have concentrated on Bantu labour only, for, if we can improve Bantu productivity whilst maintaining the same European/Bantu numerical relationship, we must achieve a commensurate improvement in European productivity.

This is probably the first time such detailed studies have been carried out and a paper describing them will, it is hoped, be presented in the near future. For this reason, further explanation here is unnecessary except to define efficiency as referred to below.

Efficiency or percentage performance can be defined as work input divided by work output expressed as a percentage. Knowing the work content in labour effort required to achieve a certain production rate (which we do from our studies) and recording the labour time actually spent, we can calculate performance.

The results show that at present our stoping operations, for instance, are about 80 per cent efficient, labourwise.

We must improve this performance to 100 per cent, or standard performance.

STEP 2: From the results of the study, it has been possible to propose a bonus scheme based on performance. It is felt that using this bonus scheme sufficient incentive will be given for standard performance to be achieved throughout the mines of the group.

Table IV of Mr McGregor's paper shows that the Evander area is far above other areas in labour efficiency. This is not at the expense of working costs, another measure of productivity; average working costs for the Evander area for 1968 were R5.12 per ton milled compared to an industry average of R6.29.

The mines in the Evander area are not any easier to work than mines in other areas. Hanging wall conditions are not particularly good, faulting is prolific, reef is being worked to depths of more than 1 500 metres and payability is erratic. All four mines use the strike track system of stoping, handlashing into $\frac{3}{4}$ ton cars being used in stope tracks. Scrapers are used in centre gullies only.

Why, then, are these mines more efficient than those of other areas where payability is good, dip is constant, faulting is negligible and long scraper faces are worked?

Either the overall labour effort required is less or the performance achieved is that much better. Does the difference lie in stoping activities or in other aspects of underground work? Studies, similar to those carried out in our mines, may give an answer to this question.

STEP 3: In looking ahead to the time when the average stoping performance achieved is 100 per cent, we must try to visualize the changes that must be made to maintain an improvement in productivity. With the strike track system, we find the bottleneck to any improvement will be handlashing. Lash, tram and tip represent 50 per cent of the work content per unit in a stope. Drilling, blasting, support, etc., form the remainder. For this reason we are concentrating our efforts on improving lashing performance. We are at present engaged in testing the suitability of using a small (1 cu yd capacity) load haul dump machine in 'track' cuttings to replace the lashing boy. These machines load in the face, tram to the gully and tip into the gully scraper path. We hope to improve stope productivity by 100 per cent (i.e. increase tons per Bantu shift from 3 to 6). Overall mine efficiency could then increase from less than 1 ton to $2\frac{1}{2}$ to 3 tons per Bantu shift by virtue of the savings made possible by extremely concentrated mining techniques.

I would make the following general comments on Mr McGregor's paper:

1. When comparing improvements in productivity in different areas of the mining industry, it will be appreciated that it is far easier to improve productivity in mines with a present poor efficiency than it is in mines with an already good efficiency.
2. When introducing mechanization to any project in order to increase output per manshift, the introduction of the machinery must be accompanied either by a reduction in labour strength or an increase in the rate of production. All too often, machinery is introduced without either of these requirements being achieved.
3. When the number of Boss Boys at work in the mining industry increased, the increase is in many cases due to a reduction in European labour strength. Extra Bantu supervision (Boss Boys) increased productivity per gang and consequently per ganger or European.

In conclusion, I will leave you with this thought which may be considered irrelevant at this time, but in, say, 10-15 years, may be extremely relevant. It is said that 'necessity is the mother of invention'—how would the South African gold mines operate at a profit if they were situated in Europe and minimum wages for production workers were of the order of R3 per hour? How would we achieve the requisite stope production of 40 tons/man shift instead of less than 3 tons/man shift as at present?

My thanks are due to the Chief Consulting Engineer, Union Corporation Limited, for permission to publish this contribution.

Author's reply to discussion

In replying to the extensive and well-informed contributions to my paper, my strongest impression is that of regret that space does not allow me to do justice to the care and research upon which they have been based. There is no doubt that in these 12 000 words or so of written contribution, there is material for at least two basic and original papers. I hope that eventually these will be produced. For the time being, I hope contributors will view with understanding my brief and inevitably, through space limitation, somewhat superficial comment.

Mr Keeley: Some extensive original research has been made in the endeavour to analyze the reasons for what is accepted as an apparently disappointing overall rate of improvement in labour productivity. Tonnage broken per month per Bantu employed underground on all areas of the gold mining industry between 1937 and 1969 has been analyzed to give a compound interest increase over this period of one per cent. This corresponds exactly to the figure given in my paper for the years 1958 to 1968 using tons milled as the basis. Mr Keeley has developed a mining factor which represents an index of 'the difficulty of extraction'. He states that productivities should be multiplied by this mining factor to give a comparison in absolute terms. I am impressed by this approach, as representing a conscientious endeavour to make the comparison. Nevertheless, I cannot overlook the fact that those who were responsible for fixing the price of the product at $35 per ounce take no account of the difficulty of mining. In the end, it is the ability to produce the product at a price that the market will accept which is the ultimately decisive factor in whether a business keeps going.

Mr Keeley feels that 'the regular improvement of $1\frac{1}{4}$ per cent per annum for the industry as a whole is merely the fortuitous result of adding together a number of unrelated positive and negative trends, and by itself

is valueless as a measure of improving efficiency'. I accept this only with reservations because what we are interested in is the utilization of the country's basic resources. The dividend paid by, for example, the Anglo American Corporation is 'the result of adding together a number of unrelated positive and negative trends' in the performance of its component companies. Nevertheless, the figure reached is of great importance and value to the shareholders. We are all shareholders in South Africa, and it is the pay-off which counts.

In his most interesting paragraph on the analysis of capital, and its relationship to working costs, Mr Keeley says that '60 years of mining experience have not succeeded in altering costs. The obvious conclusion is that increases in efficiency have almost exactly balanced increases in the mining factor'. Having regard to the rising complexity of mining over this period, the tremendous increases which productivity must have made in order outwardly to remain somewhat static gives rise to interesting speculation using the extension of Mr Keeley's argument. If these enormous increases were possible as they must have been to balance the 'increased difficulty', why did they stop short at only one per cent better than every previous year? Might not the enthusiasm and technical innovative ability which produced such undoubted improvement be capable of even greater improvement in the light of modern concepts of what is possible? Mr Keeley's argument seems to strengthen the case for higher improvement in labour productivity in future than in the past.

Mr T. Watt: I am heartened by the support this contribution gives to the need for the establishment of independent operations research facilities. However, I wonder how far these facilities would ever see the light of day if they happened to reflect adversely on the performance of local management. Somehow, it is difficult to see an avenue of success which does not incorporate utilization of the vested interests of that group which is responsible for achieving the results. This represents a fruitful avenue of future investigation.

Mr J. M. Pike: This contribution is a most interesting description of the way in which an ageing mine can recognize a difficulty and overcome it by systematic planning. Mr Pike says 'shafts and compound capacities could not cope with a higher complement . . . . thus the mine's future rested on a mechanization programme' (presumably because this will improve productivity).

From information submitted, E.R.P.M. has improved its tons milled per Bantu from 13.8 to 17.3 over 10 years to 1970, which is equivalent to an increase each year of 2¼ per cent. It is most interesting to note that this mine, amongst the oldest and certainly the deepest in the industry, has produced an improvement on its own record, greater than that averaged by any of the five main geographical areas of the industry, and approximately equal to the target productivity improvement for the Republic as a whole. This achievement is heartening indeed.

Mr Pike asks elsewhere whether we are correct in assuming that an increase in Bantu productivity is a primarily desirable objective. My paper does not set out to answer this question over every sector of the economy, but merely bases its standpoint on the obvious position that labour productivity of the economy is inseparable, in total, from improvement in the standard of living.

Mr Pike also places capitalization of the expenditure to replace one Bantu labourer at current rate of interest, including amortization, at some R2 000. He goes on to question whether this justifies modern equipment costs. Would it perhaps not be more correct to point out that his figure is a minimum, and even then a marginal expenditure of say R200 000 to save 100 Bantu is often economic in the mining context. But how much more economic is it if the labour so saved can go onto ore production as was the case in the E.R.P.M. example Mr Pike gives, because shaft and compound capacity placed a ceiling on labour employment. The mine is surely to be congratulated on making what must have been a very profitable investment in labour productivity.

Mr E. W. Thiel: The disappointing improvement in Bantu labour productivity is accepted, and the contributor offers comment in mitigation of this state of affairs. Whilst agreeing the value and validity of the points made, surely we should concentrate on plans for future improvement rather than apologia for the past. The restless and dynamic search for future improvement should not be held in check by all the valid reasons as to why it was not done before.

The contributor comments that analysis of productivity on a regional basis is meaningless and conclusions based on it are fallacious. I wonder if perhaps he has not missed the point of my arithmetic which was not to compare one area with another, but to compare each area with its own previous performance. This is statistically valid and is, amongst other things, the basis for evaluating progress in such questions as accident prevention where conditions differ greatly as between one plant or mine, and another.

Dr N. C. Joughin: I think that in some respects this contributor has missed the essence of my presentation, namely that, as pointed out in relation to Mr Thiel's contribution, no attempt has been made to make an absolute comparison of productivity, as between the various sectors of the economy, but only to compare each sector with its own previous performance. This, for reasons I have pointed out in my comment on Mr Thiel's contribution, is valid, an aspect which Dr Joughin seems to have missed entirely, particularly in drawing the conclusion that 'the productivity of Whites in mining is more than twice that of Whites in any other sector except electricity, gas and water'. Even assuming the validity of Dr Joughin's figures, which are open to serious question because of the absence of any price deflation, my paper made no effort to compare productivities of mining, construction and manufacturing in absolute terms. Dr Joughin's figures though perhaps interesting are, I think, irrelevant in the context in which they are given. From the standpoint of an economist, Mr Dagut, in his contribution, commented adequately on these aspects of Dr Joughin's remarks which he said 'offered us a meaningless exercise'. With this view I agree.

Finally, I am grateful to Dr Joughin for his contribution but would ask him to analyze the productivity performance of the mining industry over a period and to assess its performance against itself. If he can develop a more valid basis than 'tons milled' or, as Mr Keeley, 'tons handled', he would, I think, be making a valuable contribution.

Mr E. Margo: Several important principles are enunciated in this characteristically carefully thought-out contribution. Perhaps the most important of these is 'the Bantu because of the nature of his employment and the organizational environment in which he operates is the only significant measure of labour productivity'. The contributor proceeds to substantiate this statement

with strong logic. He points out that growth in a dynamic system is obtained through the organizational environment providing the means and opportunity together with training and education, in which the relevant skills can be developed and practiced. This is what Dr P. I. Rieckert, quoted by the contributor, has called elsewhere, the 'productivity of the residual factor'. The contributor rightly calls attention to the fact that in the mining industry the unions which control the majority of European workers have vehemently resisted innovations in the work pattern of the overall labour force. He comments accurately that 'this considerable reluctance to change is probably the one single factor which inhibits the labour productivity growth rate'.

The contributor mentions the possible value of an MTM approach. I would comment that a standard productivity estimate of mining operations synthesized on MTM data, would be an enormously valuable and instructive exercise.

This contributor calls attention to massive expenditure on rock handling equipment underground, and in so doing contrasts strongly with Dr Joughin who says that expenditure in this area is negligible in the overall picture.

Mr Merton Dagut: This carefully thought out contribution highlights the difficulties of trying to produce a valid statistical picture and concludes that on balance the exercise is worthwhile.

It is to be hoped that Mr Dagut will in due course present a further paper on this whole question of manpower utilization and its relationship to standard of living, of which he has such a meaningful and penetrating knowledge.

Dr W. S. Rapson: This contributor criticizes my treatment of the subject as inadequate, because he states that I have failed to take into account the increasingly difficult conditions of greater depths, thinness of reef, and the problems of unskilled and migratory African labour. I would point out that I made no attempt whatever to adduce reasons for the trends shown in the statistics I have presented. My object was only to present relevant statistics, unaccompanied by apologia for what they may show. Dr Rapson's statement that I have formulated my conclusions based on this inadequate treatment, is therefore, I submit with the greatest respect, meaningless. It is fully accepted that the Chamber's research organization is doing praiseworthy work, but I fail to see what effect this could have on the trend of a series of results, except to improve them. Future results will doubtless show if this is the case, as I am sure it will be.

Dr Rapson rightly draws attention to the beneficial impact of new and sophisticated use of computer techniques for assistance in planning maximum safety and productivity, and the design and development of new equipment which this has made possible. He goes on to say that 'only now, for example, are items of equipment designed and developed by the organization in collaboration with the manufacturers, being brought into use'. Yet, does Dr Rapson not fall into the trap of criticizing my figures for the fact that they have not yet responded to these important influences? If this is really what he means, then I accept the criticism.

There is no doubt that Dr Rapson's masterly description of the work of the Chamber's research organization is most interesting, and the Institution will benefit greatly from having it on record. Particularly is the contributor's reference to the relationship between operations research and simulation interesting. He says '*conventional operations research is in our view much less rewarding than this true simulation approach to mining problems*'. With respect, I would suggest that simulation is one of the important tools in the operations research kit bag, and in no sense are the two approaches mutually exclusive as Dr Rapson states they are.

Perhaps this contributor will allow me to express the view that the investigation of actual operational production conditions is an indispensable (though by no means the only) component of achieving lasting improvement. Simulation of the production situation is a valuable tool because of its versatility in assessing the effects of change in the component conditions, and having done so for training and other purposes also.

Mr J. R. Brett: This contributor's approach is getting on with the job of improving manpower utilization is wholly to be applauded. The methods so ably described are doubtless significant factors in producing the results already clearly to be seen in labour utilization in the Evander area.

Mr A. A. Hazel's contribution opens up, very thoughtfully, a wide area of useful investigation. For practical purposes, his is the only contribution to emphasize the essentially human aspects of the problem of labour productivity and manpower utilization in the mining industry. He is surely correct when he points by inference to the fact that the reason for unproductive expenditure on mechanization is purely and simply failure to pay the necessary attention to the manpower training and motivational aspects on the strictly human plane.

Mr Hazel seems to me to present a very valid viewpoint, incorporating a balanced appreciation and use of the various tools at his disposal for achieving overall improvement in manpower utilization.

The paper which he tells us is in the course of preapration, covering this work, should be very well worth careful study and will be awaited with interest.