The development and application of a computer system to aid in the planning of production in mines

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Although the Mine Planning Simulation Programme was originally developed as an aid to coal-mine planning, its extreme flexibility has enabled us to simulate gold-mine planning with equal facility.

The initial application of the Mine Planning Simulation Model was in a small area of a large Free State gold mine where the primary aim was to assess the applicability of the programme to the gold-mining situation. Naturally, it was hoped that the exercise would also prove to be of some practical benefit to Management in the overall planning of the area considered; however, this was of secondary importance.

As the area planned to be mined was of relatively small size, it was decided to set the mine plan up in some detail, where stoping blocks worked from separate raise-winze connections were considered. In this manner, the whole area to be mined was divided into twenty stoping 'resource blocks' as shown in Fig. 1. Each block was assigned a 'reserve' in centares (square metres) with an associated 'operations definition' detailing the production rate required in centares per month, and the planned Bantu and European labour complements. Costs were associated with the stoping operation in the form of timber, explosives, and stores costs per centare and labour costs per man-month. Next, the development to be completed in the area to generate stoping blocks was classified into five types, viz, haulage, crosscut, raise, boxhole, and travelling-way. Each separate length of haulage was considered as a resource block with its own reserve, in metres, and an associated operation specifying the rate of development in metres per month and the labour complements required. Again, costs of development per metre and labour costs per man-month were associated with the operation. A transport block for both stoping and developing was included to simulate tramming and hoisting of all reef and waste produced, with a unit cost per ton trammed. A restriction in terms of tons per month was placed on this transport leg, as there was a limitation on hoisting from the subvertical shaft serving the area. Only reef was considered as a separate product for the purpose of the 'product distribution' section of the programme, with a single 'quality number', whose 'quality value' was assigned as grams of gold per ton of reef. In this way, tons milled and gold produced were accumulated and a revenue figure was obtained for a specified gold price.

Once this information was established on the computer, the various planned sequences of operations were simulated. In each case the operations were tied to each other in order to achieve the normal mining sequence, e.g., stoping in a particular block could not commence until the raise-winze connection had been equipped, which was dependent on its being ledged and, in turn, on the raise development being completed. In the original example, the mine production plan was varied by working the area with two, three, and four contractors and by leaving an area of unpay ground unmined.

Four tabulations were prepared by the report generator of data that were considered of use to Management. Examples of values obtained for a two-year period are shown as Tables I to III.

Table I shows typical production figures obtained for the area. Although the over and under mining figures have little meaning over such a small area, they serve to indicate that such a parameter could be obtained when the whole mine is set up. The figures for gold produced are based on survey estimates of grade decreased by the stated mine-call factor and metal-recovery factor.

Table II shows the selected form of costs that were evaluated by the computer programme. The cost of tramming and hoisting per ton is given in the input. However, both the milling cost and overheads cost are derived from a facility within the programme to summate a cost from a fixed and a variable component. Thus, each is made up of a figure in rand per month and rand per ton milled or mined.

Table III shows the total working costs for the area, the revenue from the gold produced within the area, and finally the working profit for the area in alternative forms, including a discount total at a specified rate that is summated to give the net present value of the gold production of the area.

The original plan prepared at the mine was drawn up to use three contractors, and it was of interest to see from the results that the simulation with two contractors offered a possible alternative, and that mining the block of 'unpay' ground increased the profitability of the area, always, of course, provided mill capacity was available.

With the experience obtained from the abovementioned planning exercise and the enthusiasm shown by Mine Management, a small team of Project Engineers has been set up to assist Group Mine Managers in the following types of planning exercises.

(1) The assessment of a series of long-term plans in a new gold-mining area currently being developed as an extension of an existing mine. At this mine, only limited knowledge is available with regard to the gold distribution in the new lease area, and we are interested in evaluating the total economic effects of possible variations in the projected gold values.

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(2) The determination of the most suitable sequence of closing down the three shaft systems of a mine, with special reference to financial returns and the overall life of the mine.

(3) The simulation of a projected two-year mine-production programme, and the effects on this programme of reducing the tons mined in certain low-grade areas, running the mill below capacity by different amounts, etc. In this case, the mine is a short-life mine and there is a need to extend operations by selecting the most suitable parameters to ensure the required profit margin.

In conclusion, the following points should be noted.

(a) The simulation of a mine plan on a computer can provide data that are only as accurate as the

TABLE I

PRODUCTION FROM AREA P, NO. 2 SHAFT, A GOLD MINE

MINING AREA P WITH TWO STOPERS

MINE-CALL FACTOR=80% METAL-RECOVERY FACTOR=96%

Quarter ending		Reef tons mined $\times 10^3$		Av. grade g/ton	Over / Under mining %	Tons milled after 11% waste sorted $\times 10^3$	Gold produced kg
		Stoping	Development				
1972	4,0	16,5	2,2	49,73	117,0	16,6	760
	7,0	14,0	0,9	31,10	73,2	13,3	380
	10,0	14,0	0,8	30,46	71,7	13,2	369
1973	1,0	13,7	1,3	29,81	70,1	13,4	365
	4,0	11,4	0,8	30,43	71,6	10,9	303
	7,0	16,5	0,4	52,08	122,6	15,0	718
	10,0	17,1	0,8	55,11	129,7	15,9	803
TOTALS		103,2	7,2	41,03	96,5	98,3	3698

TABLE II

COSTS FOR AREA P, NO. 2 SHAFT, A GOLD MINE

MINING AREA P WITH TWO STOPERS

Quarter ending		Mining Costs				Tramming and hoisting costs		Milling costs		Overheads and other costs	
		Stoping		Development		R/ton	Total $R \times 10^3$	R/ton	Total $R \times 10^3$	R/ton	Total $R \times 10^3$
		R/Ca*	Total $R \times 10^3$	R/m	Total $R \times 10^3$						
1972	4,0	6,70	38,2	52,6	11,7	0,36	7,0	0,79	13,1	4,44	85,4
	7,0	6,36	28,6	45,1	11,4	0,37	6,7	0,89	11,8	4,66	85,2
	10,0	6,11	36,6	49,1	10,9	0,37	6,5	0,89	11,8	4,86	84,7
1973	1,0	6,79	40,8	57,0	13,0	0,37	6,3	0,88	11,8	5,02	84,6
	4,0	6,06	35,7	78,8	21,2	0,38	6,8	1,00	10,9	4,77	85,2
	7,0	6,40	32,4	74,4	20,7	0,38	9,0	0,83	12,5	3,72	87,5
	10,0	6,23	32,7	63,5	17,2	0,39	9,1	0,80	12,8	3,70	87,5

*Ca=centare

TABLE III

WORKING PROFIT AND LOSS FOR AREA P, NO. 2 SHAFT, A GOLD MINE

MINING AREA P WITH 2 STOPERS

Quarter ending		Working costs		Revenue		Working profit		
		R/ton mined	Total $R \times 10^3$	R/ton mined	Total $R \times 10^3$	R/ton mined	Actual total $R \times 10^3$	Discounted total $R \times 10^3$ at 10%
1972	4,0	10,0	186	37,3	696	27,3	511	498
	7.0	9,7	144	23,4	348	13,7	204	194
	10,0	9,9	147	22,8	338	12,9	191	177
1973	1,0	10,3	154	22,3	335	12,0	180	163
	4,0	13,5	166	22,7	278	9,2	112	99
	7,0	9,7	163	39,0	658	29,3	495	426
	10,0	9,0	161	41,2	736	32,2	575	483
TOTALS		10,2	1121	30,7	3389	20,5	2268	2060

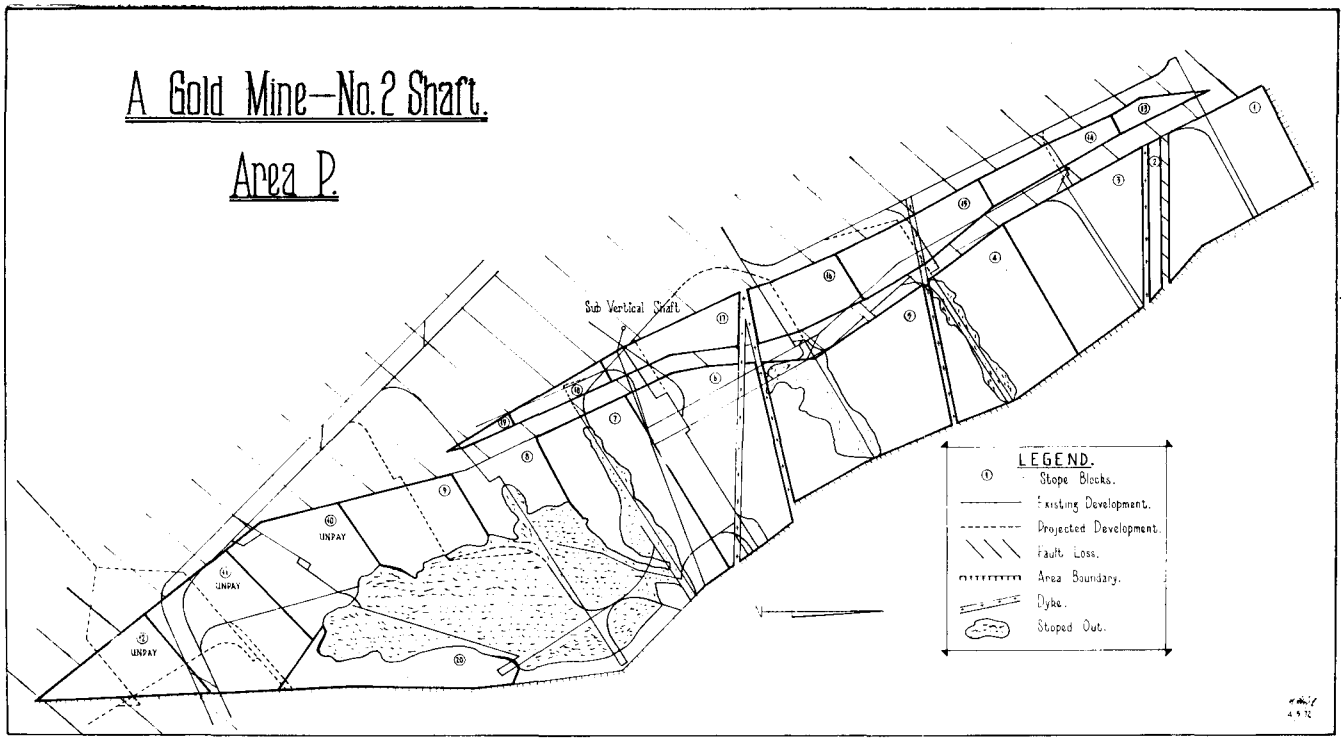

Fig. 1

information given in the input. Thus, the input data must be carefully and accurately established before meaningful results can be obtained from the computer output.

(b) When evaluating the economic implications of a long-term plan on a South African gold mine, one deals essentially with large sums of money—often in the range of tens of millions of rand per annum. Consequently, small improvements in a planning forecast can provide highly significant economic savings for a mine.