Project Design and Analysis

Chairman: Mr. K. F. LANE

Rapporteur: Mr C. T. SHAW

Papers:

Design of crushing plant flow sheets by simulation by T. Gurun

The impact of transportation networks upon the potential supply of base and precious metals from Sonora, Mexico by P. de V. Harris and D. E. Euresty

Profitability sensitivity analysis of a mining venture by C. A. Beasley and E. P. Pfleider

Technological innovation and its potential effect on the opening of new gold mines in South Africa by N. C. Joughin

Mr Turgay Gurun, in presenting his paper, indicated that this simulator was no purely theoretical exercise, but that the model had been used in the design of crushing plants of capacities ranging from 3 000 tons per day to 66 000 tons per day, and that recently the design of a plant of capacity of 99 000 tons per day had been studied.

The crushing plant simulator was an independent portion of a much more comprehensive simulator for the design of a complete recovery plant. It would be possible to use each section of this simulator on its own, and simulators would be designed to cover flotation concentrates, cash flow analyses of the entire project, and so on.

Each simulator would be backed by a comprehensive data bank. For example, the crushing plant simulator was backed by such a data bank which included the performance and cost data from five manufacturers for an average of 30 items of process and materials handling equipment each. This meant that data preparation involved generally less work than would be required for a manual calculation. On average, data preparation for one run took 30 minutes and three minutes of computer time on an IBM 360/40 completed the run. The model could be valuable as a design tool in that it allowed the designers an opportunity to make a thorough examination of many alternative designs. It was also of value to plant operators as it could be used to predict the consequences of operating decisions.

This paper generated much interest and there were numerous questions and contributions, so many, in fact, that the discussion had to be cut short.

It was pointed out by Mr K. F. Lane that crushing plants represented a very large capital investment. A plant designed for 40 000 tons per day at 98 per cent efficiency might well in practice be run at 50 000 tons per day at, say, 88 per cent efficiency. He asked how, therefore, their design could be investigated without building economic criteria into the model? The author conceded that this was a tender point. He would have liked to have given facilities for more variability of the metallurgical information. He pointed out, however, that while there was no overdesign for conservatism built into his system, some overdesign was inevitable as the performance characteristics given by the manufacturers were generally conservative. Also, in his system, if lower recovery was allowed for, the system would put through more tonnage.

Dr Whiten asked how the present crusher product size distribution was chosen to be appropriate to the crusher operating conditions. Mr Gurun replied that initially the manufacturers' information was accepted. However, there were errors of size distribution, particularly if tests were made and it was not taken as constant. This was one of the reasons why the simulator was tested with case studies.

Dr Whiten also asked whether normal screen data did not have a constant split for each size fraction and whether there were any data to justify this model. To this Mr Gurun replied that the simulator had been tested against previously designed and now operating plants. It was found easy to get the size distributions, tonnages and splits which justified the simulator. This test was done against at least a dozen operating plants.

Dr Whiten said that the solution of the equations for the process streams could be factorized into, first, the calculations of mass flows and, second, the calculations of sizing, and that with the models in the paper both these stages were short calculations. He asked whether factorizing was used or whether the simulator solved the matrices. Mr Gurun replied that he did not believe that the calculations were, in fact, simple. In the simulator they did solve the matrix but not by inversion. Many methods were tried for solving the matrix including the numerical method.

An explanation of the calculations of required screening area shown in Fig. 4 was asked for by Dr Whiten. Mr Gurun said that the screen area calculations were very complex, and included such factors as incoming size distribution, efficiency, wetness of the material, the amount of undersize in the incoming stream, and the design of the screen slots. He referred Dr Whiten to the first reference cited in the paper.

Dr R. P. King asked how good the linear characteristics of the model were in view of the fact that the matrices were a strong function of the flow rate. Mr Gurun replied that the model was linear though, for example, the screen analysis was not, but the model worked over short lengths which could be regarded as linear.

Dr King asked also what selection criteria were used for equipment solutions. Mr Gurun said that the selection criteria were very complex, over 100 variables being considered. Crusher selection was two-stage; in the first stage, 12 performance variables were considered and the program would select six to ten crushers that would satisfy these criteria. Then other criteria such as weight, size and price were considered.

At this point the discussion on Mr Gurun's paper was terminated.

Dr De V. P. Harris presented the second paper entitled *The impact of transportation network upon the potential supply of base and precious metals from Sonora, Mexico.* The objective of the study, Dr Harris said, was to provide a basis for estimating potential mineral occurrences, and to translate

these potential occurrences into potential supply. In this instance a special feature was the emphasis on the transportation network.

More detail was given on the method used for gathering data from the local geologists. Figure 1 shows the area discussed relative to the Southern United States which was used as a comparative area for metal endowment. Figure 2 shows the remarkable conformity achieved by the geologists in selecting priority resource areas. Figure 3 shows the other areas selected by the geologists and again it was interesting to note the degree of conformity achieved, although this time not quite so marked.

Each of the geologists was given brand new geological maps of the area prepared with information supplied by NASA, and was promised a set of these maps as an incentive. They then completed three questionnaires. The first was to give a complete table of priority information for each area; the results of this questionnaire are shown in Fig. 4. The second asked them to consider any one area and give probability information for tonnage in that area—this is shown in Fig. 5. Lastly, for any of the above selected areas, they were asked to put probabilities on grades. This is shown in Fig. 6.

All this information was merged on to a common grid giving the result shown in Fig. 2 of the paper. Once mineral occurrences were simulated, exploitation was simulated. In general it turned out that only 26 per cent of occurrences would contribute to supply, but since the expected occurrences were nine times that expected in Arizona, it showed that to the geologists' minds there is a great potential.

From the data obtained the transportation required was simulated. In general the transport network was well situated, but one route required altering. Figure 7 shows a cost benefit analysis of this change in route.

Mr A. Weiss wanted to know whether the authors could relate this work to a similar study done in Alaska. Dr Harris replied that in Alaska they were attempting to infer gross value and did not do simulations except in one instance on the Sere peninsula. The reason for this was that they could not get any information other than subjective information. They even thought of using Arizona as a comparison. In general, in Alaska, they had less information.

Referring back to the paper by B. W. MacKenzie who used a statistical approach, Mr Weiss asked whether it would not be possible to use a multivariate approach as against the subjective approach to get *a priori* the size of the exploration budget. Dr Harris replied that this would depend on circumstances. In this instance they had access to the ten best geologists and so the subjective approach was better. Had they had only maps, however, a multivariate approach would have been used.

Dr Koch asked whether in the interviewing of the ten geologists any measure of operator variability had been arrived at. The reply was that no statistical analysis was done, and as could be seen from Figs. 2 and 3, surprisingly good agreement had been obtained. There was one geologist who gave no useful information on areas, but even he in his other estimates was much in accord with the rest.

Dr Agterberg asked whether it would not be better and easier to analyze using cells on a regular grid as was done in one of the previous studies in Northwestern Canada where subjective probabilities were obtained for each cell of the grid. He asked also what the advantage was in the use in this study of irregular shapes.

Dr Harris answered that as far as processing was concerned, the use of grids was easier. However, in obtaining information from people who could not afford much time, and who were nervous of being completely honest, particularly if the cells were small, better information was obtained if they were allowed a free hand with shapes. The problem in this case was that information in areas that were not 'hot' became very sketchy.

The next paper entitled *Profitability sensitivity analysis of a mining venture* was introduced by Prof E. P. Pfleider. The subject of the paper was work done in the course of his doctoral studies by Charles A. Beasley. The study to determine the relative ranking of various simulators to mining ventures was in two parts. First, the major participants in the general resource-to-reserve conversion process were contacted by a questionnaire which was sent to industry, financial, government and universities and political organizations. About 50 responses were obtained. The second part entailed making a profitability sensitivity analysis on a case example of a marginal large-size copper-nickel body. This formed the substance of the paper.

Numerous computer programs were written or adapted for the study. As a result of this work, rankings were given to the various stimulatory parameters. In the paper, Table I showing these rankings shows price level as ranking number 4. Later work, assuming that price could vary by about 20 per cent instead of the 10 per cent used for the table in the paper, moved price up to number 1 rank, Table I below:

TABLE I

RANKING OF OPERATING, DESIGN AND REGULATORY COSTS ON VENTURE PROFITABILITY

(Considering variance range of ± 20% for price level)

Variable	Standard value	Variance range	Differential rate of return	Ranking
Commodity price level, $/lb Cu	0,50	0,40–0,60	12,7	1
$/lb Ni	1,10	0,90–1,30		
Unit operating and overhead costs, $/ton	2,75	2,00–3,50	9,2	2
Equity-loan structure . . .	50–50E	75–25E	8,6	3
Capital cost requirements, % of design cost	100	80–120	6,5	4
Productive capacity, tons/day	20 000	$15–25 \times 10^3$	3,9	5
Loan interest rate, % . . .	7	3–9	2,5	6
Loan payback period, years	20	10–20	1,3	7
Joint depletion, % of net . .	50	40–60	1,3	7
% of gross .	15 Cu	12–18		
	23 Ni	18–28		
Depletion, % of net . . .	50	40-60	1.3	7
Exploration costs, $/yr, for initial 3-yr period	500 000	$0–1,5 \times 10^6$	1,1	8
Federal income tax rate, % .	48	45–55	0,6	9
Federal tax moratorium, yrs	0	0–3	0,6	9
Depreciation methods . . .	DD	DD-SYD-SL	0,5	10
State income tax rate, % of Federal tax	18	12–24	0,3	11
Depletion, % of gross . . .	15 Cu	12–18	0,1	12
	23 Ni	18–28		
State tax moratorium, yrs .	0	0–3	0,1	12

Professor Pfleider also showed Table II which gives a preliminary analysis of the comparative stimuli assessments made by the industrial entities participating in the study. It is interesting to note that, much to the surprise of the governmental departments concerned, regulatory stimulants, especially for a marginal reserve, had a relatively low ranking.

TABLE II

OPTIMUM GENERAL CONVERSION ENVIRONMENT STRUCTURE—INDUSTRY ASSESSMENT

Main stimulant groups and subgroups	Relative rank of conversion effect	
	Main group	Subgroup
Industry Factor Group	1	
Profit objectives		1
Operating costs		2
Capital factors		3
Direct financial aids		4
Economic Factor Group	2	
Supply-demand factors		i
Marketing factors		2
Regulatory Factor Group	3	
Tax policies		1
Mineral Law factors		i
Trade policy factors		i
Politial Factor Group	4	

i = pure dominance indeterminate.

Mr K. F. Lane said that what concerned the practical man most was to know which of the factors over which he had some measure of control were the most important. Price may be important but with few possible exceptions not much could be done about it. The most important controllable factors would appear to be capacity, grade through selective mining, and 'dead' equity.

Mr D. A. C. Purser suggested that in the long term commodity price level was a function of the industry's average operating costs. In a recent exercise into the long-term regression growth rates of various operating parameters it had been found that the growth rate of the price of the particular commodity was 4,12 per cent compounded annually over a 20-year period while the growth rate in the cost of production was 4,14 per cent.

Mr Lane said that before starting a mining operation one should try to establish the average world-wide cost of production (a difficult task in itself) and then ensure that one's own cost of production fell within, say, the lower third of the producers making up the industrial average.

Professor Pfleider pointed out at this stage that the study had gone only half way as it varied each stimulant keeping the others standard, whereas, in fact, they were all really interdependent. He mentioned that some work had been done on this but that a great amount of work was required. He also pointed out that in recent times, long-term sales contracts at decent price levels had been more and more in evidence.

Mr M. R. Fuller-Good pointed out that such ventures were twice as sensitive to price fluctuations as to any other factor. In fact, cases arose where one had to take a position on the commodity price with its attendant risks or lose the orebody. Figure 6 of the paper showed that as the rate of return rose the project became less sensitive to price.

Mr J. M. Rose expressed surprise that grade was not included as a parameter as in his experience grade ranked in importance with price, and he asked why grade had not been included. Mr Rose added that his experience led him to believe that the range used for capital expenditure was rather optimistic. In reply Prof Pfleider pointed out that grade was normally taken into consideration but as in this case the mining method postulated was sub-level caving and hence there was little or no control over grade, it had been ignored.

Dr Joughin in introducing his paper emphasized that he believed that the South African gold mining industry still had a long future. He drew this conclusion as a result of the strides made to evaluate what factors made a material difference to the chance of opening new mines. Originally, conventional computer programs were used. In this work, changes had been restricted to technological changes and did not include changes in taxation or price. As the work had developed, a relatively simple economic model was devised based on the premise that a gold mining investment was assessed by the degree to which the present value of net profits exceeded the present value of capital expenditure. This model was described in the paper.

Three points arose from the work with this model. First, the viability of the initial stage of the mine was the crucial time period. Second, for a mine of fixed capacity, the return was not very sensitive to changes in capital cost. Third, there should be sufficient reef available to stope for a period exceeding 10 years from the area opened in the initial stage. The result of these three conclusions was the controversial conclusion that where the area of mineable reef was limited, a smaller mine would give at least as good, or a better, return than a large mine, with much lower risk.

The two technological breakthroughs that might make the greatest difference were stressed as, first, a new valuation technique which would give a better idea of the grade and, second, a method which would materially reduce the stope tramming widths in mines where this was applicable.

The main point which drew the comments of a number of contributors was Dr Joughin's assertion that small mines would give at least as good a return or better with less risk. The assertion was made that each mine had an optimum size and factors such as benefits of size with respect to incremental capital, benefits of size with respect of working costs and today's high cost of capital, tended to favour large mines. Dr Joughin replied that he had, in fact, tried to include all these points and that while he agreed that for any mine there was an optimum, in the area where the optimum lies the curve was generally fairly flat. Therefore, since the risk was lower with a smaller mine and the return not materially reduced the smaller mine was favoured. He also pointed out that he had, in fact, allowed a 12,5 per cent reduction in costs for the large mine.

There were several other contributions to the paper. These offered further data with respect to shafts and their design and the best methods of opening a new mine cheaply. They also covered the size and shape of the mine area and the effect this might have on the size of mine.