Operations Planning and Control

Chairman: Dr N. G. W. COOK

Rapporteur: Mr M. P. ROBERTS

Papers:

Planning open pit mining operations using simulation by A. Bauer and P. N. Calder

Simulation for control of underground liquid flow by G. N. Pitts and P. B. Crawford

Evaluation of production strategies in a group of copper mines by linear programming by P. H. Williams, J. N. Brooke and D. M. Poulter

An equipment maintenance system by D. W. Dean and J. A. Ryder

Taken as a whole, the difference between the four papers in this session were perhaps more illuminating than their similarities. The titles of the first and second papers contained the word 'simulation', and in both papers random number generation was relied upon in the selection of inputs from empirical distributions, but the nature of the models to which these values were inputs were quite different. The third paper displayed another method of uniting the empirical and the theoretical in a linear programming formulation whose matrix coefficients were measured empirically, and here some apt remarks on computer implementation were included. This paved the way for the last paper which abandoned all theoretical pretensions in favour of a detailed description of computer implementation and perhaps as a result gave rise to the most feeling audience participation.

The systems mentioned were developed for the iron, petrol, copper and gold producing industries in the US, Canada, Zambia and South Africa.

As with all the parallel sessions, contributions from the floor may have been limited by the shorter time available to delegates to acquaint themselves with the papers before the session. In spite of this, and due largely to the active chairmanship of Dr Cook, the discussion during the session which is summarized here contributed much to the information contained in the papers themselves.

In his presentation, Dr Calder summarized his paper. He expected that simulation would be used in future on an almost universal basis in open pit mining. It could contribute new knowledge more cheaply than experimentation in the field. For example, this study had shown what was previously thought to be a matter of more shovels and trucks was really a blasting problem, and improving blasting had increased production to the desired level. The simulation had shown that uniformity of truck performance was a desirable factor. It had also been used to study the advisability of a dispatching system.

Dr Ramani contended that where equipment characteristics were available, deterministic standard simulation could adequately simulate systems in which interference occurred. Operator performance could be measured against performance curves predicted by standard simulation and poor operators spotted and retrained. The present system did not take into account variability in truck loading, for instance. Dr Calder replied that if the number of variables was large, the standard approach became too complicated for operating personnel to follow. He admitted he had not tried it. The variability of truck loading could be coped with easily using the Monte Carlo approach. Operator variability was already incorporated because the time studies are actual.

Replying to Dr Falkie he said that a data bank was being developed to hold performance data of various equipment in various situations which could be drawn on when a new mine was being planned.

Mr Splaine commented that at Nchanga some years ago graphs similar to those in Fig. 2 had been derived and that dispatching of trucks to shovels had improved the production curve analogous to that marked 'poor digging'. Professor Pfleider commented on the situation in Fig. 4 where there was a big difference between the optimum costs for one and three shovels and asked for an explanation. Dr Calder replied that he thought it was a measure of increased congestion, more trucks being required for more shovels. He agreed that dispatching of trucks to shovels would help, and this was becoming quite popular in Canada.

Dr Crawford's presentation was distinguished by his entertaining introduction and a particularly fine series of colour slides of the illustrations in the paper. He explained that when an oil well is abandoned as uneconomical, eighty per cent of the oil may be left in the ground, hence the vital importance of simulation methods. The model described could be applied to flows of gas, oil, or mixtures. It was extendable to three dimensions but at greater computing cost. In choosing the size of the grid to represent the problem, the authors had tried out different sizes and had found 20 ft $\times$ 20 ft satisfactory. This work dealing with heterogeneous rock was new; they believed that if the method worked for randomly selected permeabilities it would work well for other cases. All cases tried so far had resulted in convergence of the method. The use of the stream function value method gave better control to the computation and hence faster convergence than earlier methods.

Dr Venter congratulated the authors on a new approach to the problem of fluid flow in heterogeneous media. He pointed out that although South Africa had no oil recovery problem yet, they did have underground water problems in the mines, and that the aquifer is heterogeneous. Flow occurs along cracks traversing impervious rock. Equations assuming flow and homogeneous media became hopelessly inaccurate when applied to small areas. He thought the method might be relevant in pit slope draining and grouting. He pointed out that randomly selected values of permeability would not have to be used where the actual values were known as was often the case in mining. One problem was that methods assuming laminar flow overestimate the inflow of water through cracks where the rate of flow is high enough to cause turbulence.

Dr Crawford said the method was certainly applicable to the flow of water. Turbulent flow had not been considered;

it could perhaps be included by testing the flow values during the solution process and decreasing the permeability at that point after reference to a table of friction factors. He also believed the method could have an application in grouting.

Dr King commented that a degree of correlation between continuous values of permeability would be related in some way to geological structure. Dr Crawford said that in later versions dealing with stratified media this was being allowed for, but for the purpose of testing the model the totally random distribution was considered the toughest problem. In this case the data they had used were 'shotgun' data, so it was thought that a random number generator was good enough.

Dr Brooke preferred to comment about his paper rather than summarize it, as many delegates might not yet have read it. The paper was one of a sequence describing the work of his department, and it summarized experience since the last paper. The department must be seen as a user department with respect to the computing and operations research services of the company, but as a service department with respect to the rest of the company.

As a user department, they had chosen linear programming methods, which was a controversial choice. Dr Brooke defended it for three reasons. First, use of a package meant that the user department could do its own coding. This meant quicker production of the system. No great computer experience was necessary. The use of the package also made the alteration of models and reports easier than before. The second reason was that linear programming allowed the use of a simple modelling technique particularly with regard to systematic use of variables. This simple linearizing approach was no great disadvantage. The worst offender was the flotation model, but Dr Brooke asserted that the anomalies of introducing linearity disappeared automatically in the smelting section of the model. Thirdly, LP represents unforeseen interaction effects very well, which was important in a very variable situation such as month-to-month production.

As a service department, they had the task of producing official production targets for the coming year by month; also a reconciled set of metals accounts and an actual versus targets variance report, which formed the basis of discussion at monthly production meetings; and they had to estimate production for longer periods, of up to five years by year.

Future areas of expansion included trying to treat the uncertainty of the input data, which tended to reduce management's seriousness about forecasting work; expanding to include multi-time periods; and using integer programming to study sequencing of mining and metallurgical operations.

Dr Cook asked to what extent the success of this direct approach was due to the wealth of experience gained in earlier systems. Dr Brooke replied that the personnel working on the projects had acquired a great deal of experience, but that a different technique had been used for each system. He thought that LP would have a longer period of success than some of the earlier methods.

Mr Splaine commented that Dr Brooke's scheduling systems had become almost an integral part of the company. Dr Brooke said they did a fantastic amount of work in a year. The department's justification was that it helped ensure the meeting of production targets.

Mr Dean also made his presentation into an additional discussion of the system rather than a summary of the printed paper. He emphasized that the computer was a tool which could be used correctly or incorrectly and the system was to be judged on the success of its implementation.

It appeared that the application of computers to equipment maintenance was a neglected subject. A substantial proportion of mine costs lay in the purchase and maintenance of equipment. An equipment maintenance system was a long-term project and required an act of faith by management but it was difficult to persuade production management, who perhaps regarded maintenance as a necessary evil, to spend now in order to benefit later. Use of a computer would be necessary to handle the large quantities of data involved.

The system described in the paper had first been introduced in a gold mine in 1966. Early problems had been the acquisition of data and basic lack of experience of such a system on both sides. However, the system had been continually developed and is still in operation on the same mine. By choosing numbering codes suitably the system was being adapted to record details of expenditure on capital projects. Another area where such a system would be of use would be in the control of plant shutdowns. Prior to shutdown of the plant, the computer could be interrogated to ensure availability of spares most likely to be needed, on the basis of past shutdowns.

Mr Waterman contributed from the floor as the main user of the system to date. He recalled that an early problem had been the production of more computer output than the staff involved could cope with. The interrogation facility had also been used over-enthusiastically at first. On the other hand, use of the system had resulted in measurable direct benefits. Amongst other examples were the placing of contracts for scraper winches to those manufacturers whose products were cheapest to maintain, and the detection of an increase in spare parts consumption of underground diesel locomotives which was traced to the manufacturer's quality control.

Mr Kaas asked how the computer reduced costs in South Africa's labour-intensive mining environment. He noted that in the US most mining was open pit and relied heavily on expensive larger equipment. In this case the contribution of equipment maintenance systems lay, on the one hand, in reducing the number of breakdowns and, on the other hand, to increasing productivity of labour. Both aims could be achieved directly or indirectly by providing information which helped to transfer more breakdown maintenance from unscheduled to scheduled, for instance by reporting on inspections, lubrications, etc., to ensure they were done. The causes of equipment breakdown could be categorized broadly into infant mortality, wear-out, and random, and some of these could be predicted. Mr Kaas did not think a batch computing system could provide timely enough information for on-the-job scheduling decisions, and it also required too much paper work. Terminals on site or small computers in the maintenance department could solve some of these problems and as a further advantage data errors could be corrected at source.

Mr Dean agreed that labour costs would be reduced by better scheduling of labour. The aim of his system was not day-to-day maintenance. He believed that in most South African cases, except where it involved continuous process plant maintenance, the costs of terminals or small computers would be uneconomic, and that overnight turnaround was adequate.

Mr O'Beirne made the point that every computer application should be justified. In the case of his own company, he believed that 80 per cent of the system objectives were already met by the existing manual system. If the computer was to benefit the maintenance area, those benefits should come from conventional computer routines.

Mr Dean replied that a system like Mr O'Beirne's manual one which did not use stores information was not, properly

speaking, an equipment maintenance system. He agreed that many people did not analyse their existing manual methods sufficiently before deciding there was a case for computerizing.

Replying to Mr Clifford, Mr Dean has written since the session that the system can hold figures on a basis other than per hour or per shift; for instance, it could hold figures of metres drilled, etc. This could be a necessary statistic for evaluating equipment performance. Replying to another written question from Mr Pirow who asked how mechanics can be stopped from building their own substores and thus distorting the system reports, the answer was that the system can compare the value of stores drawn with the value of stores used. It also reports if, for instance, stores usage but no labour is reported for a particular job.