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APPLICATION PAPER

OPTIMUM ALLOCATION OF BOREHOLES IN GEOLOGICAL PROSPECTING

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ABSTRACT

In the literature on probabilistic financial analysis on exploration, there does not exist any decision analysis in case of a business enterprise where a fixed amount of money is to be optimally allocated in various types of exploration ventures. In this paper a dynamic programming method is applied to handle a case study in this type of constrained optimisation problem.

1. Introduction

The problem was referred to by a captive mine of an iron and steel plant in a public sector undertaking in course of the detailed exploration of Fe content of iron ore so as to have a planned mining operation. Under the existing scheme a given budgeted amount was proportionately spent on the sizes of the subareas in a given area and the number of boreholes in a subarea is sunk accordingly. Actual positioning of the drill is of course determined by the geologists on the basis of density of exploration grids. Even different parts of the ore deposit may require different grids depending on the complexity of its geological structure. The main factor controlling the density of the grid is the variability of the properties of the deposit. The records of exploring openings are used to obtain a correct idea of the deposit and the assay values thus obtained provide a basis for estimating ore and metal reserves. The main drawback in proportional allocation was against the principle of bulk sampling where number of observation should be on the basis of variability of the deposit rather than the area of the deposit. This in turn is reflected in the confidence coefficient of the estimate corresponding to a given number of observations. Moreover, the costs of explorations in different subareas differ quite significantly on the basis of accessibility and the soil condition of the area. Hence any decision regarding the number of boreholes should take into account the variation in costs in different subareas along with the variation in quality of the deposit. Thus the

3. The Problem

The available amount of resources with the company is Rs. 4.5 million and this has to be optimally allocated by sinking different number of bore-holes in different subareas. The confidence coefficient of the estimates by sinking different number of boreholes in different subareas and their cost structures are described in a tabular form.

TABLE 1—CONFIDENCE COEFFICIENT WITH 2% ACCURACY OF THE ESTIMATE

Number of boreholes / *Subareas*	1	2	3	4
1	0.65	0.45	0.75	0.60
2	0.80	0.65	0.85	0.70
3	0.90	0.80	0.95	0.90

TABLE 2—COST IN MILLIONS OF RUPEES

Number of boreholes / *Subareas*	1	2	3	4
1	0.6	1.0	0.5	0.8
2	1.1	1.6	1.0	1.3
3	1.5	2.0	1.4	1.7

With the restriction that atleast one borehole has to be sunk in each of the subareas, the optimum allocation of boreholes in subareas 1,2,3,4 worked out to be 2,3,1, respectively.

4. Comparison of Optimum Solution Against the Existing Procedure

In the existing procedure the number of boreholes sunk in subareas is proportional to the size of the subarea. In the present example the sub-areas were of equal size. Hence out of Rs. 4.5 million approximately, Rs. 1.1 million will be subdivided amongst the four subareas; accordingly the number of boreholes in subareas 1,2,3,4 will be 2,1,2,2. The overall confidence coefficient corresponding to the present procedure will work out as 0.2142 where as for the optimum procedure, it works out as 0.2880.

5. Remark

The above problem can be extended to a case where exploration is conducted for a particular grade of assay values, e.g., iron content of ore should be $\geq$ 60 per cent. Here search is conducted in an area with a given number of boreholes and the attempt is either successful or a failure. Similar searches are conducted in other areas also. A probabilistic dynamic programming is a powerful technique tackling such type of problems where the cost of abondonment of the project after the several stages of search is known.

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REFERENCES

[1] COYLE, R.G. (1971), A dynamic model of the copper industry—Some preliminary results, *Proceedings of the 9th International Symposium on Techniques for Decision Making in the Mineral Industry*, Canadian Institute of Mining and Metallurgy, CIM Special Volume, **12**, 53-86.

[2] GRAYSON, C.J. Jr. (1960), Decisions under Uncertainty; Drilling Decisions by Oil and Gas Operators, Harvard Business School, Division of Research, Cambridge, Mass.

[3] MEGILL, R.E. (1971), *An Introduction to Exploration Economics*, Petroleum Publishing Co., Tulsa.

[4] NEWENDROP, P.D., A Decision Criterion for Drilling Investment, Society of Petroleum Engineers, Preprint, SPE 2219, SPE 43rd Annual Fall Meeting, Houston, Texas.

[5] RAIFFA, H. (1970), *Decision Analysis: Introductory Lectures on Choice under Uncertainly*, Addison-Wesley, Reading, Mass.

[6] SCHLAIFER, R. (1961), *Introduction to Statistics for Business Decision*, McGraw Hill, New York.