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Dr. Şinasi ESKİKAYA

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LONG TERM PRODUCTION SCHEDULING OF SUNGUN COPPER MINE USING NPV SCHEDULER SOFTWARE

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ABSTRACT

In this paper are given some ways to suppose the manage and planning production on the one big active mine for cooper ore in Iran. For this action in past years are used more techniques and software programs.

Determining optimal pit and mine scheduling is not a static task. This piece of work always should be injected with latest updated information in order to guarantee the best performance of mining procedures. Production planning details is involved with combination of spatial units called ore and waste. Each of them has their own characteristics, values and geometric positions.

All Variations and combinations range of production planning are considered by a three dimensional matrix which is known as block model. Each component of this matrix (a block) includes size, location, and result of interpolation data which was collected from holes drilled throughout the ore body.

Production planning in Sungun copper ore mine is an immense and complicated task. Despite the number of optimization method which has been done, the difficulty of determining optimum production scheduling throughout the life of mine is remained almost unsolved.

Scheduling for extraction these matrixes, aim to maximize the Net Present Value (NVP) of mining procedures over the life of mine. Most of the problem for a proper production planning is due to limitations.

In open pit operation, sequential constraints have conceptual connection with mine slope and the order of blocks related to each other. Also production constraints are directly linked to production issues such as amount of output, modal quality and other important topics.

In this paper (after the introduction of Sungun copper ore mine and NPVScheduler software we try to design the final pit and obtain the optimal production scheduling by using the mentioned software.

Key words: mining, exploitation, scheduling, optimal production

1. INTRODUCTION

The economic feasibility of each mine is firmly rely on meticulous planning and management. Decreasing in average ore grade, increasing mining expense and other consideration guarantee that this situation requires more solution in future. The management and planning Sungun copper ore mine is an immense and complicated task. Scheduling for extraction these matrixes, aim to maximize the Net Present Value of mining procedures over the life of mine. Most of the problem for a proper production planning is due to limitations imposed as follows:

- Restrictions associates with the extraction of blocks which are in connection with other blocks (Sequential Constraints).
- Limitations that determine the quality and quantity of objectives (Production Constraints).

Sungun mine is located in North-West of IRAN in east Azerbaijan province. In this area two major ore type including Supergene and Hypogene is determined. Sungun copper project with the aim of recovery of copper from rock by using modern mining techniques is in construction to gain the following goals [1]:

- 150 thousand tons annual production of 30% copper concentrates in the first phase and 300 thousand tons in second phase.
- Providing the feed for IRAN copper melting factories and export surpluses.
- Providing opportunities for employment and transferring technical knowledge.

Kind of software for optimization and production planning in mines. It can generate economic model, determine final pit, find the optimal sequence of phases and perform cut-off grade optimization [2]. The procedure of above mentioned point is illustrated in Figure 1.

In open pit operation, sequential constraints have conceptual connection with mine slope and the order of blocks related to each other. Also production constraints are directly linked to production issues such as amount of output, modal quality and other important topics.

Optimization of geological model is a time consuming work. It demands an intelligent manner. In this paper (after the introduction of Sungun copper ore mine and NPV Scheduler software) we try to design the final pit and obtain the optimal production scheduling by using the mentioned software.

2. ECONOMIC PARAMETERS PREPARATION

The normal and most convenient method of preparing economic data is to first prepare a spreadsheet model, for input and appropriate processing of relevant cost information. This will also normally be accompanied by processing data, as some of the processing throughputs are necessary for cost manipulation and other processing-related values may be required for open pit analysis.

The spreadsheet can be customized according to the particular project requirements, producing final quantities that are suitable for direct use as optimization parameters.

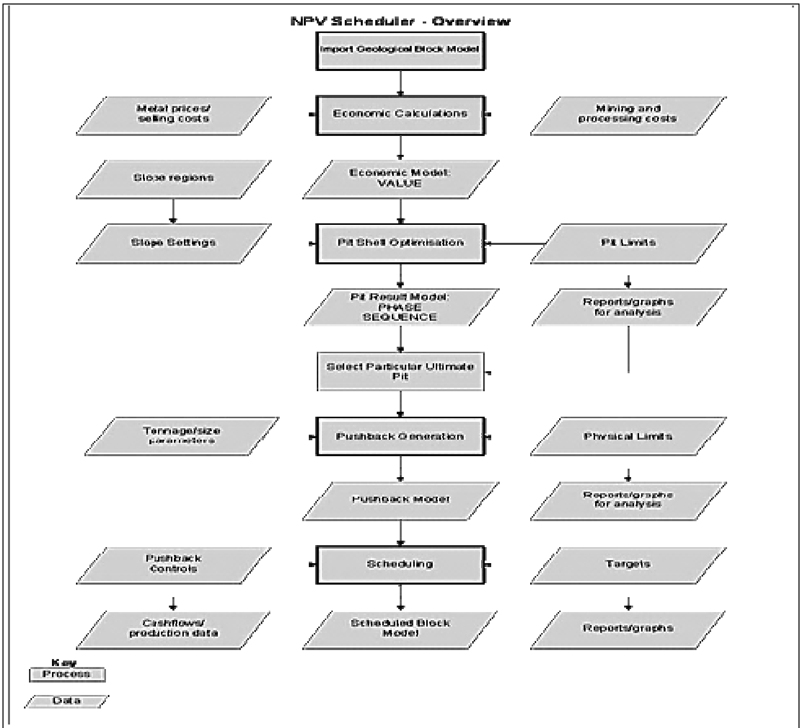

Figure 1. Optimization process in NPV Scheduler

The most important premise is to include in some way all costs that would stop if the mine stopped production. For example, certain sunk capital costs will normally be excluded by this consideration. Another useful guide in this debate is to sometimes consider how pit costs would be considered if contractors were being used. They would normally submit a cost/ton figure that would include a number of operational and capital costs, but this overall cost/ton figure would normally be directly used for pit optimization.

Time (e.g. general and administration) and replacement costs will not normally be available in a cost/ton form. It is, however, necessary to determine component cost per ton figures that can be accrued for pit optimization purposes.

In order to convert such costs, the type of production limitation at the mine must first be chosen - the commonest form is probably mill-limited.

Based on the relevant limitation type, the time cost is divided by the corresponding production capacity, to yield an effective cost/ton figure.

Frequently, the cost per ton of mining ore will be greater than the cost of mining waste, e.g. due to different equipment. In this case, the additional (i.e. the difference) cost incurred must be calculated and then added onto the processing cost. Therefore the processing cost for optimization purposes actually includes cost components for the mining of ore as well 'pure' processing. Financial and technical data used in this study is shown in Table 1 and 2.

Table 1. Financial Data (1)

Copper Price ($)	Refinery ($/ton)	Smelting ($/ton)	Transporting ($/ton)	Processing Cost ($/ton)	Mining Cost ($/ton)
3500	118	208	24	2,80	1,250

Table 2.Technical Parameters (1)

Annual Production (phase1,phase2)	Discount Rate (%)	Total Slope (^{0})	Specific gravity of different rocks , t/m^3	Total Recovery (Hypogene %)	Total Recovery (Supergene %)
7mton , 14mton	10	37	3,3 2,57 2,50 2,42 2,55	82	76,6

3. ULTIMATE PIT GENERATION

Based on the generated economic block model, and a supplied set of overall slope angles, NPVS will determine an ultimate pit that yields the highest possible cash flow (maximum profit). After attaining the maximum cash flow pit, a number of (normally) internal pit phases (shells) are also determined. Each of these phases represents an alternative maximum cash flow pit, in which one of the economic parameters has been varied from the supplied parameters. A whole series of phases can be produced, each of which represents a different factor which has been applied to one of the following variables:

- Profit
- Price
- Mining cost

These internal phases are important for the selection of alternative optimal pits, for the generation of mining sequences and for the demarcation of pushback expansions.

For all of the blocks inside the ultimate pit, an idealized optimal extraction sequence (OES) is also generated. This OES strives to attain the highest discounted cash flow possible, based on the supplied discount rate and ore processing rate.

Ultimate Pit is used as the basis for constructing the OES (a block by block extraction sequence), however the OES is selected to produce the highest discounted cash flow, whereas each phase has been constructed to represent the highest undiscounted cash flow for given economic parameters. It may occur that some blocks towards the end of the ultimate pit may not add onto the DCF, in which case a smaller pit than the ultimate pit may yield the highest DCF. However, it is up to the user whether all blocks from the ultimate pit should still be included. A maximum revenue factor of more than 100% can be defined, in which case the largest ultimate pit produced will be a pit 'past the peak', in terms of the base economic parameters. Figure 2 and Table 3 respectively shows the trend of NPV and features of ultimate pit.

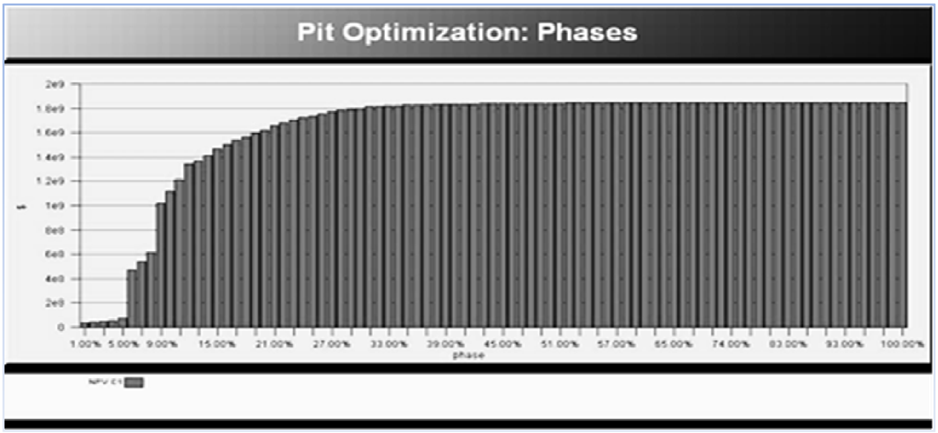

Figure 2. NPV trend based on extractive phases

Table 3. Ultimate pit specifications

Total Waste (t)	Total Ore (t)	Stripping Ratio	NPV($)	Life (year)
1.493.236.010	596.383.577	2,50 : 1	1.846.799.221	45,6

•

3.1. Determining Optimal Pit

Ultimate pit selection will normally be carried out according to defined corporate objectives. These objectives may be quite different, depending on the mining company involved, the status of deposit exploration and specific financial constraints for the particular project. Most objectives involve the assessment of value, of which there are 3 principal types:

1. Cash flow = Revenue - Costs
2. Time Value – NPV, Internal rate of return
3. Value in Reduced Risk e.g. short payback, low capital starts

Often the required objective will be the maximization of value, of the value per ton mined, of the value per unit of metal produced. NPV-related objectives can suffer from having to have some sort of schedule, so that an NPV can be devised. At early stages of optimization, setting up realistic schedules can be difficult, so it may be better to quickly produce 'best' and 'worst' case NPVs. If there is a large difference between the NPVs of these two extremes, then this highlights the opportunity for optimizing the NPV through scheduling.

Other criteria that are typically applied include:

- Cut-off cost criteria
- Maximize metal throughput
- Maintain product-oriented blend

As can be seen from the Figure 2, the trend started at first phase and continuing to top out at phase no 69, however this growth was followed by a significant steady trend in NPV. Phase 69 contains more than 590 mton of ore. This phase with the stripping ratio of 2/455 worth 1800 million dollar. Finally it was selected as final pit. According to this phase the life of mine would be 45 years. To matching the life of machines with life time of project and reduce the risk, phase no 24 with amount of 338 mton of ore, was picked out for scheduling.

3.2. Pushback Generation

The ultimate pit within which pushbacks are created can be defined in one of two ways:

- By taking the maximum ultimate pit produced previously in the same preceding case.
- By defining a specific block number within the previous ultimate pit's optimum extraction sequence.

The next main control is to define the maximum number of pushbacks that can be generated. In addition to this, an option can be enabled, which ensures that the pushbacks will definitely reach the final (supplied) ultimate pit shell.

For each pushback, the minimum quantity of ore is specified, as well as the maximum depth of each pushback. The same parameters can be defined for all pushbacks, or different parameters per pushback.

Another option defines whether each pushback must forma contiguous volume i.e. can the same pushback be made of more than one physical volume.

Access space (width) can also be defined, to ensure that each pushback meets minimum width requirements. In addition, the minimum size of any individual pushback can be defined, in terms of the number of parent blocks.

Therefore, finding the number of optimal pushbacks that guarantee the profitability of project and not impose some restriction, is the most important principles in mine scheduling.

Different combination of pushbacks studied and eventually the combination with the highest NPV was selected. To maintain minimum mining width of 60m, maximum 5 pushbacks can be considered. Figure 3 and Table 4 show the properties of selected pushbacks.

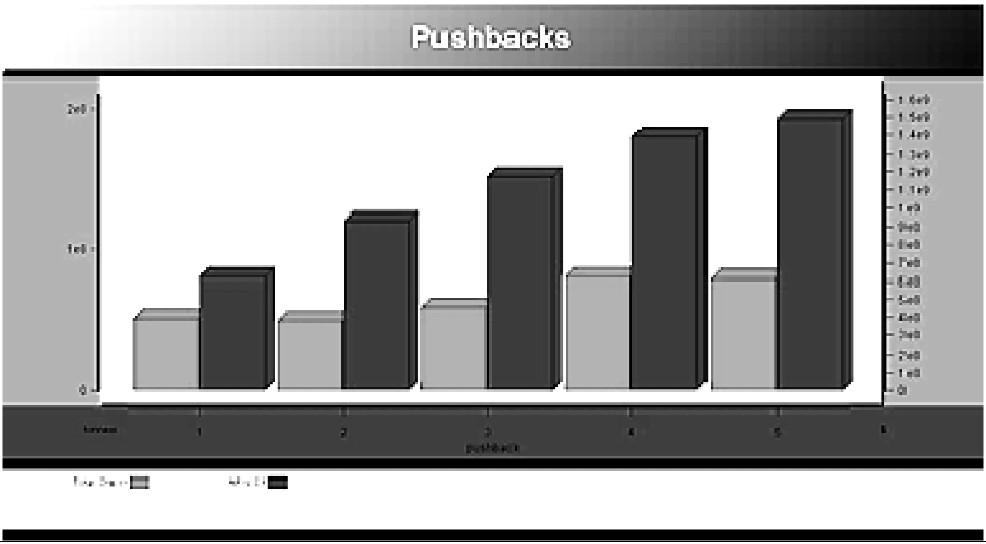

Figure 3. Gradually changes of ore tonnage VS cumulative NPV of pushbacks

Table 4. Cumulative data in 5 pushbacks

Push Back, N°	Processing Cost($)	Mining Cost ($)	NPV($)	Extracted Rock (t)	Ore(t))	Waste(t)	Stripping Ratio	Copper (t)	Total Recovered Copper(t)
1	147,805,228	167,102,074	644,459,805	133,681,659	52,919,880	80,761,778	1.526	464,304	344,054
2	290,163,505	322,257,659	962,533,945	257,806,127	103,889,547	153,916,580	1.482	798,592	597,044
3	460,484,035	504,409,223	1,215,739,274	403,527,378	164,870,760	238,656,617	1.448	1,164,490	877,523
4	693,226,355	796,278,393	1,435,909,834	637,022,715	248,201,344	388,821,370	1.567	1,677,123	1,275,017
5	922,311,808	1,145,075,954	1,538,157,903	916,060,763	330,222,630	585,838,133	1.774	2,158,008	1,649,096

4. PRODUCTION SCHEDULING

Within the same case study branch, scheduling starts with the pushback model generated just previously. The first step is then to define targets, which may be related to grades, tonnages and/or truck hours. The required ore production rate(s) then need to be specified, along with the production periods required (default is years).

The final step is to define how mining may advance along and between the various pushbacks.

Once the controls have been set-up, the schedule may be generated, in which NPVS will strive to meet all of the defined targets, as well as to maximize NPV. A scheduled block model is generated, along with various results tables. The brief result of scheduling Sungun copper ore mine is shown in Table 5.

Table 5. Features of 27 years scheduling for Sungun mine

NPV of Scheduling (mil $)	Scheduled years	NPV of selected Pushbacks (mil $)	N^o of Pushbacks	Constant Cut-off Grade (%)	Copper Average Grade (%)	Stripping Ratio	Ore (mton)	NPV of Final Pit($)
942	27	1538	5	0,36	0,539	2,5 : 1	596	1886

5. SENSITIVITY ANALYSIS

After or during selection of a ‘base case’ optimal pit, it is often required to complete a number of alternative sensitivity runs. There are two fundamentally different types of sensitivity that can be tested:

A. Different pit optimizations from varying parameters
B. Testing the economic results for a specific pit, for different parameters

The type A sensitivities can be thought of as really testing the deposit, with a view to seeing what different sorts of pits may be possible. Type B sensitivities are for really testing how robust a particular ultimate pit, or actual design, can prove under different imposed conditions.

Type A sensitivity runs are often required different costs or prices.

In both of these cases, there are 2 alternative ways of getting sensitivity results:

1. Define separate economic model cases, with different cost/price values.
2. Use the phase-revenue factor tools when generating the ultimate pit, so that each phase automatically represents a parameter. These phases can therefore represent different:
    - Profit factors
    - Price factors
    - Mining cost factors

After performing the sensitivity analysis, price of copper and discount rate was determined as the most critical parameters.

6. CONCLUSION

The most important part for a proper scheduling is determining the best combination of **pushbacks,** so to improve NPV, using trial and error technique is necessary.

NPV can be increased by manual adjustment of transposition of block extraction.

Pit selection (ultimate) will normally be carried out according to defined corporate objectives. These objectives may be quite different, depending on the mining company involved, the status of deposit exploration and specific financial constraints for the particular project.

On base, the generated economic block model, and a supplied set of overall slope angles, NPVS will determine an ultimate pit that yields the highest possible cash flow (maximum profit).

After attaining the maximum cash flow pit, a number of (normally) internal pit phases (shells), can also be determined.

REFERENCES

[1] ITUK IRAN, The Final Feasibility Study of Sungun Copper Deposit, Volume 7, Internal Report of National Iranian Copper Industries.
[2] NPVScheduler [NPVScheduler V3.4 Help]
[3] Kenedy, B.A. (1994), Surface mining, Biro of Mines, Ohio, Usa
[4] Journal “Macedonian mining and geology”, N^0 8/2008, 15/2009, SRGIM, ISSN 1409-8288, Skopje, R. Macedonia
[5] Journal ”Minno delo i geologija”, No.9/2006, Editor ”Zemja 93”, ISSN 0861–5713, Sofija, R. Bulgarija