Open Pit Mine Scheduling – A Case Study at Bogoso Gold Limited

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Key words:

SUMMARY

The main objective of this paper is to describe the process of mine scheduling as is being practiced at Bogoso Gold Limited in its mine planning activities.

The Bogoso area has a long and chequered mining history of both open pit and underground workings.

Open pit mining operations recommenced in 1990 to the present. Bogoso Gold Limited has moved from the exclusive use of mathematical models (excel spreadsheet) in its scheduling programs to a more sophisticated graphic-based method of scheduling – Minesched.
1. WHAT IS SCHEDULING?

Scheduling may be defined as the allocation of available resources to activities over time in a manner to meet corporate objectives. According to RG Schroeder (2000) it is the final and most constrained decision in the hierarchy of mine planning decisions.

There is however no universal scheduling method for all situations. One scheduling method may not necessarily satisfy the requirements of another mine due to several reasons both tangible and intangible. Thus, the choice of a scheduling method/software should be dictated by the nature of the operation and its sophistication.

Bogoso Gold Limited have moved from the use of mathematical models (excel spreadsheet) to a more sophisticated graphical and spreadsheet methods of scheduling as their operations have become more complex and the use of only spreadsheets may be risky as one cannot determine which portion within the flitch is being mined.

The above criteria have guided Bogoso Gold Limited to adopt Minesched as its current scheduling tool.

Its benefits are follows:
- It operates in familiar environments as
  - Microsoft excel
  - Microsoft project interface
  - 3D viewing, validation and animation
- Process is user controlled
- Priority and sequencing rules are easy to set
- Shortfalls or risks are brought to the fore for resolution.

Though it has no financial modeling tool, it can be customized to achieve the relevant financial results/report.

There is no doubt that a mine scheduling exercise that is painstakingly done will bring to the fore the strengths, weaknesses and risks involved in executing that plan. Consequently it will offer a window for remedial measures prior to its adoption as a working plan.

Scheduling is required in both short-term and long-term production planning though they differ in sophistication. While the former is necessary for the function of an operating mine, the latter is usually done for feasibility or budget studies.
A practical question that confronts the planning engineer in scheduling is “how would I schedule this pit if I were the mine superintendent responsible for making it work”?

Couzens (1979) has proposed the following five planning/scheduling “commandments” to guide the planning engineer in answering this question:

1.1 What is to be done?

This requires a clear definition of the objectives of a particular scheduling exercise. For instance a planning engineer may produce a one-year budget schedule with emphasis on the production of a particular type of ore for processing for that financial year. It must be cautioned that we are dealing with estimates of grade, projections of geology and guesses about economics as such there must be openness to change by all parties involved either actively or passively in the scheduling process.

1.2 When?

The time frame for executing the plan/schedule must be clearly specified. Since volumes must be moved in time to realize production goals, the productive use of time will determine efficiency and cost-effectiveness of the schedule.

1.3 By Whom?

Responsibilities as to who does what must be clearly defined devoid of any ambiguities. This calls for effective communication among all the key players. If the plan or schedule is not clear to those who must make decisions and to those who must execute the plans, then the plans/schedules stand a good chance of being misunderstood or ignored.

1.4 What Resources are Required?

Plans remain a mere paper work unless resources are allocated for their execution. This requires the allocation of equipment type and quantity and the quantum of manpower required for the equipment.

1.5 Cash Flow and Management Decisions

Every plan must have the blessing of management prior to its implementation. However, for such a decision to be made, knowledge of the cash-flow position is required.

2. MINESCHED FEATURES

Minesched is a mining scheduler for both surface and underground mining operations. It has been developed in 1999 by the Surpac Minex Group (SMG). Its versatility is due to the fact that it uses existing and proven technology where appropriate – Microsoft Excel is an integral
tool in minesched while it also has live, two-way communication with Microsoft Project, giving users the option to present and further refine their schedules.

One powerful feature of minesched is its ability to automatically create the graphical output that shows where mining has taken place for each scheduling time period, in the form of a three-dimensional solid. The polygons carry their associated tonnage and grade data as attributes allowing for easy map generation of the schedules. The mining sequence can be shown animated on-screen.

Reports in minesched are generated with production tonnage and grade data output for each time period. These reports can be presented in Microsoft Excel and their formats are flexible and user-defined. Templates are generally created so that report quality tables and graphs directly linked to the Minesched raw results can be studied and printed immediately upon completion of the Minesched scheduling run.

Minesched has no in-built financial modeling tool but can be customized to give cash-flow reports.

Minesched consists of a series of worksheets in Microsoft Excel. These worksheets constitute the ‘’engine room ‘’ of the program and its output is depended on the quality of completing these worksheets. These worksheets include:
- Time Parameter Worksheet
- Block Model Parameter Worksheet
- Mining Location Worksheet
- Production Parameter Worksheet
- Report Definition Worksheet

2.1 Time Parameters

The time parameters sheet is where you define your scheduling start date, scheduling period length details, date and time formats, and holiday details. The time parameters sheet is used by both the production and development schedulers.

![Time Parameter Sheet](image)

**Figure 1.0: Time Parameter Sheet**
2.2 Scheduling Periods

The user has complete flexibility in defining scheduling period lengths. The period length is specified by choosing the time units and the number of time units in a single scheduling period. You also choose the number of periods of this length that you wish to schedule for. Units go down to seconds, giving the user total flexibility.

Different scheduling period lengths can be scheduled on simply by choosing additional scheduling period lengths in successive rows. All of the periods specified in the first row will be scheduled and then all of the periods in the next row, and so on. For example, you may report weekly results for a few weeks, followed by monthly results, then quarterly results (see illustration in figure 1.0).

Example: to report quarterly (3 month) results for 2 years, the number of periods is 8, the time units are months and the number of time units in one period is 3. (8 months 3)

2.3 Block Model Parameters

The block model parameters sheet is where you enter information about the resource models you are scheduling from. Resource models are usually block models, however they can also be string models. (see illustration in figure 1.1)

![Figure 1.1: Block model Sheet](image)

2.4 Mining Locations

The mining locations sheet is for defining where mining takes place. Essentially a mining location is simply a group of blocks to mine. If this group of blocks comes from a block model, you can think of your location as simply a block model
constraint. We assign this group of blocks a name, which is the mining location name. In the locations sheet we also specify how we are going to mine this group of blocks. This may be by horizontal slices (benches) or by vertical cookie-cuts (polygons). We also specify our direction of mining. So think of the mining locations sheet as defining where and how you are going to mine, but nothing to do with when or at what rate you are going to mine.

**LOCATION SHEET**

<table>
<thead>
<tr>
<th>Location Name</th>
<th>Mining Blocks Name</th>
<th>Method</th>
<th>Black Model</th>
<th>Mining Direction</th>
<th>Inv. Mid-Bench</th>
<th>Inv. Mid-Bench</th>
<th>String File</th>
<th>String Range</th>
<th>String</th>
<th>String Block</th>
<th>Partial or Partial</th>
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<th>Principal</th>
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<td>LT south</td>
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<td>4520</td>
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**Figure1.3:** Mining Location Sheet

### 2.5 The Use of Constraints in Surpac

One of the very powerful features of Surpac Block Modelling is the ability to apply constraints. Constraints are the logical combinations of spatial operators and objects and may be used to control the selection of blocks from which information may be retrieved and/or into which interpolations may be made.

Constraints may be as simple or as complex as you like, and are most commonly used when:
- Filling the Block Model with values
- Producing Reports
- Viewing models in Graphics.
- Loading a constrained portion of a model

The choice of spatial operators you have are:
- ABOVE
- INSIDE
- >
- <
- =

The operator you will use will depend on the nature of your objects. In order to reduce the number of spatial operators, the word 'NOT' is used to imply the opposite of an operation. For example, OUTSIDE would be represented by the expression NOT INSIDE.

The choice of objects you have are:
- Surpac Vision Digital Terrain Model (DTM)
- Surpac Vision Solid Model (3DM)
3. PRODUCTION PARAMETERS

3.1 Introduction

The production parameters sheet is the main "working" sheet in MineSched. This is where you will spend most of your time refining your schedules. The typical layout of the production parameters sheet is as shown in figure 1.5.

Figure 1.5: Production Parameter WorkSheet
Some Salient Production Definitions

**MAX_RATE** is defined as a daily rate. If you only know your production rate as a monthly or annual rate, this is where the benefit of having mathematical formulas within the user interface is evident. Enter the monthly rate in the comments column to the right. Then in the value column reference the cell containing the annual or monthly rate with an appropriate formula that converts this to a daily rate. For example, this might be = K26 * 12 / 365 to convert a monthly rate to a daily rate.

**V_LAG_ALL** refers to vertical lag in all directions. Vertical lags determine when a block in the bench below becomes available for mining. It is called a "vertical" lag because block availability is controlled by the blocks on the bench vertically above.

**H_LAG_ALL** - Horizontal lags are similar to vertical lags in that they control when a block becomes available for mining. Vertical lags control when blocks in the bench vertically below the block being mined become available. Horizontal lags control when blocks on the same bench as the block being mined become available. They are called "horizontal" lags because they are between blocks on the same horizontal plane.

**DESTINATION** is used to specify the destination for the material that is mined.

**MAX_ACTIVE_BENCH** - Mining can only occur from this many benches in the location at one time. Mining will not start on a new bench until one of the active benches has been completed (or the value for this setting changes). When mining starts in a location, if you have more benches with blocks available than your maximum number of active benches, mining will start on the uppermost benches.

**RATIO** - The RATIO parameter is used in target scheduling to specify a material ratio target with ALL_LOCATIONS or with a DML that contains multiple materials.

**DML** - A stockpile is an example of a DML. Dynamic mining locations are called "dynamic" because they can have material added to them as well as removed.

**SML** - Static mining locations are fixed and can only have material removed from them. In the example above, "PIT" is a static mining location and the stockpile is a dynamic mining location.

The production sheet is used to define when mining takes place from a location and at what rate. The production sheet is also where you define your targets. Production parameters can be specific to mining locations. Production parameters can also change at any time. The production parameter can change at an exact date and time or when a bench or polygon or static mining location finishes.

*MineSched* is run in two steps.
*Step 1* prepares block models for scheduling.
*Step 2* schedules.
The production parameters sheet is not used to “Prepare Model”, it is only used in “Schedule”. Therefore production parameters may be changed and “Schedule” can be immediately run again. “Prepare Model” does not have to be re-run. MineSched has been designed in this way so that the effects of different production scenarios can be quickly and efficiently studied and re-run.

3.2 Report Definition

This sheet is where you define your custom reports. Reporting has always been a strength of MineSched because of its flexibility. Volume, mass, attribute and user calculation results can be reported for any combination of materials and any combination of locations. New in Version 4, ancillary activity quantities can also be reported. (see illustration in figure 1.6) This sheet gives you the flexibility to define exactly what is to be reported. You have complete control over the data that appears in the report and the order that it is reported. Period dates can be aligned along either rows or columns. Blank rows or columns can be inserted anywhere in the report. Row and column headings are completely under user control. Scale factors exist to factor the results.

Any number of reports can be generated in a single scheduling run. You can predefine a number of reports and then choose which reports to create when scheduling.

The output report format is a CSV file. This allows it to be brought into any number of downstream programs. The most common of course is Microsoft Excel. Although CSV files are simple text files and store no formatting information, this is not an issue because MineSched provides a function to open a number of CSV files at one time with corresponding XLS files. An XLS file that links to the CSV can be quickly and easily created in Excel. You then have all of Excels very powerful formatting, charting and presentation tools at your disposal to present the scheduling report data however you wish. Once a XLS template has been created, you never look at the raw CSV report again.

![Figure 1.6: Report Definition Sheet](image-url)
A CASE STUDY OF THE PLANT NORTH PIT OF BOGOSO GOLD LIMITED

Pictorial View Of The Plant North Pit Of Bogoso Gold Ltd

Plant North Design Pit
Block Model Of The Plant North Pit

Underground Workings Within The Open Pit
Quantitative Data Output Report

<table>
<thead>
<tr>
<th>Period</th>
<th>Ore</th>
<th>Calcin</th>
<th>Spoil</th>
<th>Sulphide Ore</th>
<th>Oxide Ore</th>
<th>Total Tonnage</th>
<th>Total Tons</th>
<th>Total Grade</th>
<th>Total Wt</th>
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</tbody>
</table>

Ore Tonnage by type Mined

- Calcine
- Spoil
- Sulphide Ore
- Oxide Ore
- Total Tonnage
- Total Tons
- Total Grade
- Total Wt

TS 17 – Mine Issues – Ecological and Environmental Issues
Ken Allen
TS17.2 Open Pit Mine Scheduling – A Case Study at Bogoso Gold Limited
Promoting Land Administration and Good Governance
5th FIG Regional Conference
Accra, Ghana, March 8-11, 2006

12/17
Waste Tonnage by type Mined

Tonnes and SR Mined
Ore Tonnage and Grade Milled

MS Project Output Report

Promoting Land Administration and Good Governance
5th FIG Regional Conference
Accra, Ghana, March 8-11, 2006
4. CONCLUSION

There is no doubt that the 20th century has witnessed a real revolution in computer technology and the mining industry has had its fair share. This has led to a sophistication in mine planning tools resulting in greater confidence level in planning results.

With mining operations becoming ever more complex and costly, the use of sophisticated methods/tools to accurately predict the strengths, weaknesses and risks of a particular operation cannot be over-emphasised.

No single scheduling method would be suitable for all situations due to the fact that all operations vary in size, location, material type and labour. One package may be suitably used at one site but may turn a disaster at another site.

The following criteria are therefore prescribed for the selection of a scheduling package for a mine site:
- Management’s expectation of the results the package can provide for decision making.
- Management’s knowledge in a particular package.
- The level of knowledge of the planning engineers in that package.
- Management’s appreciation of the difficulties planning engineers encounter in producing a result for decision-making.
- The user-friendliness of the package.
- The cost of the package
- Training of staff and level of technical support.
A scheduling process that is painstakingly done would certainly pay dividends at the end. It is therefore advised that both time and money are invested for the above to be achieved.

CONTACTS

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