PINCOCK Perspectives

ISSUE NO. 101— March 2010

Automated Mine Scheduling: What is it and will it help me?

CALENDAR

■ **EXPOMIN 2010**
April 12 – 16, 2010
Espacio Riesco Convention Center
Santiago, Chile
Email: coordinadora@expomin.cl

■ **LatAm Mining Congress 2010**
April 27 – 29, 2010
Westin Colonnade
Coral Gables, Florida
Email: stephanie.baronoff@terrapinn.com

■ **CIM Exhibition 2010**
May 9 – 11, 2010
Vancouver Convention Centre
Vancouver, BC, Canada
Email: cmurphy@cim.org
Visit PAH/Runge at Booth 1125

■ **2010 Elko Mining Expo**
June 10 – 11, 2010
Elko Convention Center
Elko, Nevada
Email: ExploreElko.com
Visit PAH/Runge at Booth 666

■ **Africa mining Congress 2010**
July 26 – 28, 2010
Sandton Convention Centre
Johannesburg, Gauteng,South Africa
Email: taryn.vanzanten@terrapinn.co.za

■ **Argentina Mining 2010**
August 24 – 26, 2010
Guillermo Barrena Guzman Convention Center
San Juan, Argentina
Email: paola@argentinamining.com

Introduction

This issue discusses the philosophies, strategies, goals and pitfalls in automating a mine schedule. The intention is to give an open and honest view of who could benefit from moving to an automated system, what you can expect from such a system, and what you should be aware of.

Many companies feel that moving to an automated mine planning solution will allow the mine scheduling engineer to push a button and walk away, but the reality is that is hardly ever the case. Part of that awareness comes from understanding what is meant by “automated mine scheduling.” By contrasting what is meant by “manual scheduling” and “automated scheduling” it is hoped that the reader can gain an appreciation of the entire process.

What is Mine Scheduling?

Mine scheduling is the process of calculating or predicting what will happen in a mine over time. To a production manager, it means ensuring that the right dirt is moved from and to the right place at the right time. To a financial controller, it means predicable revenues and expenses. To a processing manager, it means the right ore quantities and quality characteristics are available to the mill when they are required. To the marketing team it means the right products are delivered to the right customers when and as promised.

As the mine changes, and as the market changes, it is inevitable that schedules need to be redone to produce new mine plans. Seldom is scheduling a simple one step procedure – it is usually an iterative process which involves the following steps:

1. Create a geological model of the particular coal or ore deposit.
2. Divide the deposit into discrete units or mining blocks. The size of the blocks depends on the mining method, the data accuracy and the purpose of the schedule.
3. Convert this “geological” data into mining data by manipulating it according to engineering logic. For example the conversion of in-situ geological data to run of mine data by adding dilution gain and subtracting pit losses.
4. Rank the mining blocks according to a combination of their relative costs and revenue. This is termed an economic ranking. The results of this ranking provides direction for the first phase of scheduling.
5. Define the time frame for the schedule taking into account the total schedule length, the amount of detail required and the purpose of the schedule. For example early phases of the planning process might look at year by year data for the life of the asset. Detailed schedules might look at month by month extending for a period of 2-3years in advance of the current mine position.
6. Undertake broad-brush scheduling to establish quantity and quality trends over time. This enables refinement of the mine planning logic and mining concepts, leading to a better understanding on the constraints on mining and preliminary selection of equipment and its most efficient application.
7. The trends learned from the broad-brush scheduling phase become the primary

guidelines for a more detailed scheduling phase which simulates the extraction sequence over time using discrete items of equipment with specific mining logic.

8. Report results of the schedules including quantities, qualities, equipment, manpower, estimated cost and revenues over time.

In determining what is an acceptable schedule, mine scheduling engineers need to make trade-offs between the many competing objectives required of a schedule. For example, it would be very enviable to produce a schedule with constant quantity and quality of ore, fixed and uniform stripping rate and constant equipment and manpower thoughout the life of a mine, but this is rarely the case. Instead, the engineer must make compromises to produce acceptable (but not perfect) results that satisfy most of the objectives most of the time.

The scheduling engineer's job is in many respects one of the most important planning roles in the mine. Scheduling engineers need a high degree of skill and a great deal of diplomacy to produce schedules that satisfy the often competing objectives of a diverse group of internal departmental customers: marketing, commercial, corporate, management, processing plant, waste removal, ore mining, maintenance and logistics.

Manual Verses Automated Mine Scheduling

The easiest way to explain automated mine scheduling is to compare and contrast it with manual scheduling.

Manual scheduling within any software package is the process of: selecting the mining sequence of the deposit; analyzing the results of the schedule; then repeating the process until corporate objectives are achieved. This process is shown in Figure 1. Each time the schedule is refined, the user must manually change the path or sequence of mining. This often becomes a slow, labor intensive and arduous task and the result is that with time constraints there is usually only time to do a few iterations to the schedule before the results must be presented.

Manual scheduling gives users the greatest amount of flexibility. It allows the mine scheduling engineer to break standard long term scheduling rules; for example, a rule to always maintain a one-to-one layback can be broken in the short term to get around a problem period in the schedule. In the end, the main advantage of this type of scheduling is that the mine scheduling engineer has complete control over the sequence of mining and that the style of scheduling is relatively intuitive and easy to grasp.

The disadvantages of manual scheduling are: the time required to set up each mining path and refine the schedule; as well as limitations in the user's ability to select the correct combination of blocks to meet corporate objectives. For these reasons, manual input path scheduling is more suited to shorter range planning. For example, an engineer wanting to plan what an individual shovel has to do over the next 6 to 12 week time frame will use a manual scheduling method to explicitly state where the shovel is going to operate.

Automated scheduling, on the other hand, allows users to specify rules and constraints relating to the way blocks in the deposit must be mined. The computer driven automated scheduler then selects which block to mine from the list of available blocks. Objectives (such as targeting a desired grade) can also be used to guide the automated scheduler in which of the available blocks should be mined in preference if there are more than two available.

As shown in Figure 2, once the mining rules are set and the schedule has been run, the user analyzes it to ensure it is feasible (for example no undermining occurs where it shouldn't). If the schedule is not feasible, the user is required to amend the operational rules until it is considered acceptable. Following this, the user then checks that corporate objectives are met. If they have not been met, rules can be edited, created, or removed quickly and easily, then the schedule rerun and results reviewed.

The key advantages of using an automated scheduling process are as follows:

- The extremely fast scheduling speed allows many more scenarios to be

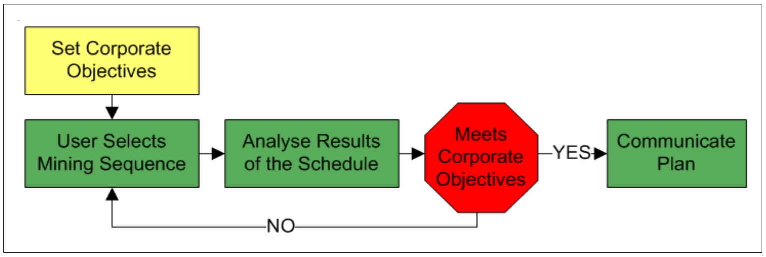

FIGURE 1: Manual Scheduling Process

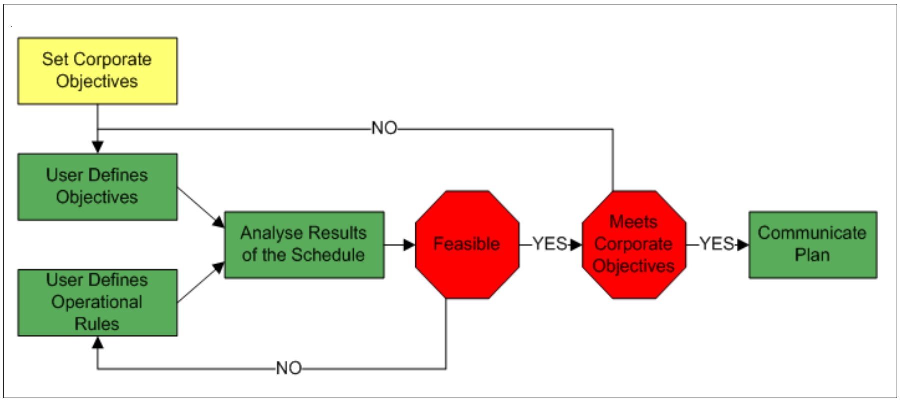

FIGURE 2: Automated Mine Scheduling Process

evaluated. The result is that mine scheduling engineers spend less time creating schedules and more time evaluating them.

- Scheduling rules, once defined, are always honored and this reduces the risk of human error. Rules are based on planners experience and are captured in a format that is retained for new engineers.

- Conflicting objectives (such as target grade and haul length) can be played off against each other by adjusting their priorities. Often the mine scheduling engineers "art" will involve gaining an understanding of the relative sensitivity of achieving these objectives and understanding the compromise that must be reached in order to produce an acceptable schedule.

Initial configuration of an automated scheduling model is more complex and requires an increased learning curve. Automated scheduling is sometimes perceived as being inflexible as mining rules are always honored and can't be temporarily ignored to achieve a certain result in a particular period. For these reasons, mine sites typically use automated scheduling models for long range planning where multiple alternate scenarios must be performed and analyzed in a relatively short period of time. Automated models are also suited to mines which have: complex product blending or scheduling rules; stockpile requirements; dynamic cut off strategies; large datasets or a requirement to minimize haul times.

Example of an Automated Schedule

Figure 3 shows some results from an automated mine schedule run in a hypothetical oil sands deposit.

In the case shown in Figure 3, an oil sands deposit with three waste benches overlaying two oil sands benches is being mined. The automated schedule model has been set up with mining rules that prevent undermining, maintain a particular maximum and minimum layback angle and a general mining direction that fans mining out from one corner of the deposit. The deposit's bitumen grade is variable with a sweet "high grade" section on the right side of the deposit.

Two automated schedules have been run on this deposit and were completed within just a few minutes. One schedule which maximized the bitumen grade is shown on the left of Figure 3 and one that minimized the bitumen grade is shown on the right of Figure 3. The results produced were quite different in terms of what was mined when.

The purpose of the automated schedule was not to try and "optimize" the solution but to provide quick results back to the mine scheduling engineer so that he / she could then determine which is the most appropriate schedule to use as a "go forward" case.

In this example, only one objective (to minimize or maximize the bitumen grade) was tested. In a real life scheduling scenario, these cases along with others to target a particular bitumen grade, maximize pit floor foot print for dikes, minimizing haulage, maximize NPV and combinations of all of the above would also need to be run to provide the mine scheduling engineer with the best possible schedule. The automated scheduling process in the end just provides the tool to enable this to be done in a reasonable time frame.

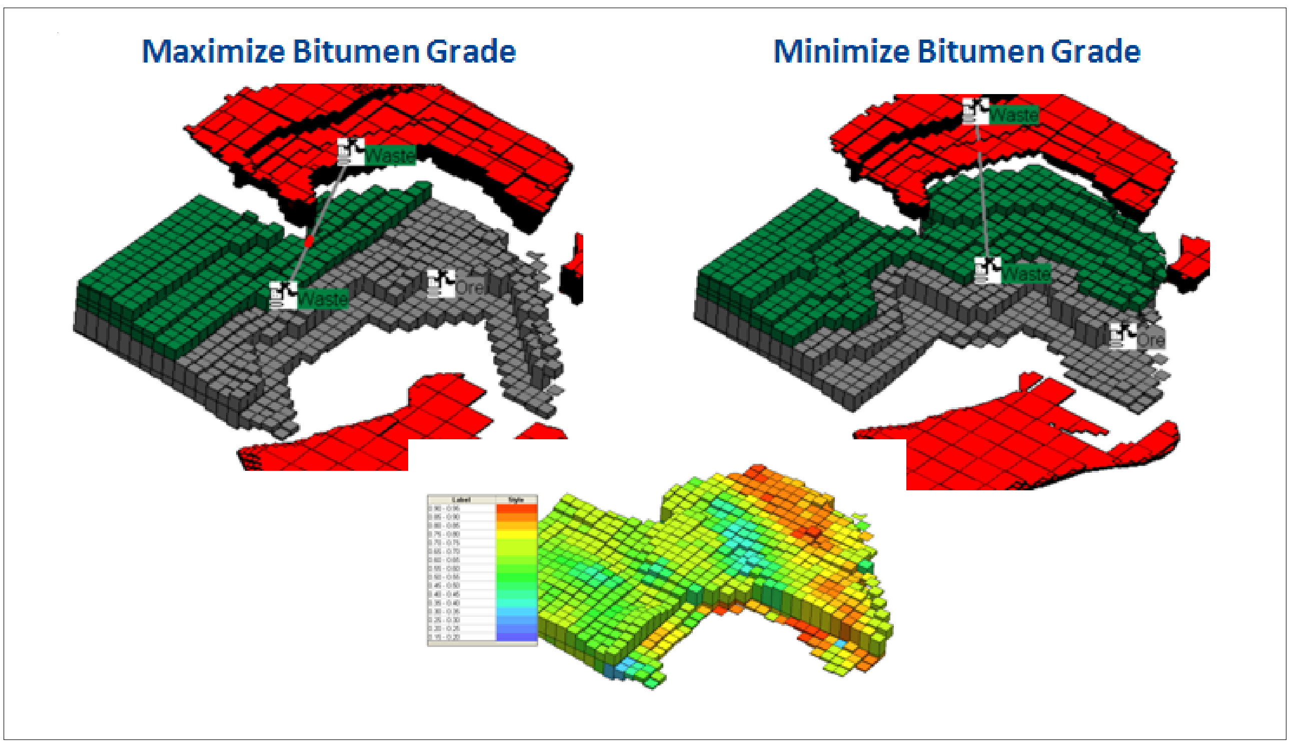

FIGURE 3: Example of Automated Schedule Result in an Oil Sand Deposit

Approaches to the Set Up of Successful Automated Scheduling Models

As stated earlier, setting up an automated scheduling model is more complex than a manual model and more attention needs to be payed to the methodology of creating and building these models. In building automated scheduling models the following recommendations are suggested:

- In defining the rules that control mining, ensure that they are indeed rules rather than objectives (i.e., the nice to haves). For example a scheduling engineer may be tempted to say that maintaining a 200m wide bench is a "rule" of mining, but in reality a width much less than this is more than acceptable, particularly if it enables the uncovery of the ore sooner. Thus, the scheduling engineer should configure the model with a rule to maintain a 100m minimum bench with an objective to maintain a 200m bench if possible and assess the merits of wider benches verses the timing of ore uncovery.

- Do not over constrain an automated schedule. New users often fall into the trap of applying to many rules, constraints and objectives in an effort to obtain that "magical" scheduling solution. A better approach is to apply each rule, constraint and objective one at a time with the engineer observing and noting the effect on the schedules outcome.

- Use a "staged" approach wherever possible to building scheduling models. Before building anything, spend as much time as possible planning what the end result should be. Define the deliverables and prioritize them in order in which the model is to be built. In the end it is better to phase the construction of the scheduling model building it in "bite" size "chunks" rather than trying to solve the whole scheduling dilemma in one go. An example of this is the recommendation for building oil sands scheduling models:
    - Stage 1 Model - Excavation model simulating waste and oil sand extraction
    - Stage 2 Model - Add the scheduling of waste materials to dykes and dumps to the above Stage 1 model
    - Stage 3 Model - Add haulage calculation logic to the Stage 2 model

- Know and understand your planning horizon and what the key outcomes of the schedule need to be. For example a life of asset schedule for an oil sand mine over 40-60 years (scheduled by year or 5 year increments) does not need to know the location of each of the 10-20 individual digging units in each scheduling period.

- Shop around the various software vendors to determine what solution will work best for the particular set of circumstances you are faced with.

- Do not fall into the trap that a single solution will solve all of your companies needs. This is particularly important if you are in a company with multiple mining operations. In these cases it will appear attractive to build a single model that does everything for everyone at every mine site. The reality is that this is often not practical or even possible. The recommendation is to build models with commonality but with the local site differences incorporated to achieve the required individual site results.

- Training and documentation of models is critical. Often automated scheduling models are difficult for new users to use correctly. The key to overcome his is in making the required resources, funds and time available for good quality training and for the production of a thorough and comprehensive user's manual to accompany the model that has been built.

Conclusion

Mine scheduling is the process of calculating or predicting what will happen in a mine over time. Manual scheduling and automated scheduling both have their place in the mine scheduling engineer's toolkit and it is appropriate to use both types of scheduling depending on the task being undertaken. The "trick" is to know what to use when.

Manual scheduling is best suited to those occasions where the engineer needs complete control over the mine sequence. It is most appropriate for use with short term scheduling. Automated scheduling, which is extremely fast, lends itself to longer term scheduling were multiple scenarios need to be tested by the engineer. In these cases the computer can take the "hack" work out of creating the schedule thus allowing the engineer to spend more time analyzing, comparing and understanding the results. If an automated scheduling solution is chosen, engineers should avoid easily made mistakes such as over constraining the schedule; incorrectly defining rules and objectives; trying to solve all the scheduling problems at once and not understanding the planning horizon of the scheduling problem being solved. If these mistakes are avoided, the automated scheduling system is set up with good quality documentation and the users are properly trained, this type of scheduling can give the engineer accurate and speedy results.

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