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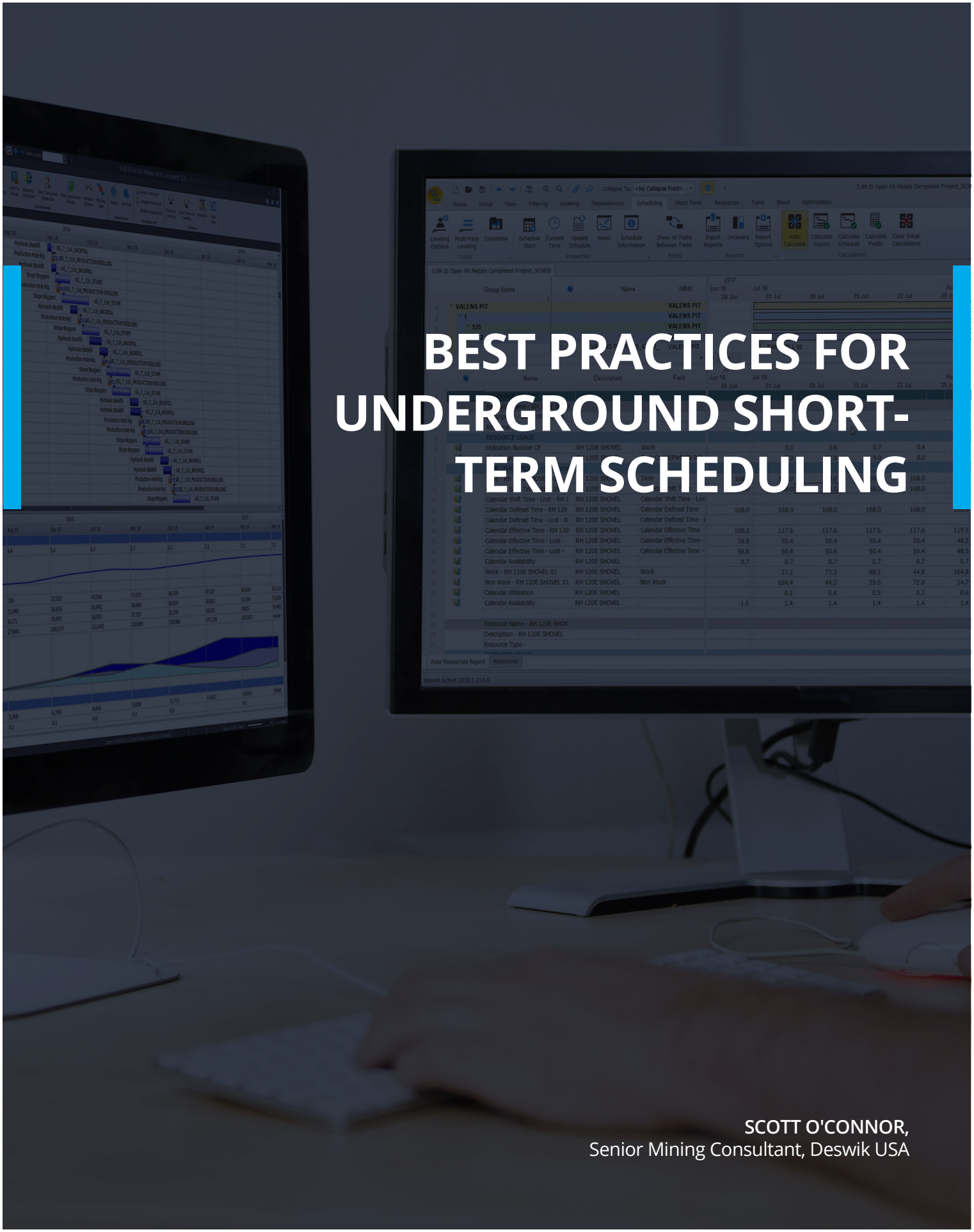

BEST PRACTICES FOR UNDERGROUND SHORT-TERM SCHEDULING

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THE CHALLENGE

Short-term scheduling of an underground mine is a fast-paced, repetitive process. Planners are repeatedly under pressure to deliver schedules that meet immediate operational constraints while adhering to business objectives. It is difficult to find the appropriate level of detail to model. Schedules are often either too detailed, difficult to understand and maintain, or they are overly simplistic, resulting in a mismatch with operational reality. Typically, short-term planners rely heavily on manual processes, rendering them reactive with a constant focus on "putting out fires" (Åstrand 2018).

Implementations of mine planning software often lead with long-range planning solutions, leaving the short-range implementations as afterthoughts. The short-term schedule inherits all the bloat from the long-range model or, worse yet, remains a decoupled spreadsheet exercise. When long-range priorities are not adhered to in the short term, any possibility of obtaining the global optimum result is precluded (Nehring et al 2010). Even in instances where common mine planning software is employed for both short- and long-term scheduling, friction can occur when integrating planning horizons. This often takes the form of large file sizes, rework as plans are passed between planning horizons, and duplication of effort.

BACKGROUND

Prior to establishing a set of short-term scheduling best practices, the battery limits and interactions between planning horizons must be defined. This guides the appropriate level of detail in each planning horizon model and informs decisions on the best fit-for-purpose software. What exactly is the "short-term" planning horizon? Deswik encounters sites that classify anything within the two-year time horizon as short term and other mines that consider it to be detailed shift plans encompassing a span of one week or less. While the definition varies from site to site, this paper focuses on the short-term planning horizon that is within the typical range of two weeks to three months duration. Deswik frequently encounters planning horizons broken down as shown in Figure 1.

Planning Horizon	Shift / Operational	Short-Term	Mid-Term	Long-Term	Strategic
Span / Duration	1d to 2wks	2wks to 3mo	3mo to 18mo	18mo to 5yrs	5yrs to LOM
Reporting Granularity	Hour to Shift	Days to Weeks	Months	Months to Years	Years
Reforecast Frequency	Intra-Shift to Daily	Weekly	Monthly	6mo to Yearly	Yearly+
Planning Tool	Deswik.OPS	Deswik.Sched	Deswik.Sched	Deswik.Sched	Deswik.GO

Figure 1 - Planning Horizon Definitions

Regardless of the interpretation of the planning horizons, they are linked together.

Plans originate as less detailed strategic forecasts, typically undertaken through optimization using high-level assumptions, which then crystalize over time, becoming more detailed operational plans. Operations should seek to improve the integration and communication between the planning horizons for the following reasons:

- Increased asset value. If each planning horizon operates as a separate silo, only local optimum solutions can be determined (Nehring et al 2010).
- Improved compliance. Priorities from the long-term schedule should be readily communicated down to the short-term schedule, ensuring consistency.
- Improved feedback. Variances in the tactical plans should be easily pushed into the longer-term plans so adjustments of assumptions can be made.
- Increased planning efficiency. Minimize any duplicated effort of scheduling tasks that overlap planning horizon boundaries.

It is important to draw a distinction between shift-based operational scheduling and short-term scheduling. The former is commonly known as Short Interval Control (SIC) and is best summarized as the "plan, do, check, act" (PDCA) cycle (Global Mining Guidelines Group 2019). A short-term plan serves as the input for SIC, which is then broken into a finer level of detail in the shift / operational plan so that it can be executed and tracked down to the hour granularity.

Deswik produces Deswik.OPS as a software solution in this space, which is a collaborative shift planning tool that imports short-term schedules generated in the Deswik suite, and further breaks them down into operational level of detail.

SIC is beyond the scope of this paper. The focus of this paper is rather on short-term scheduling, which is typically a two-week to three-month rolling plan. The reporting granularity of short-term plans is at-most broken down into days if one is looking only at the first week or two, and transitions to less detailed reporting periods of weekly or monthly over a three-month span. Deswik's software suite of tools for this planning horizon include Deswik.CAD, Deswik.Sched and Deswik.IS.

SOLUTION

Integrate Planning Horizons

For the previously stated reasons (value, compliance, feedback, and efficiency) it can be beneficial to integrate planning horizons. The best way to integrate planning horizons depends on the staff size and organizational chart of the mine. Smaller orebodies, in which a single mine planner oversees all planning horizons, can successfully use a single "live" schedule model that adequately constitutes all planning horizons. Deswik.IS provides methods to create variable task breaks and derived task cycles. Tasks in the short-term planning horizon can be recreated with the finer level of detail needed, while preserving dependencies and priorities set in the longer-term plan.

In larger operations, where there is more than one planner, each responsible for a different planning horizon or zone, having separate files is an inevitable consequence and deemed necessary to allow concurrent planning. In these cases, Deswik provides a project merge solution to integrate planning horizons.

Project merge is a mechanism built into the Deswik suite that allows updates from shorter term schedules to be merged into longer term schedules (including task percentage completion) and tasks from longer-term plans to be written back to the shorter-term plans. Multiple planning horizons can nest (Figure 2), allowing flexibility for the site's planning horizon structure.

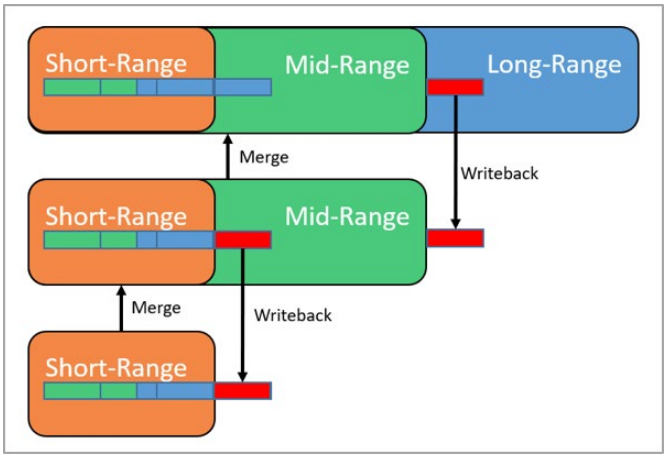

Figure 2 - Nested Planning Horizons

The benefit of merging schedules is that it permits concurrent scheduling of planning horizons, while preserving distinct, fit-for-purpose files. The short-term schedule can be small and nimble, containing only the necessary tasks in the near-term window, which most planners prefer.

Appropriate Level of Detail

The schedule model level of detail should be carefully considered and matched according to the planning horizon. This includes settings such as task break length, derived task cycles, assumed rates, assigned resources, and leveling constraints. For example, the life of mine plan (LOMP) should be modeled more coarsely than the short-term plan. It is overkill to sequence and level individual days for a LOMP that is reported by year as the daily variances within the year will be quite large. The general recommendation is that model granularity is an even match with the reporting periods, meaning tasks, rates, and constraints should be adequately sized to forecast the period.

Deswik suite contains mechanisms to allow granularity to transition from coarse to fine over time as tasks migrate from the long-term to the short-term plan. Figure 3 shows this transition. Recent enhancements to Deswik.IS permit tasks to be recreated in the short-term schedule with smaller segment lengths, additional derived tasks, and faster assumed rates, all while preserving the dependencies generated in the longer-term plan.

Instead of defining task breaks based on a "one size fits all" approach, planners are now free to size task breaks according to first principles, such as dependencies, material type classifications (ore / waste), desired resource movements or separable portions, activity cycles, and reporting accuracy.

In addition, leveling constraint period length is variable by date. These options, typically known as targets or quantity limits, allow more detail in the short term, while not burdening the long-term plan with the same level of detail.

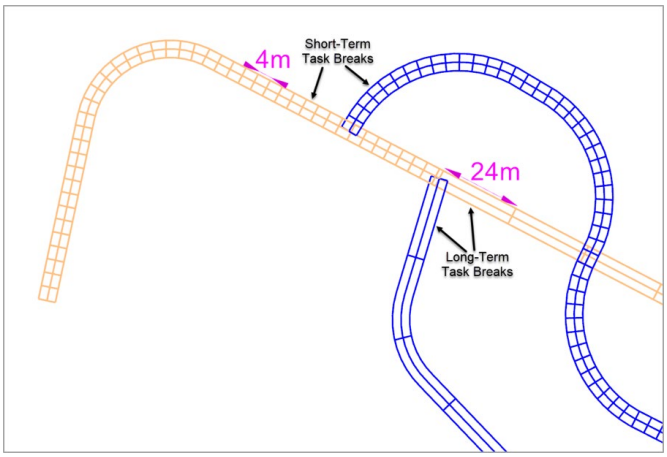

Figure 3 - Variable Task Breaks According to Planning Horizon

Updating Schedules

The basis of plans mandates depletion or removal of tasks that have been completed since the plan was issued. Due to the frequency of issuing short-term plans, considerable effort can be spent maintaining actuals in the schedule model. Manually updating percentage complete values in a schedule should be the last resort as it is time consuming and error prone. More efficient methods are available with the Deswik suite.

Complicating matters, there is often a lag in delivery of the inputs required to update schedules, such as survey as-built walls or solids. Depending on site workflows, it is possible to work around the lag by using daily updated face markers typically provided by the geology department.

Deswik.IS can reference the geology face markers to calculate lateral advance and automatically push this to the scheduler to update tasks.

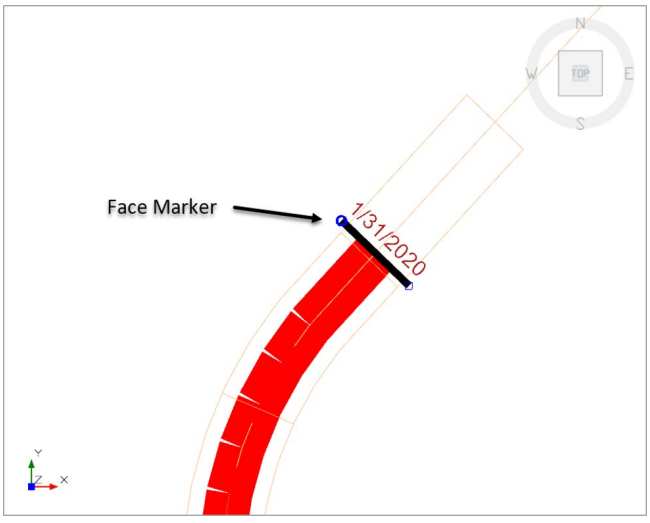

Figure 4 - Update Actual Via Face Marker

A more efficient practice to update schedules is to connect to a production database. Doing so bypasses graphical requirements and directly updates percentage completes on tasks. To setup a this process the following pre-requisites must be met:

- A consistent "primary key" location naming convention shared across planning, survey, and operations departments.
- Chainage measurements for lateral advance recorded in a database or spreadsheet with a common basis (starting measurements) for headings in Deswik and in the survey ledger.
- Incremental production actuals recorded in a database or spreadsheet, including tonnes produced by stope by day.

If the above criteria are met, Deswik.Sched offers "power tools" to automate the process of updating actuals (percentage complete of tasks). A single import can update the lateral advance headings, incremental production actuals, as well as stope-derived tasks, such as drilling or backfilling.

The proper use of this tool not only allows more time to generate and analyze scenarios, but also ensures feedback loops are in place and functioning between planning, survey, and operations.

Reporting

The product of mine plans are reports. It is important to streamline and automate the reporting process in the short-term planning horizon due to the high frequency with which these plans are issued.

Deswik commonly encounters existing reporting processes as follows:

1. Copy the reporting spreadsheet to a location on the network drive and rename it according to the forecast date.
2. Manually apply filter(s) in the schedule model.
3. Copy the report or task report from the schedule.
4. Paste it into the nominated spreadsheet tab.
5. Repeat steps two to four for multiple dump tabs in the spreadsheet.
6. Validate and print the tabulated (pivot tables) reports.

The above process is cumbersome and potentially error prone due to the manual manipulations of the data. Working in isolated spreadsheets does not maintain a centralized historical forecast repository.

The past decade has brought tremendous advances in reporting and data analysis capabilities. Business Intelligence (BI) software now exists to retrieve, transform, and summarize data. BI tools offer the following advantages over the spreadsheets they replace:

- Automation. Data can be formatted and transformed following automatically applied steps.
- Uniform data model. Multiple forecasts and actuals can be loaded into a relational data model. This allows forecasts to be compared against each other (forecast versus budget) as well as compliance to be reported (plan versus actual).
- Advanced charting capabilities. Data loaded into the model can be summarized into meaningful groups and charted. For example, overlaid Plan and Actual Gantt bars grouped by heading can show compliance.

Deswik.Sched allows task report templates to be pre-configured so that forecast data can be readily batch exported in standardized formats that are made accessible to BI software to tabulate and report.

CONCLUSION

Short-term scheduling is a fast-paced and challenging process. Every effort should be made to streamline and automate the process. Short-term plans are the link between executional plans and optimum long-term plans. Planning horizons should be integrated to ensure consistent priorities and an increased chance of compliance. Deswik provides mine planning software that addresses the following challenges:

- Integrating planning horizons.
- Modeling the appropriate level of detail.
- Automating updates based on actuals.
- Integrating with advanced BI reporting.

Contact your local Deswik office for further information about short-term scheduling or for assistance with the implementation any of the principles discussed in this whitepaper.

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