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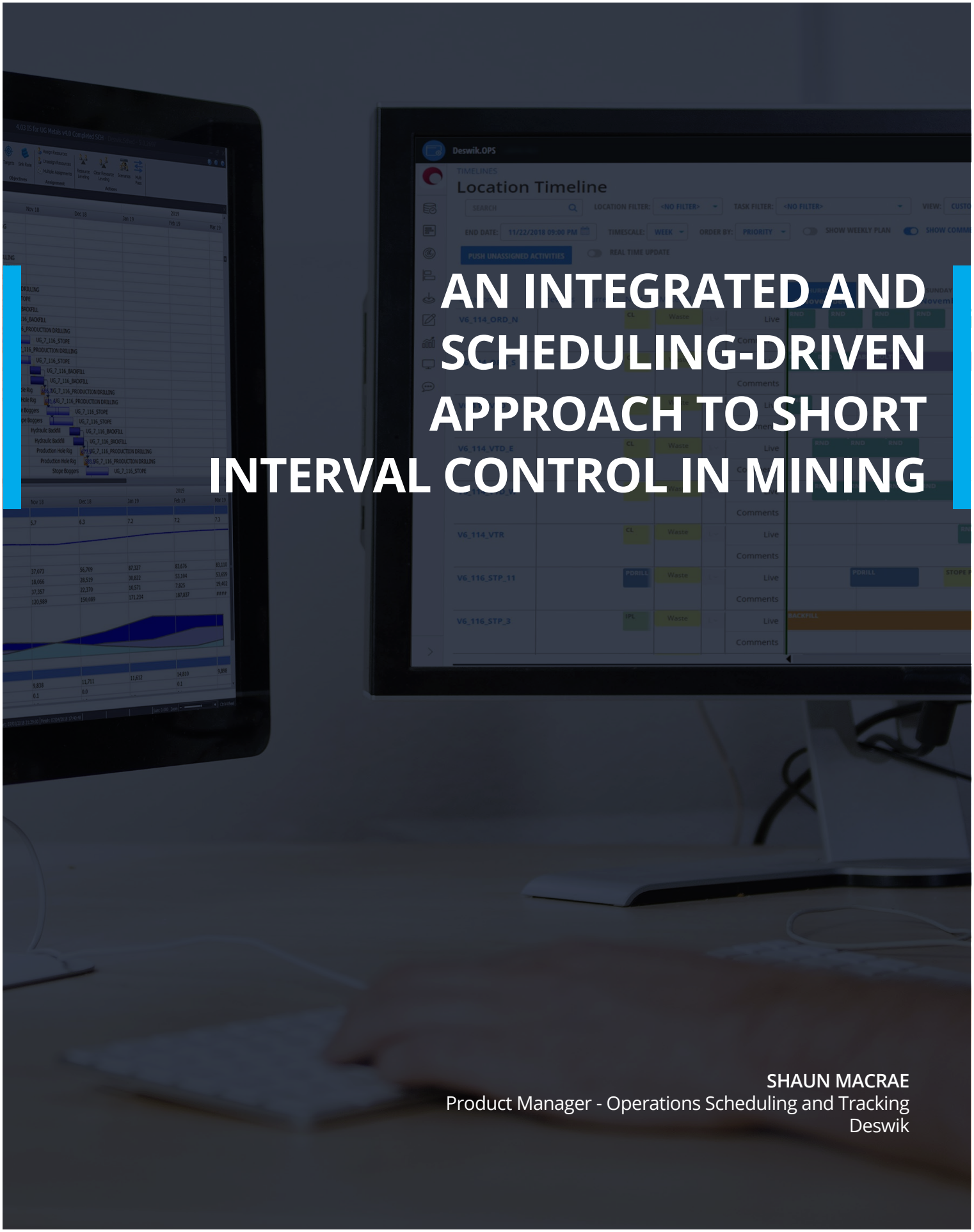

AN INTEGRATED AND SCHEDULING-DRIVEN APPROACH TO SHORT INTERVAL CONTROL IN MINING

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1. Introduction

As an engineering services and technology provider, Deswik successfully implements mine design, planning, scheduling, and operations tracking systems with a strong focus on improving overall capability by supporting people and process, and delivering technology.

As a company, we have a history built on the premise of integrated mine planning. With the increasing amount of operational execution data being generated by mining operations, Deswik has been exploring how to truly integrate operational plan execution with upstream mine planning processes.

Deswik is often asked about Short Interval Control (SIC) in mining and how an integrated SIC strategy could be implemented for mining operations. We believe that SIC in mining warrants an integrated scheduling-driven approach, which includes tactical (medium or short-term) and operational (weekly, daily, or shift) scheduling and execution.

This paper discusses the people, process, and technology considerations for SIC in mining. The paper also provides a review of several SIC concepts applied in the industry today and the reported benefits.

If you have feedback for the improvement of this document, contact the author at shaun.macrae@deswik.com or www.linkedin.com/in/shaunmacrae/.

2. SIC

According to Vorne (2018), SIC is "a factory-floor process that engages team members to review performance data three or four times within their shift to assess where they need to focus their efforts to improve performance". Vorne maintains that "manufacturing processes can make significant improvements in OEE (Overall Equipment Effectiveness) when effectively implementing SIC (e.g. a site with 60% OEE improving to 65% OEE in under three months and to 75% OEE within two years)".

While several SIC concepts have been employed in mining operations for some time, the first published account of SIC in mining was not until 2012 (Howes & Forrest, 2012). SIC developments in mining adopt ideas from other industries, such as manufacturing, in which SIC and lean concepts are clearly defined and have had the opportunity to mature over a long period of use.

Because mining is performed in a more dynamic and mobile environment than it is in industries such as manufacturing, some common SIC concepts have been more difficult to apply and require a level of industry maturity to achieve SIC at the highest level. However, many mining companies are embracing SIC concepts today. They are starting to develop SIC capability roadmaps and plans to improve the predictability and productivity of their operations.

The following table provides examples of pain points that are primarily related to scheduling that are driving SIC initiatives and the corresponding SIC challenges.

PAIN POINT	SIC CHALLENGE
Scheduling is manual and time-consuming	Automatic generation of the schedules given a set of drivers, constraints and desired outcomes with little to no manual intervention
Limited data integration across functions	Ability to integrate all scheduling together (either fully or through light integration) and with other key software packages (for example, mobile production systems, survey systems, inventory management systems, reporting and analytics, and corporate or IT systems)
Complex processes to align long-term schedule objectives with medium-term, short-term and operational schedules	Easy translation and clear interfaces between long-term schedule objectives Medium- and short-term asset scheduling to ensure that key long-term objectives are being met while still considering short-term constraints
Lack of decision support capability	Basic to advanced decision support to highlight the effects of key trade-off decisions at different levels of detail, such as short range (for example, corrective actions when the schedule is interrupted) and long range (for example, development options or optimal production rates)
Inaccurate schedules	Integrated, up-to-date and accurate schedules which outline current assumptions driving performance and track changes in assumptions across previous versions
No feedback on performance	Dynamic updating of schedules based on real-time decisions and performance to account for events outside of the plan

3. Maturity Model

SIC is not just the buzzword of the moment in mining; mining, along with many other industries, is looking for a way to become more efficient and productive. Based on experience in other industries, SIC in mining is here to stay and SIC capabilities in mining will continue to improve.

As mining adopts people, process, and technology improvements (SIC enablers), SIC concepts will become easier to apply and, more importantly, easier to adopt in a persistent or 'sticky' way that will last the life of the mine.

The Global Mining Guidelines Group (2018) defines six potential SIC maturity levels:

- Basic
- Foundation
- Integrated
- Decision Support
- Semi-automated
- Highly Automated

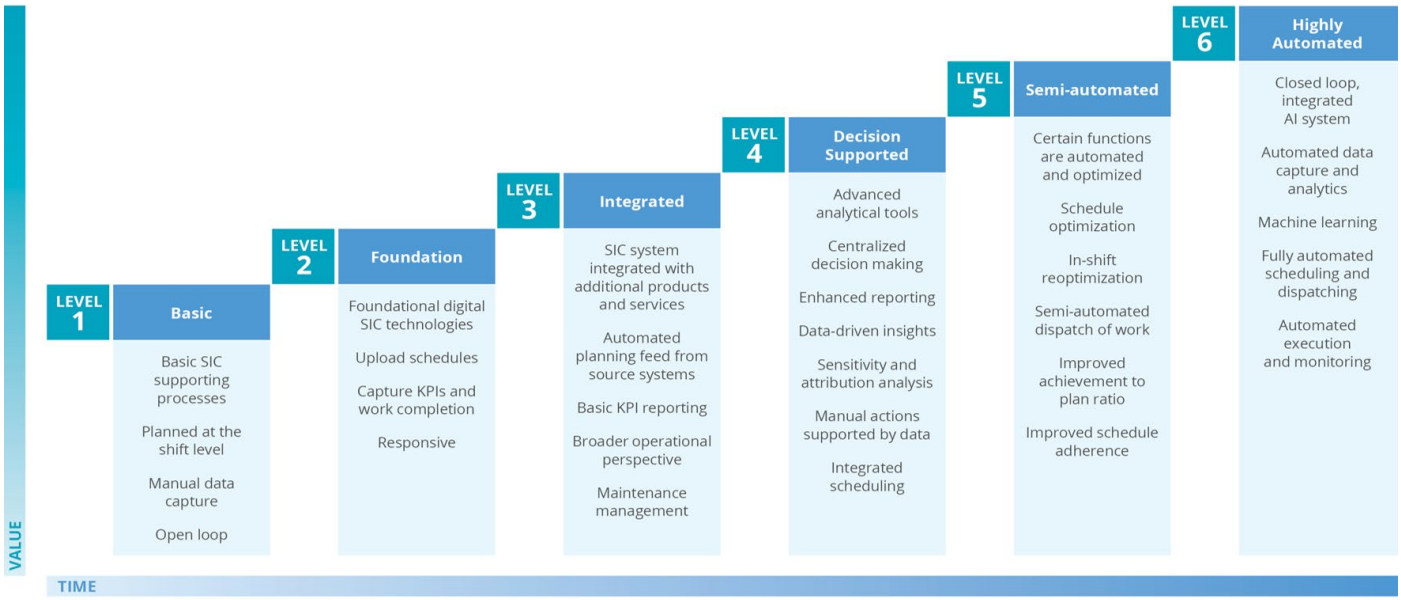

Figure 1 - SIC Maturity Levels.

Achieving the highest level of SIC maturity would require a significant investment in people, processes, and technology. It is important to develop SIC maturity over time through active management, as implementing an SIC strategy beyond the maturity of the organization would be ineffective and could prejudice any future SIC activities. It is important to step through the maturity levels without an expectation to jump quickly from a lower level to a higher level. Most sites today are likely to be operating in maturity levels 2 to 4. It is also important to note that different aspects of SIC may mature at different rates within an organization. For example, a company may be highly automated but only support basic reporting or vice versa. As a result, an organization may span a range of SIC maturity levels and have a unique SIC journey based on the organization's relative strengths and weaknesses.

4. People, Processes and Technology

The following examples of people, processes, and technology that typically form part of SIC in mining are representative of maturity levels 3 to 4 (see section 3). They are not intended to be prescriptive but rather to provide a broad overview of SIC in mining.

4.1. People

Before identifying processes and technology for an SIC strategy, it is important to first identify the roles and stakeholders involved in the strategy. This will help identify key processes and assist in uncovering challenges and opportunities. The following are examples of roles that are likely to be central to a mining operation's SIC strategy. However, the list is far from exhaustive and the best SIC strategies involve the whole operational workforce.

4.1.1. Mining Engineer

Mining engineers plan and direct the engineering aspects of locating and extracting minerals. From an SIC perspective, mining engineers develop medium- and short-term schedules (see sections 4.2.1 to 4.2.4) which guide operational scheduling processes (see sections 4.2.5 to 4.2.8).

4.1.2. Production Planner or Engineer

Production planners are often mining engineers, but they may also find their way into this role through other operational roles. They develop operational schedules downstream of the short-term tactical schedules, typically on a weekly basis (see sections 4.2.5 and 4.2.6).

The production planner ensures that the weekly schedule can be executed as delivered, and updates the schedule to include additional factors, such as the following:

- Scheduled maintenance
- Exploration drilling programs
- Geotechnical requirements

The production planner also performs the following functions:

- Adding any additional detailed activities.
- Assigning key equipment to activities.
- Adding commentary to provide specific information to the shift bosses and operators.

4.1.3. Shift Boss or Supervisor

Shift bosses or shift supervisors develop daily and shift schedules downstream of the weekly operational schedule (see sections 4.2.7 and 4.2.8).

Shift bosses ensure that the daily or shift schedule, which comes from the weekly schedule, can be executed as delivered. They also update the schedule to include additional factors, for example:

- Progress on the schedule according to the previous shift
- Availability of equipment and operators
- Priority headings

The shift boss also performs the following functions:

- Setting up and assigning the operators available for the current shift.
- Updating any known delays that may affect the shift.
- Printing workcards for operators.

4.1.4. Control Room Personnel

Control room personnel primarily monitor shift activity scheduled in the daily or shift schedule (see section 4.2.9). They dynamically reschedule the activities and manage any delays within the shift in conjunction with the shift boss or supervisor.

Control room personnel often also perform the following tasks:

- Entering production data and recording information about active tasks and resources, OR monitoring production data and how it is progressing the schedule in the case that data is being captured in the field or automatically.
- Ensuring that all movements within the shift are correctly recorded.

The control room personnel are in regular contact with the following persons:

- The shift boss or supervisor
- Operators
- Maintenance personnel.

4.1.5. Maintenance Planner

Maintenance planners work with the Operations team to ensure maintenance schedules (see section 4.3.1.2) are incorporated into the operational schedule. Maintenance planners are also interested in capturing and monitoring equipment running hours, including the running hours of individual components of each piece of equipment.

4.1.6. Geologist

Geologists provide the models that drive the whole scheduling process, and will also have medium- and short-range/operational models. Mine Engineering and operational schedules assume the geological estimates for each portion of the mining resources. Through operational execution, schedule results inform the continuous refinement of those geological estimates. This is often referred to as grade control (see section 5.5).

4.1.7. Contractors

Many mining operations employ contract resources to assist with one or more mining activities (typically operational activities). The owner or operator and contract companies are interested in combining their work schedules and tracking work progress together.

4.1.8. Mine Management

Mine managers, from an SIC perspective, are interested in tracking mine schedule conformance (see section 5.10). They are primarily consumers of information in SIC processes. The information provides valuable decision support to the mine manager, particularly when challenges and opportunities that can inform decisions are identified through SIC.

4.2. Processes

It is important to first identify the processes involved in an SIC strategy before identifying supporting technology. The aim of the defined SIC processes should be to provide ways of integrating schedules and workflows of related roles and stakeholders (see section 4.1).

Each operation may use its own terminology for the processes and schedule types that will be discussed. The processes discussed are general and common terminology is used. These processes need to be applied in the context of the operation (see section 5.1).

An integrated and schedule-driven approach to SIC is shown in the diagram that follows. Such an approach creates a continuous feedback loop based on conformance to plan, where 'conformance to plan' means executing the daily/shift schedule. The aim is that the daily/shift schedule follows the daily/shift baseline schedule, which should follow the weekly baseline schedule. Likewise, the goal is that the weekly baseline schedule follows the short-term baseline schedule, which in turn should follow the medium-term baseline schedule.

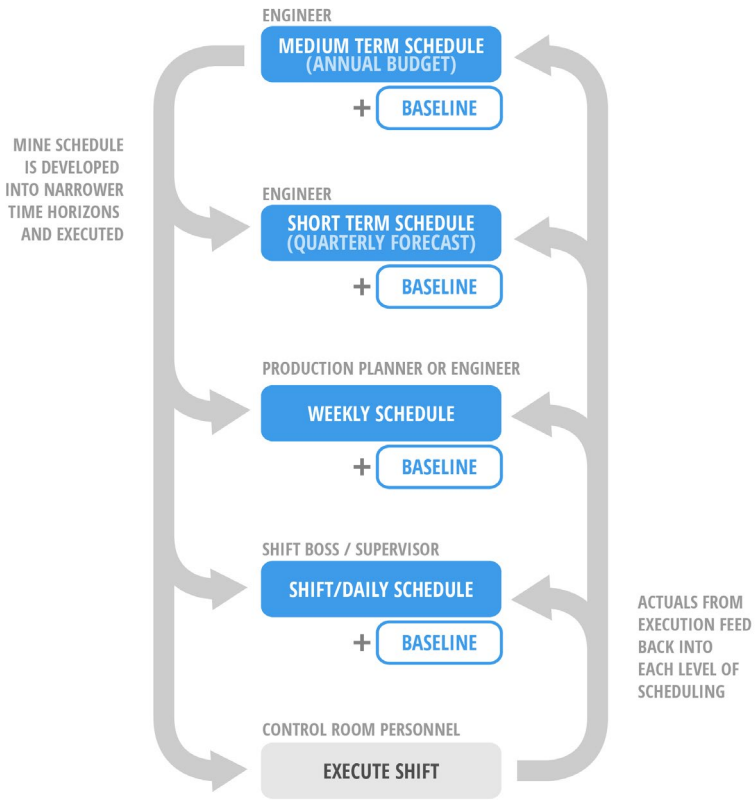

Figure 2 - Overview of SIC Processes.

4.2.1. Create Medium-Term (Annual Budget) Schedule

Generated by: Mining Engineer

Timeframe: Medium-range mining schedule

Update period: Annual budget process

Audience: Commitments the operation is making to the business and shareholders

Focus: Location targets with fleet-level equipment targets (often not at the equipment unit or individual operator level).

The following is an example of such a mining schedule.

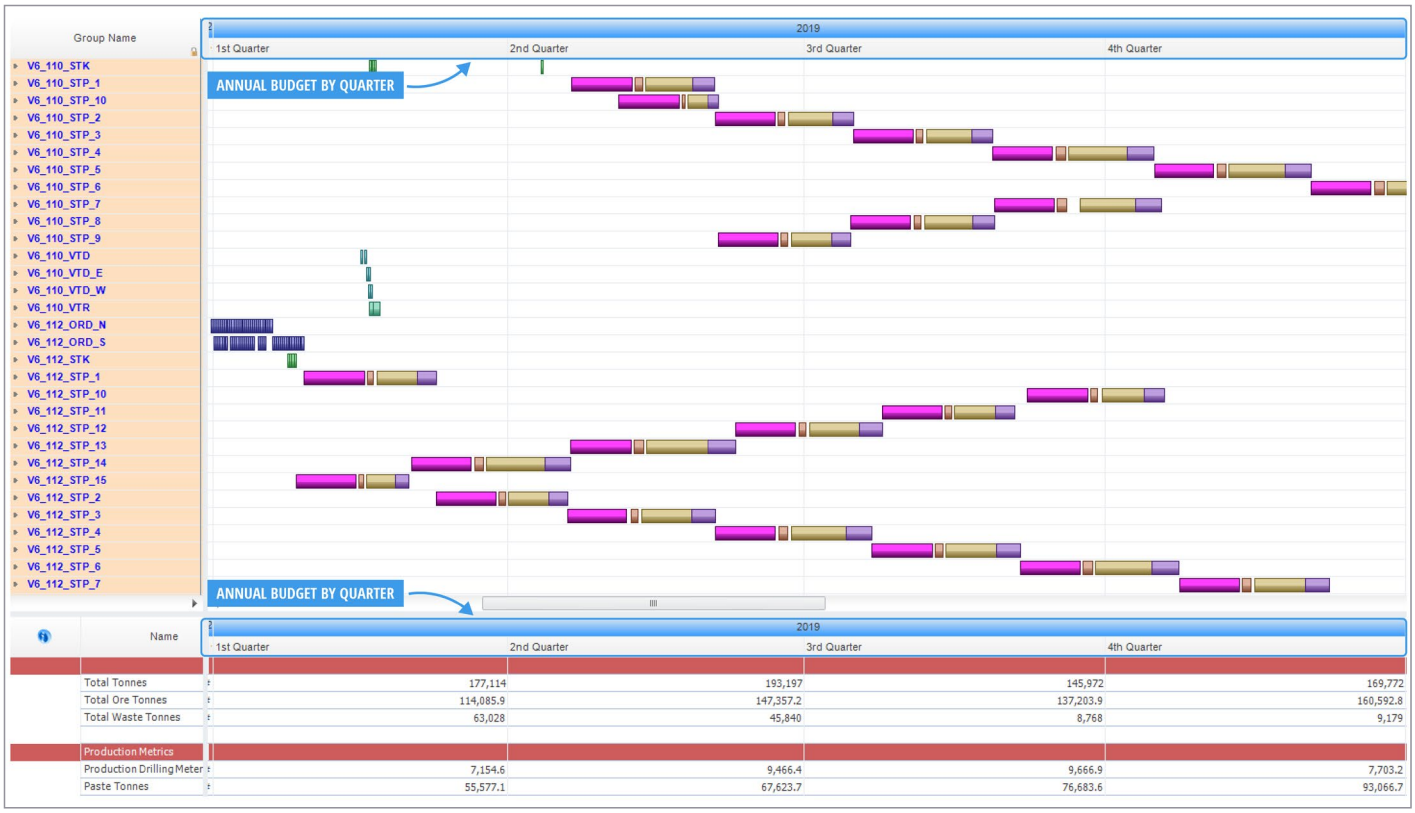

Figure 3 - Medium-Term (Annual Budget) Schedule.

4.2.2. Baseline/Publish Medium-Term (Annual Budget) Schedule

Sign-off frequency: Annual

Conformance review frequency: Continually (at least monthly).

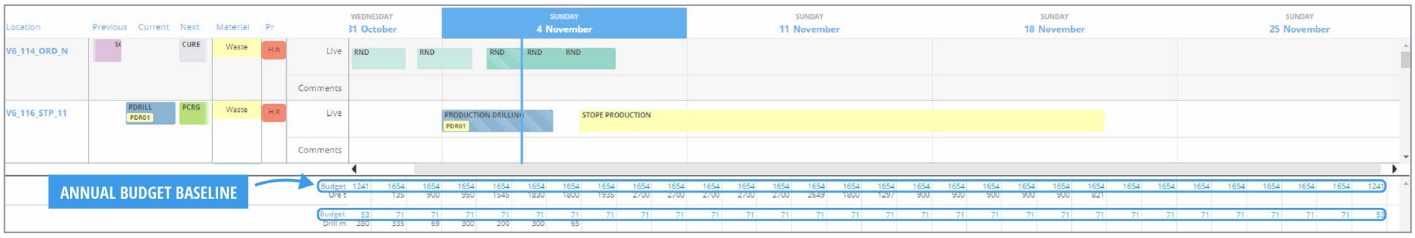

Figure 4 - Medium-Term (Annual Budget) Schedule Baseline.

4.2.3. Create Short-Term (Quarterly Forecast) Schedule

Generated by: Mining Engineer

Timeframe: Short-range mining schedule

Update period: Quarterly forecast process, although many mines are moving to rolling monthly forecasting

Audience: Commitments the operation is making to the business

Focus: Location targets with fleet-level equipment targets, and certain equipment unit level targets.

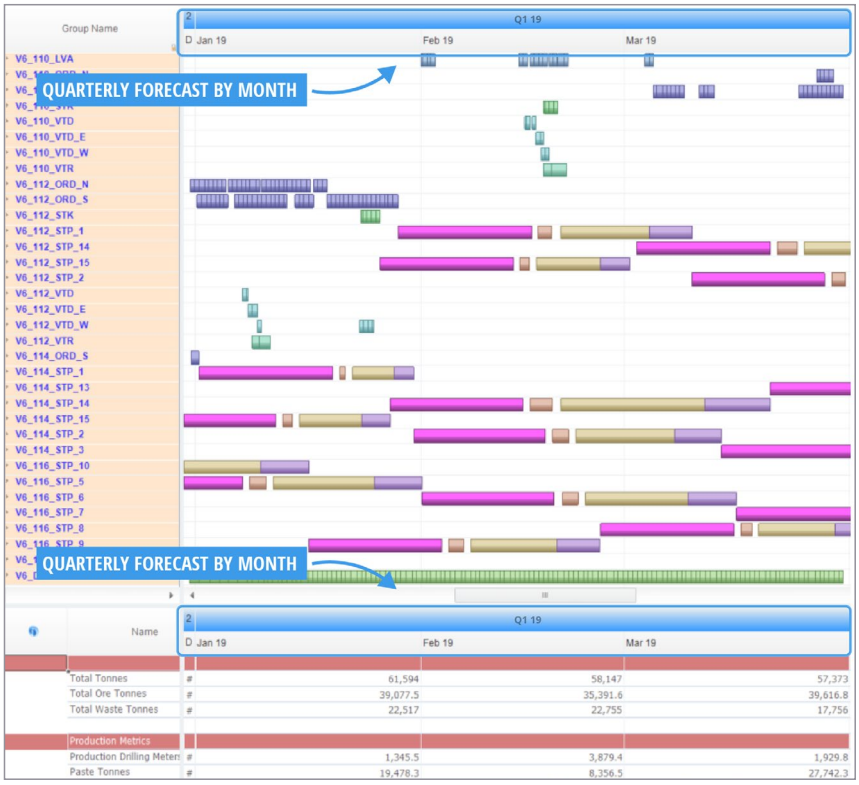

Figure 5 - Short-Term (Quarterly Forecast) Schedule.

4.2.4. Baseline/Publish Short-Term (Quarterly Forecast) Schedule

Sign-off frequency: Quarterly, although many mines are moving to rolling monthly forecasting

Conformance review frequency: Continually (at least weekly).

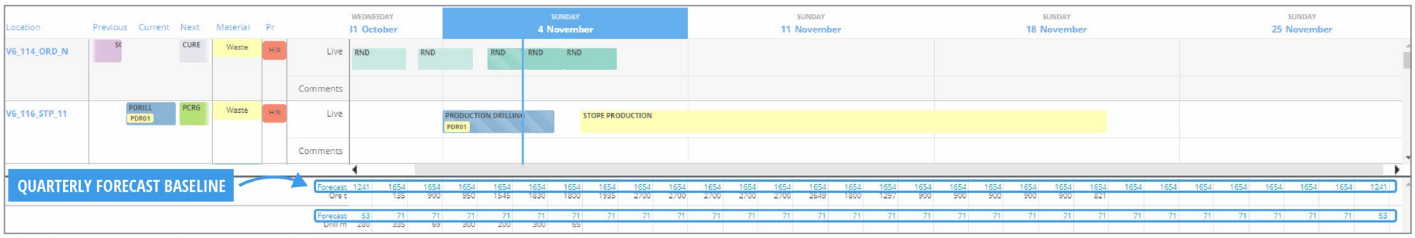

Figure 6 - Short-Term (Quarterly Forecast) Schedule Baseline.

4.2.5. Create Weekly Schedule

Generated by: Production Planners or Engineers

Timeframe: Weekly mining schedule

Update period: Weekly scheduling process

Audience: Operational team

Focus: Location and equipment tasks, often resource-leveled.

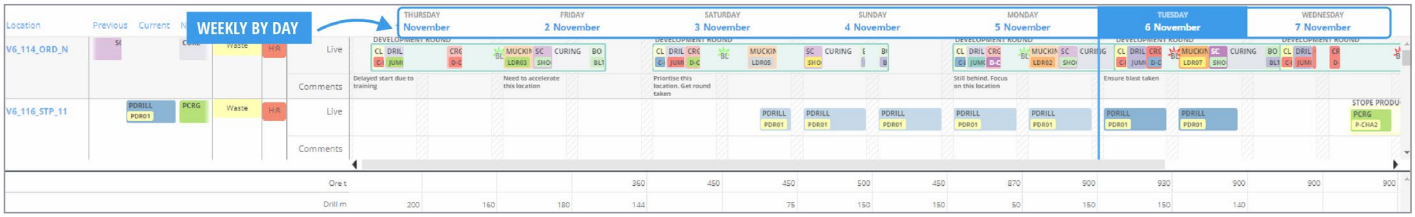

Figure 7 - Weekly Schedule.

4.2.6. Baseline/Publish Weekly Schedule

Sign-off frequency: Weekly

Conformance review frequency: Continually (at least daily).

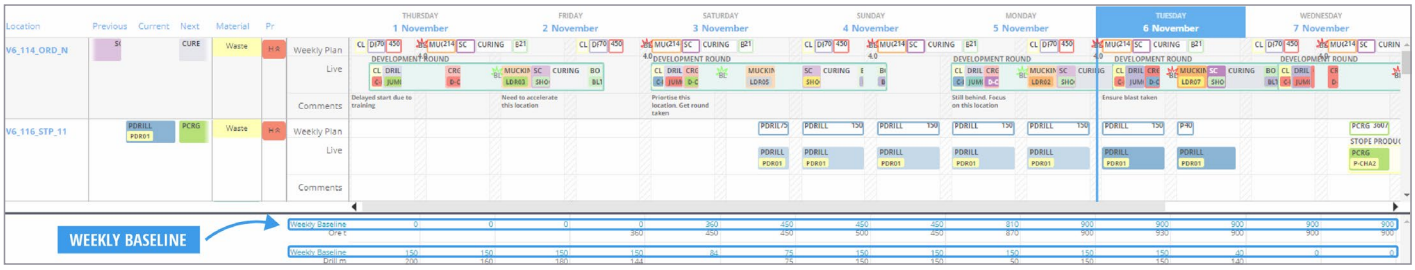

Figure 8 - Weekly Schedule Baseline.

4.2.7. Create Daily/Shift Schedule

Generated by: Shift bosses or supervisors

Timeframe: Daily/shift mining schedule

Update period: Daily/shift scheduling process

Audience: Operational team

Focus: Location and equipment tasks, including operator assignment.

The best daily/shift schedules are often the exact weekly schedule with an added pre-start or shift lineup perspective that assigns operators and makes final adjustments to existing tasks from the weekly schedule. In addition, if the weekly schedule is baselined, the daily/shift schedule will ideally simply roll forward using scheduling logic, which includes dependencies (task, location, and equipment), priorities (location headings), and calendar constraints (blast windows and firing times).

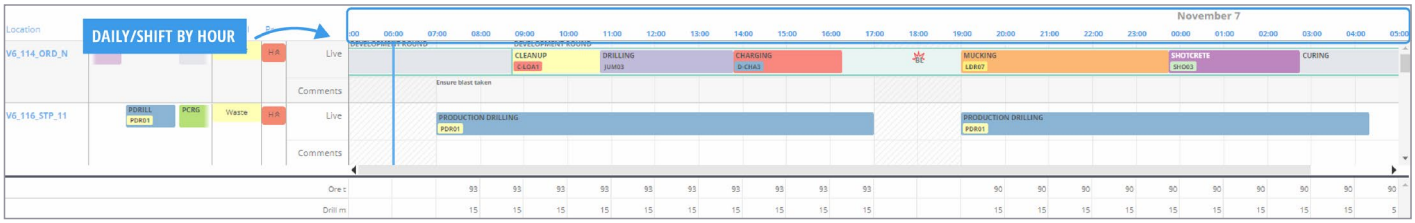

Figure 9 - Daily/Shift Schedule.

4.2.8. Baseline and Publish Daily/Shift Schedule

Sign-off frequency: Daily or at every shift

Conformance review frequency: Continually (up to hourly).

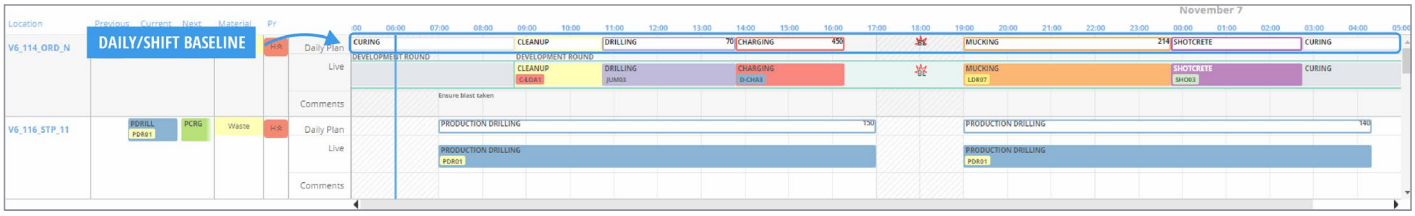

Figure 10 - Daily/Shift Schedule Baseline.

4.2.9. Execute Shift

Control room personnel (see section 4.1.4) typically update the daily/shift mining schedule as part of a daily/shift process. In addition, if the daily/shift schedule is baselined, ideally the daily/shift schedule will simply roll forward using scheduling logic, which includes dependencies (task, location, and equipment), priorities (location headings), and calendar constraints (blast windows and firing times).

The daily/shift schedule ideally will also simply roll forward using scheduling logic, as activities start and finish, production physicals are recorded, and delays and unplanned activities are tracked against the shift.

Control room operators are typically the shift boss or supervisor's 'eyes and ears', fully tracking the shift and engaging in two-way communication with the shift boss or supervisor on in-shift decision management. Decisions are often supported by comments and metadata about the decisions, particularly as part of a shift-handover process (see section 4.2.7 and 4.2.8).

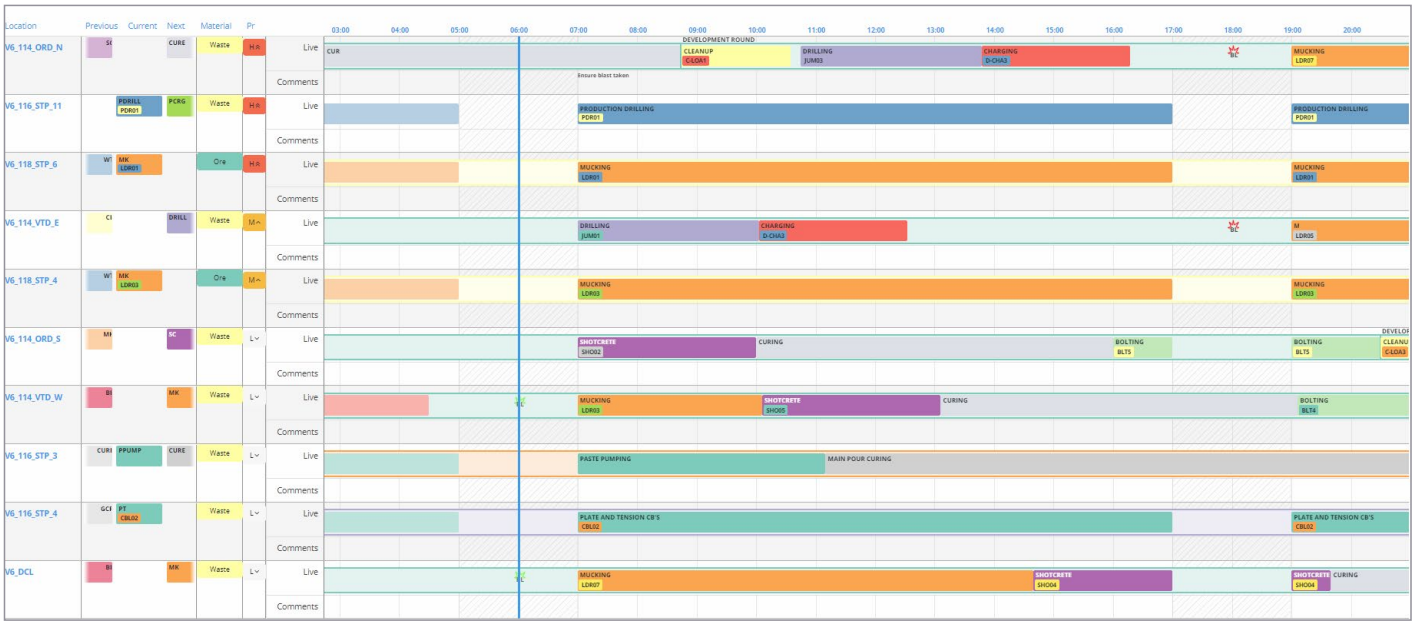

Figure 11 - Schedule Tracking.

Figure 12 - Control Room Personnel.

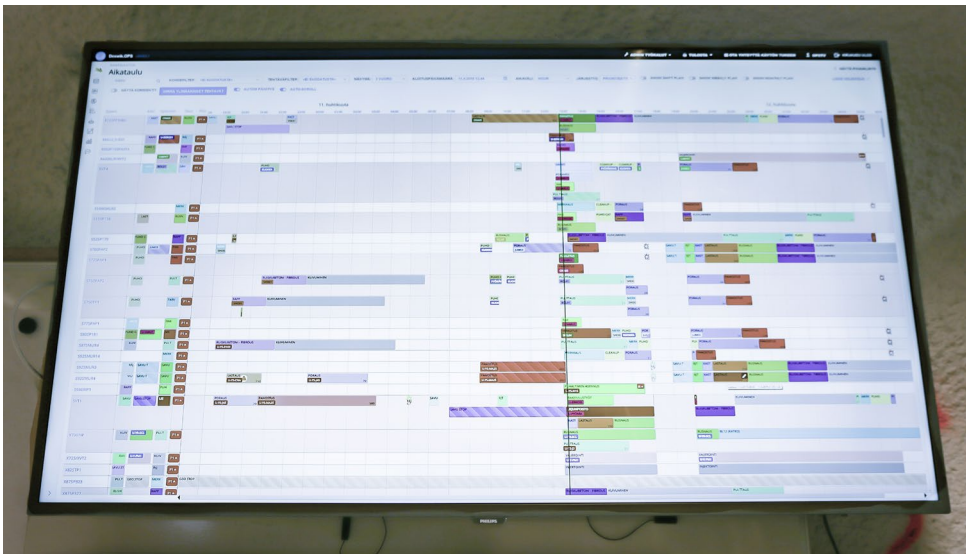

Figure 13 - Real-Time Monitoring.

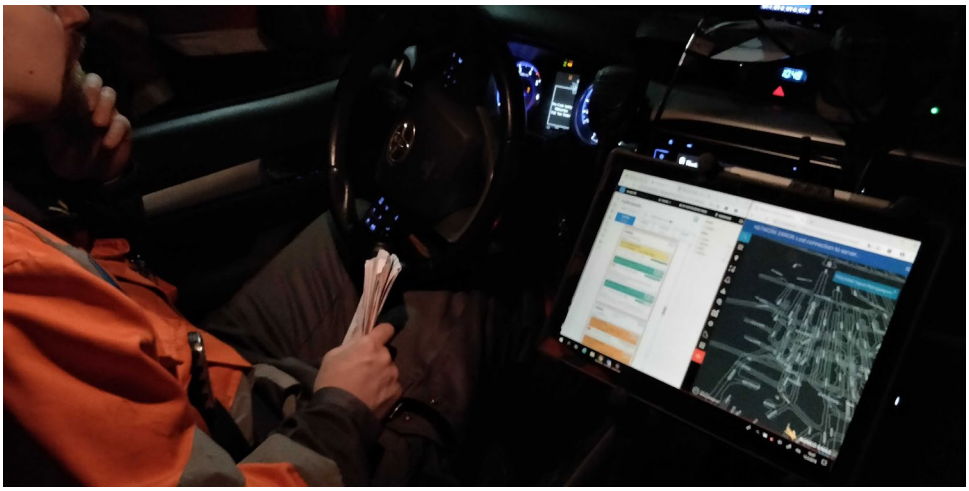

Figure 14 - Shift Boss or Supervisor.

Ideally, mining engineers (see section 4.1.1) apply all the relevant execution results, tracked against daily/shift and weekly operational schedules, to upstream short- and medium-term schedules so that they can accurately reforecast. The following image shows the result of a schedule update from actuals where green bars show the portions of the schedule that are complete.

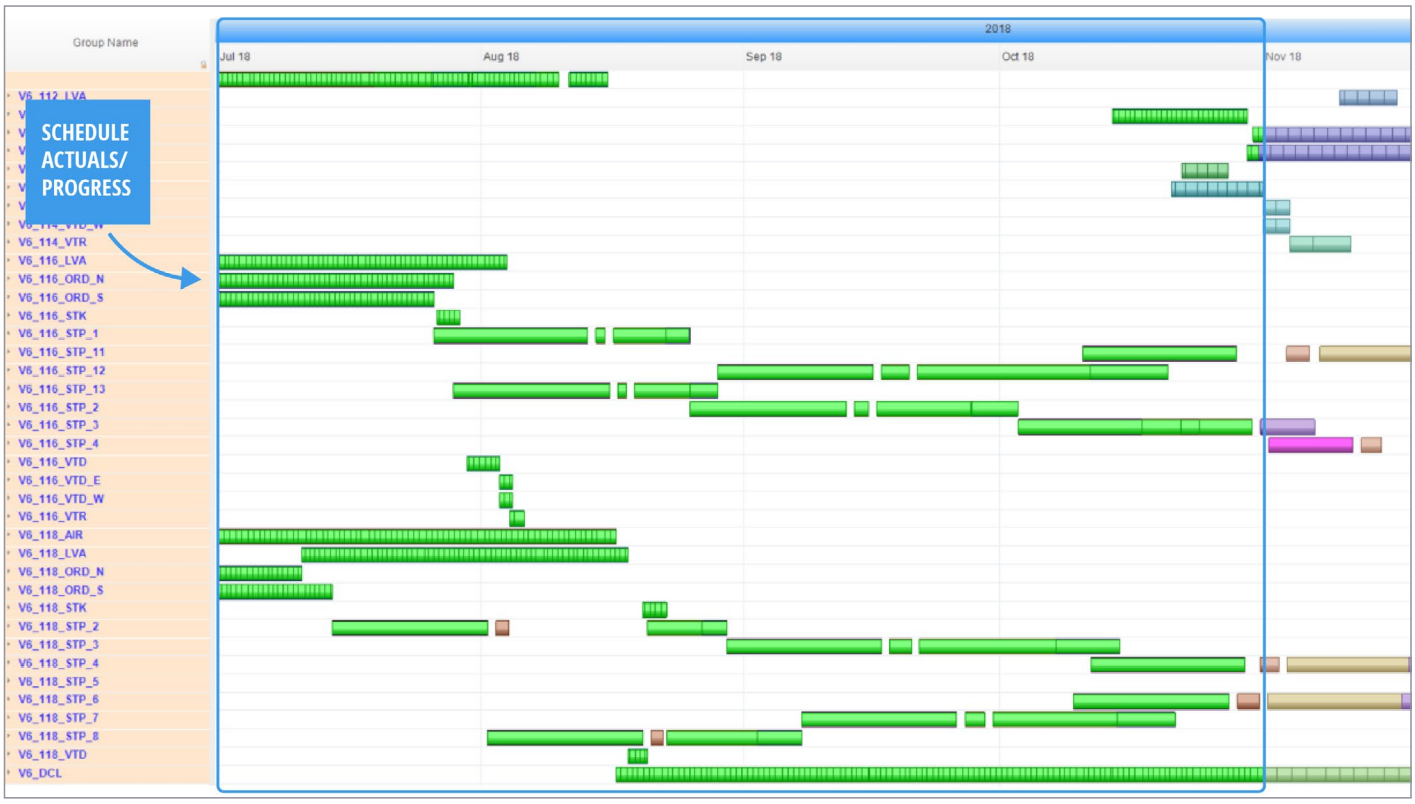

Figure 15 - Rescheduling from Actuals.

4.3. Technology

There are several technology solutions that enable different parts of each SIC maturity level. The following categories of technology each play their part in an integrated approach to SIC. Each operation might use its own terminology for the following categories of technology. The following categories of technology are general and common terminology is used. These categories need to be applied in the context of the operation (see section 5.1).

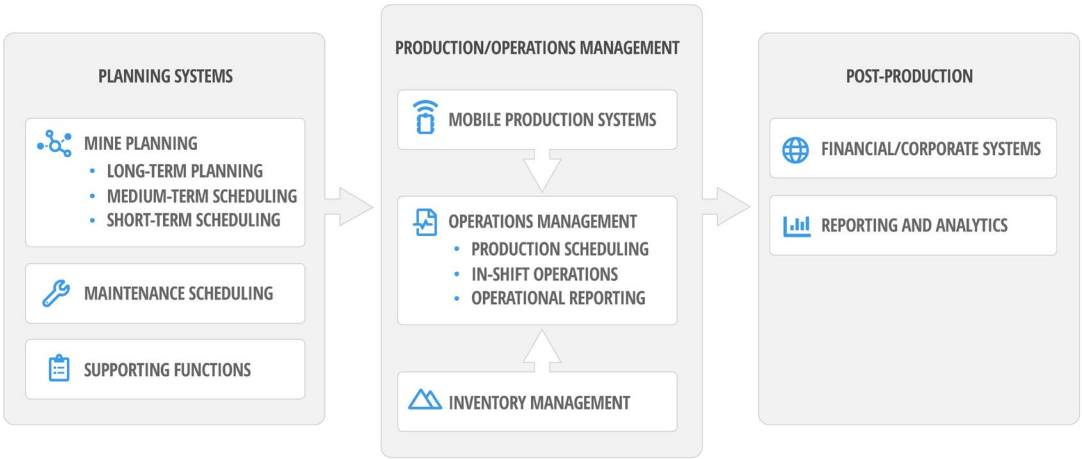

Figure 16 - Overview of SIC Technology.

4.3.1. Planning Systems

Planning is the first step of SIC (see section 4.2). There are several planning domains that feed into an integrated plan and a complete picture of work, and work relationships (see sections 4.3.2 and 5.3).

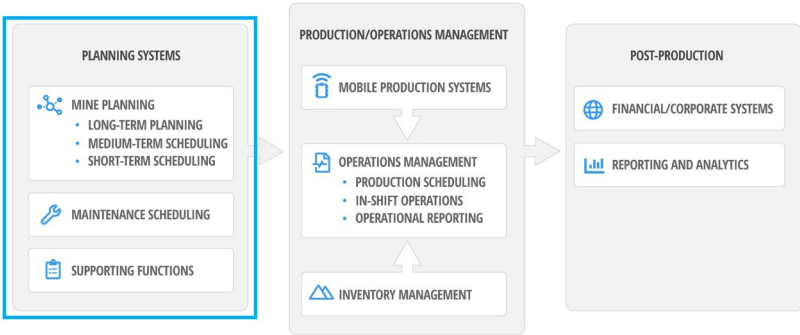

Figure 17 - Planning Systems.

4.3.1.1. Development and Production Scheduling

Development and production scheduling typically form the basis of the schedule-driven approach to SIC. This includes annual budget, quarterly forecast, weekly scheduling, and daily/shift-level scheduling.

The development and production schedules have the following attributes:

- They provide all of the key targets, activities, or tasks for production.
- They are spatially aware (considering mine design and the reality of required mining sequencing).
- They include different levels of detail on resource allocation (equipment fleets and equipment, development and production crews, and operators).

For example, a development cycle of activities for an operation may be defined as follows:

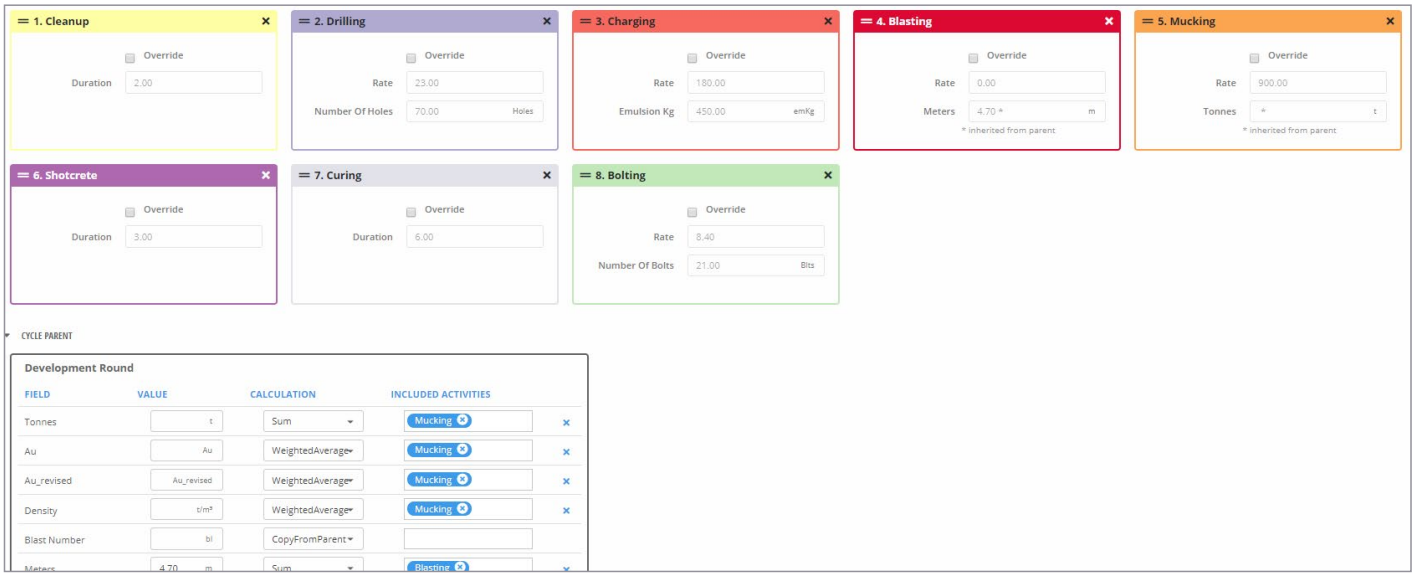

Figure 18 - Example of Development Cycle and Activities.

Similarly, a production cycle of activities for an operation may be defined as follows:

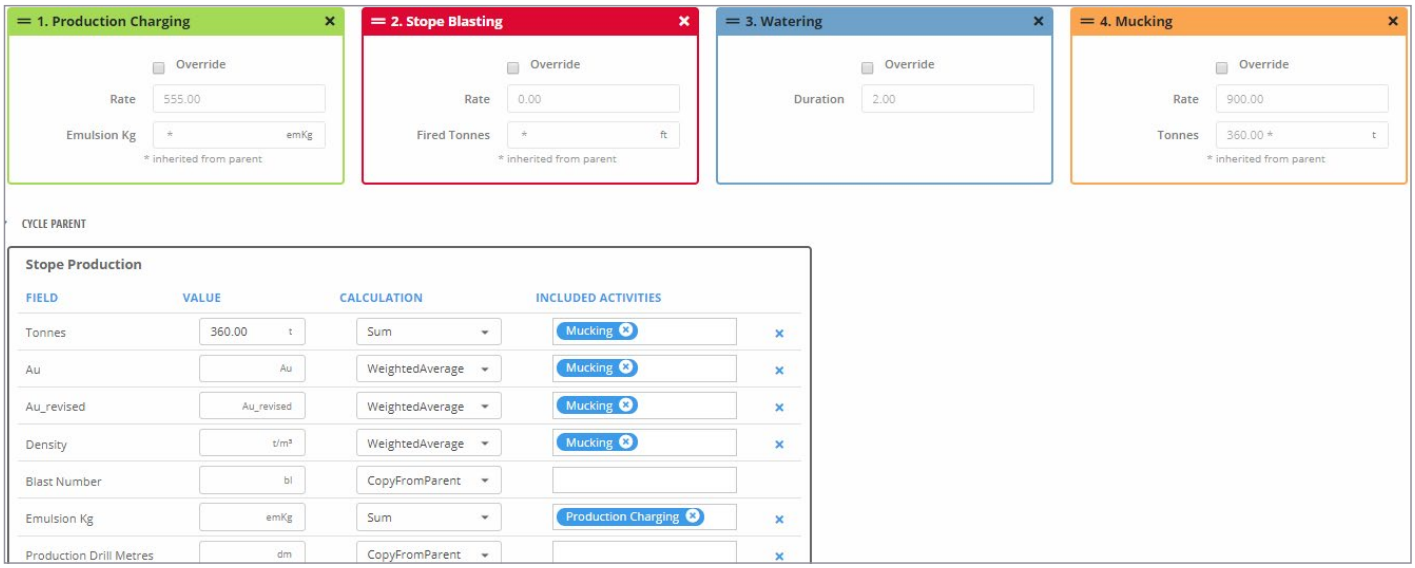

Figure 19 - Example of Production Cycle and Activities.

An integrated schedule for development and production starts to provide a view on location and equipment allocation and usage, as shown in the images that follow.

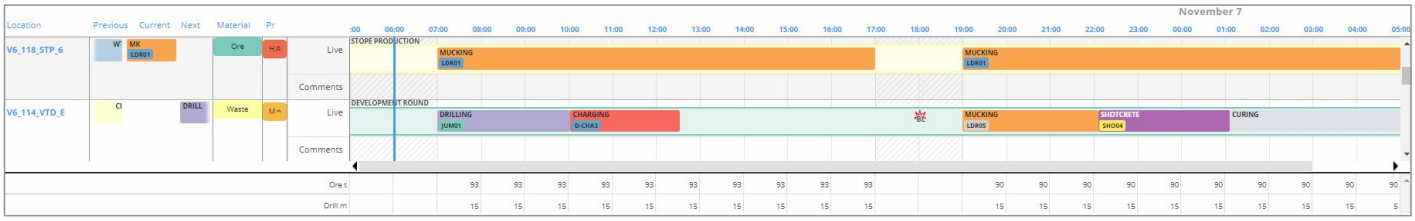

Figure 20 - Location Allocation or Usage.

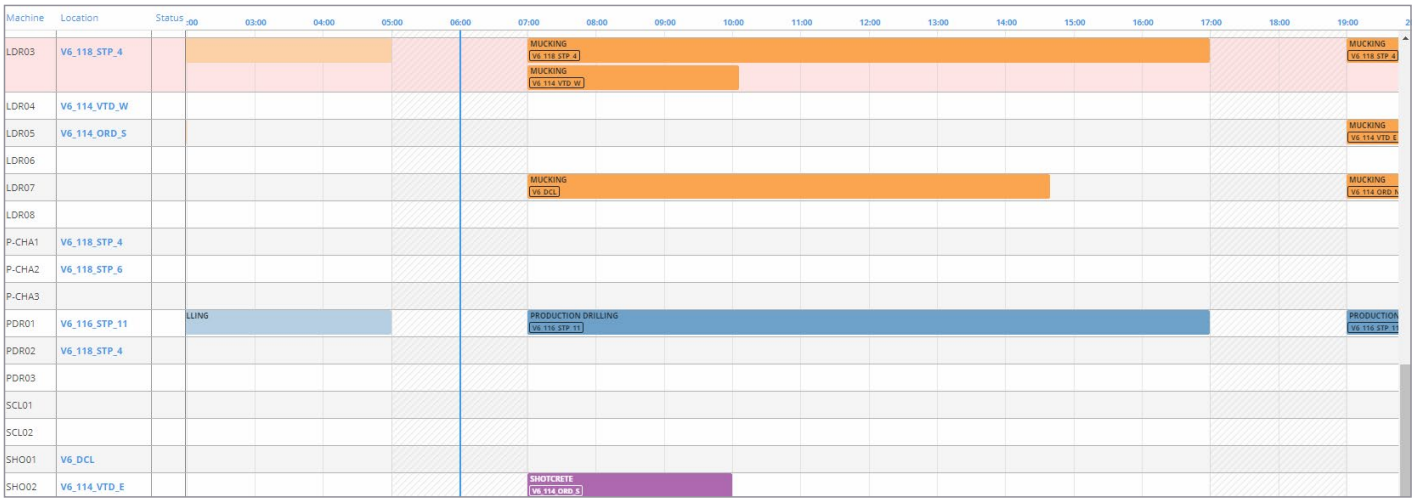

Figure 21 - Equipment Allocation or Usage.

4.3.1.2. Maintenance Scheduling

Maintenance schedules also need to be combined with development and production schedules to ensure locations and resources are not overallocated or impractically scheduled.

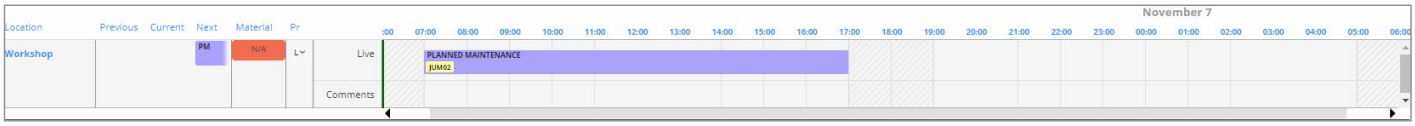

Figure 22 - Maintenance Scheduling: Locations.

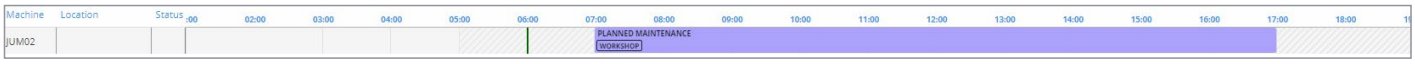

Figure 23 - Maintenance Scheduling: Equipment.

4.3.1.3. Drilling Scheduling

In mining, it is important to also consider drilling activities to ensure that locations are not overallocated or impractically scheduled.

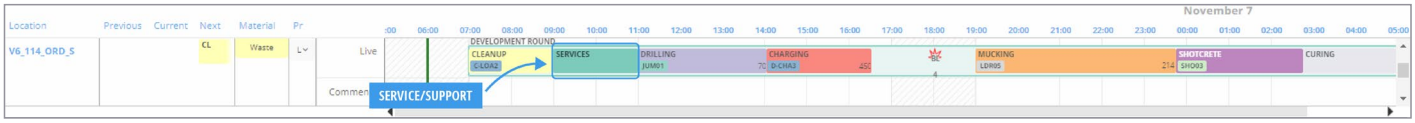

Figure 24 - Drilling Scheduling.

4.3.1.4. Service or Support Scheduling

Auxiliary work schedules become very important in operational scheduling as they ensure that all of the activities that enable development and production are managed, tracked, and well understood.

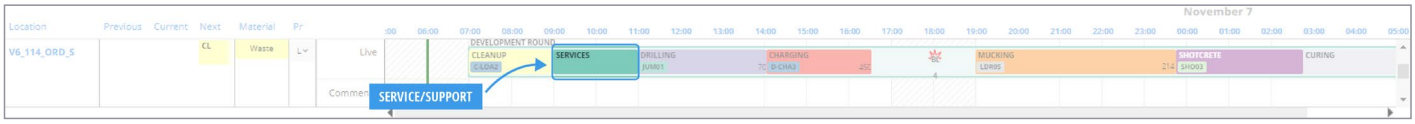

Figure 25 - Service or Support Scheduling.

4.3.1.5. Projects or Infrastructure Scheduling

Projects or infrastructure schedules help to provide the complete picture of work, particularly at the daily, shift, or weekly levels.

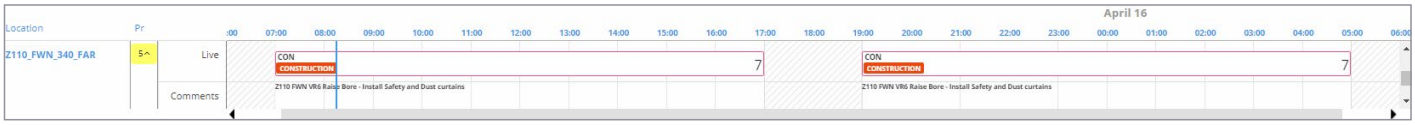

Figure 26 - Projects or Infrastructure Scheduling.

4.3.2. Production or Operations Management

Production or operations management includes operations management systems, mobile production systems, survey or sampling systems, and inventory management systems.

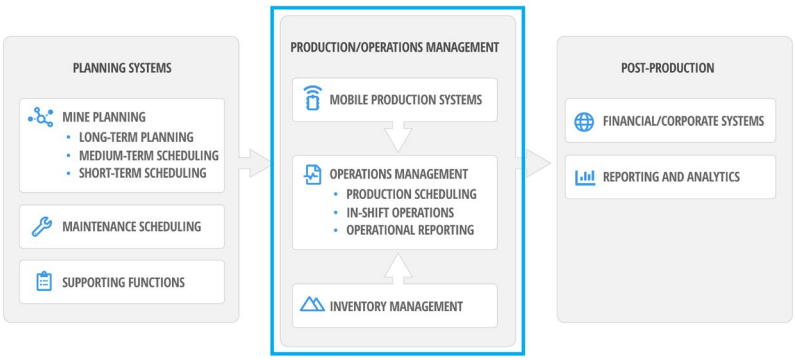

Figure 27 - Production or Operations Management.

4.3.2.1. Operations Management Systems

Operations management systems are typically meant to provide the means for providing an integrated view of all of the schedules and execution data (where execution data is aggregated for understanding the progress of schedules) in a single operating environment.

These systems quickly become the central view of all information about operational work being performed. They are typically used in control rooms and the operations general office (GO) or technical services offices.

The operational systems will almost always enable collaborative, multi-user environments and enable planners or mining engineers, shift bosses or supervisors, and control room operators to access and control the operational schedules and progress simultaneously in real time or near real time. Baseline schedules are often imported or managed directly in the operational systems.

4.3.2.2. Mobile Production Systems (Tablets and Fleet Management Systems)

Because mining activities are mainly mobile in nature, the mechanism for capturing execution data during the shift is quickly moving towards systems that move around with the equipment and operators. Equipment-based mobile production systems are often referred to as fleet management systems (FMS). Typically, they provide in-vehicle mounted displays that allow operators to receive tasks from the shift schedule managed from the GO. They also provide the current status and progress feedback to the GO monitoring the shift.

Operator-based mobile production systems are gaining traction, particularly in underground mines, to achieve a complete view of all work, including work that is not tied to equipment activities. This makes sub-surface operational activities become entirely manageable and visible from the surface, typically through on-site control room operations but also from remote or corporate environments (sometimes in very different geographical areas).

4.3.2.3. Survey or Sampling Systems

While we often refer to information collected during the shift about what happened as 'actual', it is important to note that the metrics collected about the work performed are only estimates at best. To calculate actual schedule conformance, the operations will periodically survey and sample the outputs of the work that was performed. This provides more highly trusted actuals, which not only form the basis of production accounting but are also critical periodic inputs to the scheduling (or rescheduling) process.

Surveys and samples are periodically performed at inventory locations, such as bins, stockpiles, and processing plant locations, and at the primary mining locations (e.g. underground stopes or open pit benches). All of these actual measurements can be applied as corrections to the estimates made during the shift.

4.3.2.4. Inventory Management Systems

Inventory management systems can be deployed to ease the pain of spreadsheet accounting and the reconciliation of material movements. These systems are often post-shift calculations and hence are not often discussed in the context of SIC. However, as mentioned previously, considering what actually happened versus what was estimated to have happened during the shift forms an important basis for SIC (see section 5.2.3).

Inventory management systems will typically support imports of inventory surveys and samples, and estimates or calculations of ongoing inventory based on shift estimates that are related to production mining movements. Estimates are typically calculated based on the inventory management process (in other words, stockpiling methods). Usually, this takes place at the end of each shift or day but, in some cases, it is done in near real time following the movements captured during the shift. Inventory management systems may also provide the ability to reconcile (balance or adjust) the material accounting as part of all of the inputs into an accounting process (typically at month-end).

4.3.3. Post-Production

Post-production involves financial or corporate systems, and reporting and analytics.

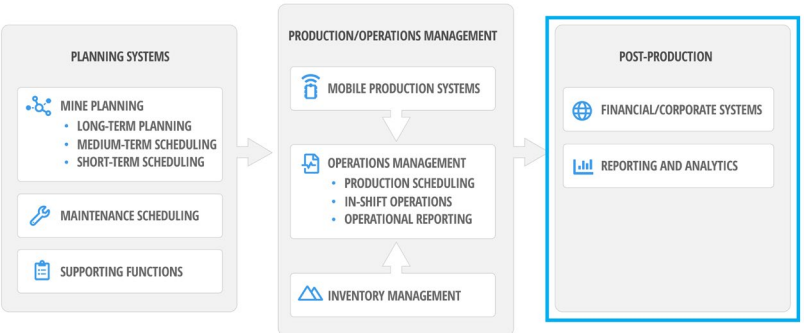

Figure 28 - Post-Production.

4.3.3.1. Financial/Corporate (IT) Systems that need to work with Operational Technology (OT) Systems

While financial or corporate systems are not specifically part of an SIC initiative, it is important to consider the required flow of information between operational teams (OT systems) and financial/corporate teams (IT systems), especially in terms of corporate strategic business planning and accounting teams. For example, some mining companies have integrated OT and IT systems in ways that support the near real-time estimation of shift results in terms of $/tonne rather than only tonnes, grades, and equipment hours. More seamless feedback loops between OT systems and IT systems are not unheard of and can be something to strive for.

Almost all month-end accounting processes at mine sites roll through to corporate processes and systems. Some mines spend almost a week out of every month performing month-end accounting processes, while others are focused on streamlining processes and integrating IT/OT to achieve a one- to two-day month-end completion.

4.3.3.2. Reporting and Analytics

Generally speaking, mines today use Microsoft® Excel for most of their reporting and analytics. Operations management systems (see section 4.3.2.1) can typically source most or all of the information required for in-shift, end-of-shift, daily, weekly, and monthly reporting. More sophisticated operations management systems can provide replicated , aggregate, clean information required for these reports from a central data source.

In-shift, real-time, or near real-time reporting and analytics typically need to tap directly into the operational systems or mobile production systems to provide the most up-to-date information possible. However, where good data replication, aggregation, and data transformation processes are configured to run during the shift, it may be possible to continuously recalculate information models for advanced in-shift reporting and analytics that do not require directly querying busy real-time transaction systems. For anything post-shift, the best reporting and analytics are supported by good quality assurance and quality control (QA/QC) processes and data transformation that can turn raw data into meaningful information.

Anticipating and finding the answers to different types of questions that could be asked of reporting and analytics enable mines to perform information visualizations. These visualizations can answer important questions immediately via pre-calculated information rather than complex database queries, or manual processes that would otherwise take hours using Microsoft® Excel. If visualizations can be accessed quickly and through user exploration, the operation is more likely to gain value from the information being tracked. Unlocking the data in this way helps operations to identify challenges and opportunities and provides a continuous improvement paradigm paramount to an SIC strategy.

5. SIC Concepts

5.1. Mine or Management Operating System

A mine or management operating system (MOS) can be a key ingredient in the implementation of an SIC strategy for a mining operation. If needed, there are operational or management consultancies with a wealth of operational mining experience that can help Operations to develop a MOS that achieves streamlined processes and operational efficiencies.

The best MOSs are typically successfully implemented as a result of operational experts rolling out the system while being fully embedded in the operation, and over a period of months. An MOS is also typically only 'sticky' beyond the life of the improvement engagement if technology systems are implemented as part of the process that will encourage and enforce the desired behavior once the improvement engagement is complete (see section 4.3).

5.2. Plan-Do-Check-Act

Plan, Do, Check and Act are the four steps that form the PDCA cycle.

Figure 29 - Plan-Do-Check-Act Cycle.

5.2.1. Plan

Tactical planning is the first element of an SIC system (see section 4.3.1). The Plan-Do-Check-Act (PDAC) approach allows the leadership team to set realistic goals and hold operators accountable.

5.2.2. Do

Accurate production data linked to planned workplaces provides mine planners with up-to-date, trustworthy information, enabling plan adjustment from a known set point.

5.2.3. Check

Collecting the results of plan execution is meaningless unless the results are checked for accuracy and operational challenges and opportunities. Finding ways to QA/QC, aggregate, reconcile, and visualize information related to the result of the plan execution arms Operations with decision support.

5.2.4. Act

Actions should be based on the result of the Check state and should impact and feed back into the plan, creating a continuous loop for operational efficiency.

5.3. Integrated Scheduling

At Deswik, we believe that integrated scheduling is the fundamental ingredient of SIC strategies. There are many scheduling horizons to consider – from annual budget to quarterly forecast, weekly to daily/shift scheduling. All of these should be integrated by the operational system in a continuous way. For example, each new annual budget should be the basis for each new quarterly forecast, and each new quarterly forecast should be the basis for each new weekly schedule.

Likewise, each new weekly schedule should be the basis for each new daily/shift schedule. The results of each daily/shift schedule should influence each new weekly schedule, and the results of each weekly schedule should influence each new quarterly forecast. Similarly, the results of each quarterly forecast should influence each annual budget.

Typically, the level of automation required at each integration point will lessen as you move towards longer-term (less frequent) scheduling processes and increase as you move towards shorter-term (more frequent) scheduling processes.

For an annual budget → quarterly forecast, the integrations can typically be managed manually without causing too much concern about the effort or accuracy of the process. However, from quarterly forecast → weekly scheduling → daily/shift scheduling, entire or near entire automatic integration is very beneficial.

For example, when a new quarterly forecast is baselined, the weekly scheduler should be able to schedule one or more weeks of operational activity automatically.

Using a controlled and automatic process to break down a quarterly forecast into executable operational tasks for one or more weeks will ensure that the operational schedule issued each week is truly based on business priorities and targets.

Similarly, when a new weekly schedule is baselined, the shift boss or supervisor should be able to schedule one or more shifts of operational activity automatically. In fact, the shift schedule could be the weekly schedule, only requiring consideration for resource assignment and actual progress against previous shifts schedules. In turn, the tracking of the shift should automatically update next week's schedule, which should automatically be factored into the next quarter's schedule. Where it is possible, creating and automating an integrated scheduling process ensures that the priorities of each scheduling horizon are represented by each downstream scheduling horizon, all the way down to the operational or shift level.

5.4. Operations Scheduling

Typically, operations scheduling is defined as everything shorter than the short-term (quarterly forecast) schedule, such as weekly, daily, or shift schedules. The key requirement that differentiates an operational schedule from short- and medium-term (or a tactical) schedule is that it needs to be operationally executable and practical based on the current operational context. For example, a short-term schedule may suggest guidance to achieve X tonnes and Y grade across fleets A, B, and C (the 'what'), whereas an operational schedule will address the 'how'. The operational schedule will suggest the sequence of activities that need to occur to achieve the short-term schedule, including all activity dependencies (for example, production or development), all of the operational maintenance activities, service and support activities, and anticipated operational challenges or delays.

In many operations, the tactical schedule is 'thrown over the fence' from Mine Engineering to Operations. Operations are then responsible for manually developing a schedule that is practical and aims to achieve the tactical schedule. Because of this, mine engineers are doing their best to set targets operationally, but often the operational team are starting with something impractical or not in context of the current operational state of things.

The best ways of resolving this are the following:

- Where possible, automate the development of the operational schedule directly from the tactical schedule.
- Provide a feedback mechanism from the operational schedule execution back to the tactical schedule so that operational context is available to the tactical mine planning engineers.

5.5. Grade Control

Operational management systems (see section 4.3.2.1) will typically provide some level of grade control functionality. Grade control in the shorter-term scheduling and operational space is commonly about providing a means for the geologists (see section 4.1.6) to track grades measured by the operation. These grades may be more precise than originally estimated grades in the resource or block model, and schedules. As part of the process of tracking these operational grades, material movements may be updated to link the new grades with sources or destinations, equipment, and operators.

Figure 30 - Grade Control.

5.6. Actuals Adjustment

Operational management systems (see section 4.3.2.1) will typically provide some ability to adjust actuals when results are measured in downstream processes. Depending on the metric, there are different approaches used to perform these updates. For example, face advance may be measured periodically, such as twice per month, so that development associated with activity source or destination locations, equipment, and operators can be adjusted in bulk based on the more accurate measurements.

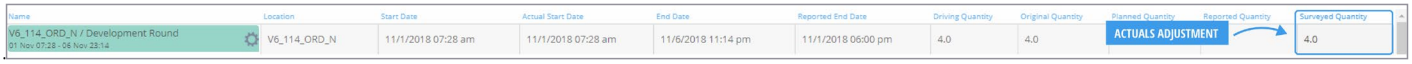

Figure 31 - Actuals Adjustment.

5.7. Time Allocation or Time Usage

Operational management systems (see section 4.3.2.1) will typically provide a time allocation or time usage model. While each operation may have their own unique model, models are all fairly similar and there are some standards bodies working through proposed industry-standard models at the moment.

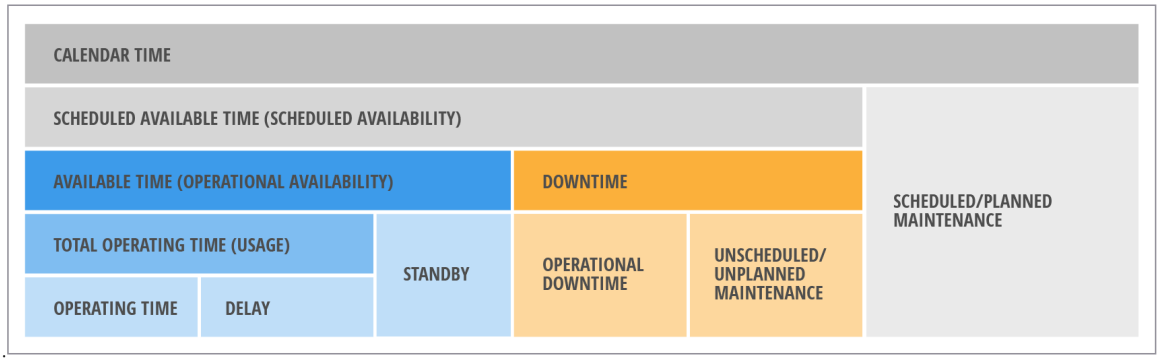

Figure 32 - Example of Time Allocation or Time Usage Model.

The following are key requirements for reporting time allocation or time usage:

DATA CAPTURE

All the hours that cannot be calculated for the time allocation or usage need to be captured somehow. These are typically captured by mobile production systems (see section 4.3.2.2) in real time or near real time. They can also be captured on paper and entered directly into operational management systems (see section 4.3.2.1) at end-of-shift. Even where mobile production systems are implemented, data capture is likely to happen in different ways or places to provide the complete time model for all resources (equipment and employees).

DATA AGGREGATION

Time-in-state and time-in-motion data (see section 5.8) can be used as the basis for parts of the time allocation or time usage model. However, the data will be raw (in the form of very small and specific time slices) and will need routines for rolling up into the time allocation categories.

DATA CALCULATION

Ideally, the time allocation model accounts for all calendar time (that is, 12-hours for the resource such as equipment or operator) in question. To do so, certain data points will be calculated as a formula based on the other data points available. For example, using the model above, Standby would often be calculated or assumed as Scheduled Available Time – Operating Time – Delay Time – Down Time.

5.8. Time-In State or Time-In Motion

Mobile production systems (see section 4.3.2.2) will typically provide a wealth of time-in-state or time-in-motion data that can be used to accumulate metrics over many small time slices of activity. (This could be, for example, looking at scoop buckets per engine hour in underground mining, or looking at truck waiting times for truck and shovel operations.)

5.9. Spatial SIC

Several operational management systems (see section 4.3.2.1) and mobile production systems (see section 4.3.3) are incorporating spatial views to support SIC processes. These views allow control room personnel (see section 4.1.4) and shift bosses or supervisors (see section 4.1.3) to visualize the mine spatially with overlapping real-time positioning data coming from, for example, equipment GIS or operator hard-hat RFID tags. Ideally, the spatial views are sourced from the planning systems where the latest mine designs or drawings are maintained.

5.10. Mine Schedule Conformance

Mine schedule conformance is one of the most important outcomes of implementing an integrated, schedule-driven approach to SIC. Mine schedule conformance should be calculated, visible, analyzed, understood, and explained and used to support continuous improvement initiatives (see section 5.2).

Note that different mining methods and commodities will warrant looking at schedule conformance from different angles. For example, location or spatial schedule conformance for tonnes may be most important in underground operations, and equipment tonnes schedule conformance may be most important in surface operations.

5.10.1. Schedule versus Actual

Comparing different schedules to the execution data is key to keeping things on track and ensuring schedule conformance. This is also referred to as 'schedule progress'. The most obvious comparison during the shift is, 'How are things progressing against the shift schedule?'. However, there can be subtle differences in priorities and challenges from shift to shift, and to achieve the weekly schedule, Operations will typically monitor week-to-date (WTD) progress against the weekly schedule, month-to-date (MTD) or quarter-to-date (QTD) progress against the quarterly forecast, and year-to-date (YTD) progress against the annual budget.

5.10.1.1. Daily/Shift Schedule versus Daily/Shift Actual

The following image illustrates monitoring the daily/shift schedule versus the daily shift actual.

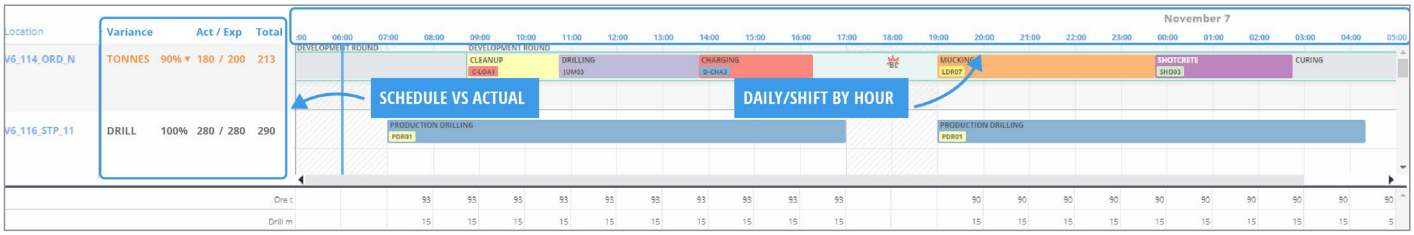

Figure 33 - Daily/Shift Schedule vs Daily/Shift Actual.

5.10.1.2. Weekly Schedule versus WTD Actual

The following image illustrates monitoring the weekly schedule versus the WTD actual.

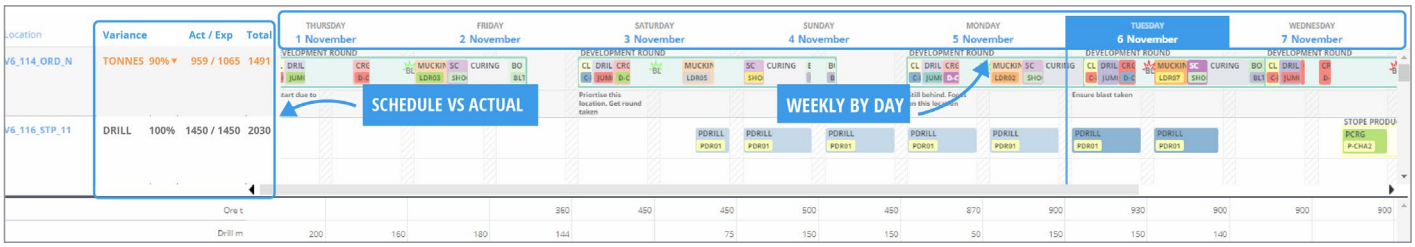

Figure 34 - Weekly Schedule vs WTD Actual.

5.10.1.3. Short-Term (Quarterly Forecast) Schedule Versus MTD/QTD Actual

The following image illustrates monitoring the short-term schedule versus the MTD/QTD actual.

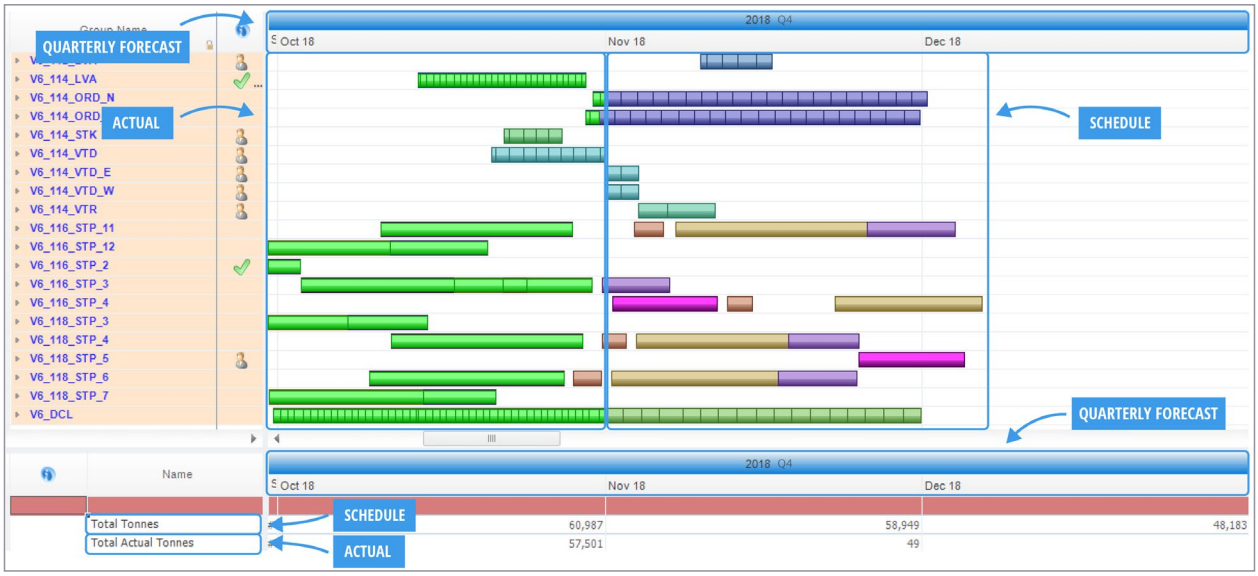

Figure 35 - Short-Term (Quarterly Forecast) Schedule vs QTD Actual.

5.10.1.4. Medium-Term (Annual Budget) Schedule versus YTD Actual

The following image illustrates monitoring the medium-term schedule versus the YTD actual.

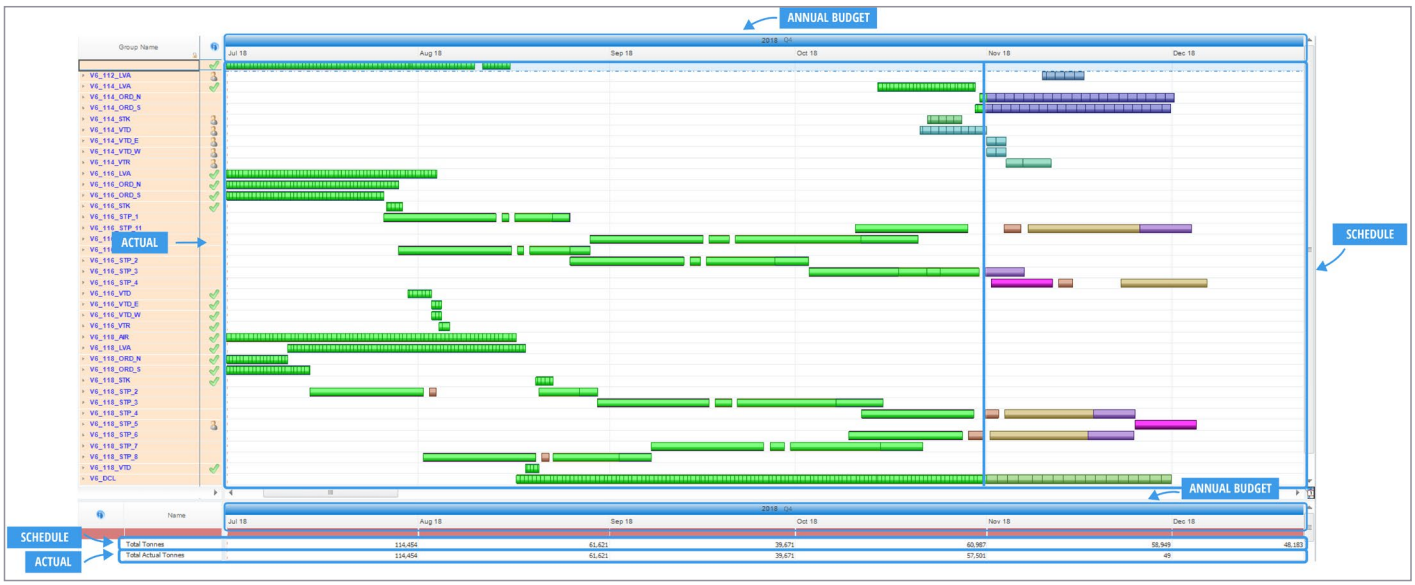

Figure 36 - Medium-Term (Annual Budget) Schedule vs YTD Actual.

5.10.1.5. Schedule versus Schedule

From a scheduling point of view, it is important to have the ability to check how your schedule conforms to other upstream schedules. For example, how does the daily or shift schedule differ from the weekly schedule?

As a weekly planner, how do changes to the weekly schedule differ from the quarterly forecast?

5.10.1.6. Daily/Shift Schedule versus Weekly Schedule

A shift boss or supervisor (see section 4.1.3) will create the daily or shift schedule (see section 4.2.7). During the creation of that schedule, they will refer to the weekly baseline schedule.

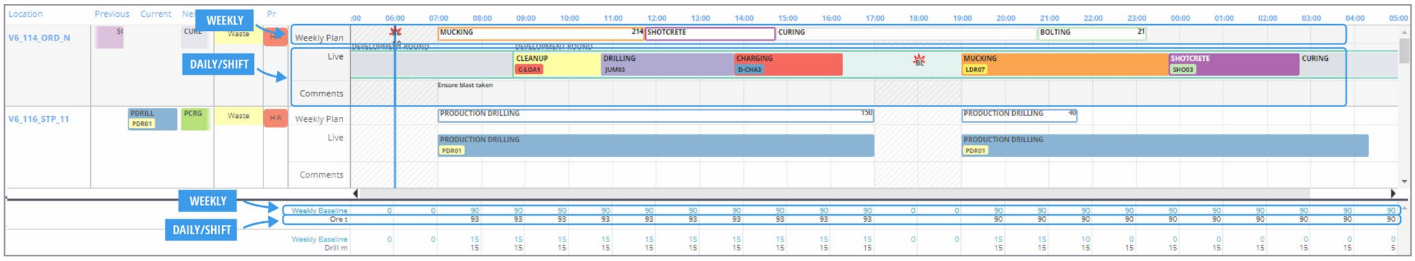

Figure 37 - Daily/Shift Schedule vs Weekly Schedule.

5.10.1.7. Weekly Schedule versus Short-Term (Quartlery Forecast) Schedule

A production planner or engineer (see section 4.1.2) will create a weekly schedule (see section 4.2.5). During the creation of that schedule, they will refer to the quarterly forecast.

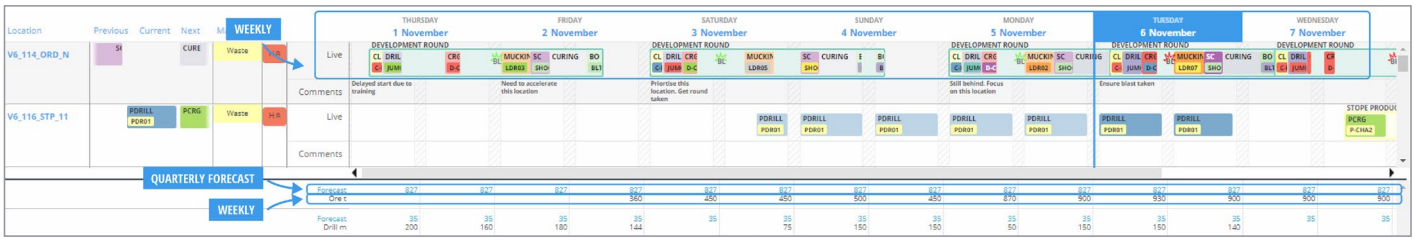

Figure 38 - Weekly Schedule vs Short-Term (Quarterly Forecast) Schedule.

5.10.1.8. Weekly Schedule versus Medium-Term (Annual Budget) Schedule

A production planner or engineer (see section 4.1.2) will create a weekly schedule (see section 4.2.5). During the creation of that schedule, they will refer to the annual budget.

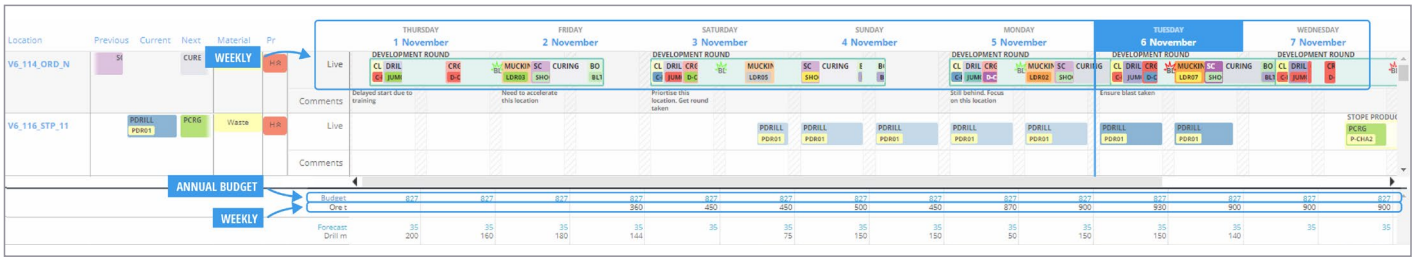

Figure 39 - Weekly Schedule vs Medium-Term (Annual Budget) Schedule.

5.10.1.9. Others

For any schedule type, there might be multiple scheduling authors experimenting with multiple ideas. It might be interesting to compare schedules. For example, how does schedule A compare to schedule B in terms of tonnes, grades, or ounces? (Some systems call these 'scenarios'.) How does my schedule compare to my colleagues' in terms of different outcomes?

The following image shows selection options a planner might consider when performing a Schedule versus Schedule comparison including the schedule author, schedule create date/time, schedule type, and schedule period (shift dates).

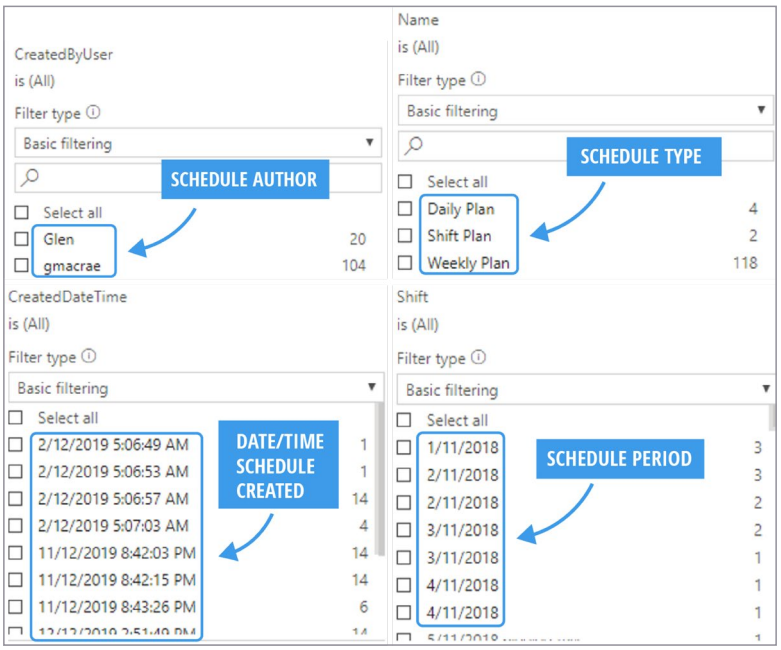

Figure 40 - Schedule versus Schedule (Others).

6. Conclusion

In summary, Deswik proposes an integrated and scheduling-driven approach to SIC in mining that considers people, processes, and technology. Taking an integrated approach means looking at all of the ingredients of an SIC solution – from annual to shift scheduling – and integrating and, where possible, automating the processes and information flows.

A scheduling-driven approach entails viewing work tasks and management as a model of work that includes and focuses on interactions and dependencies. Work tasks and work management should be generated or calculated from scheduling models as often as possible. SIC cannot be achieved with manual task planning, because the work will be too onerous to plan and, more importantly, continually re-plan as is necessary to achieve an SIC process.

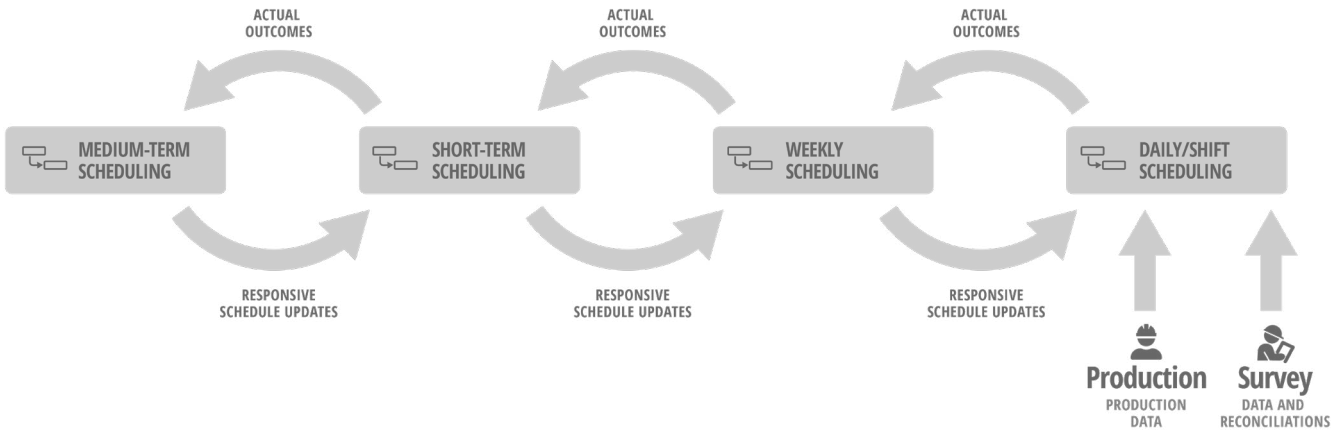

Figure 41 - Integrated and Scheduling-Driven Approach to Short Interval Control in Mining.

This paper has discussed the people, processes, and technology associated with SIC based on Deswik's experiences implementing mining solutions in this domain. If you would like to learn more about our approach for an enterprise or collaboration-based implementation of SIC for your mining operations, please reach out to us.

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