Practical Application of Schedule Optimization Technologies in Today's Complex Surface Mine Environments

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Introduction

Who are we

- Minemax is an established provider of innovative software solutions specializing in mine scheduling and optimization.

What this is

- Some observations from current industry practices in strategic open pit mine scheduling
- References to technique are solution-agnostic, though apply generally to MILP optimization methods

Standard Practice – Strategic Mine Scheduling

Mine Planners are solving larger and more complex mine scheduling problems everyday.

- Considering:
  - Time value of money and project value
  - Sequencing fundamentals driven by economic model
  - Blending, prioritization, and/or product grade restrictions
  - Constraints to revenue generation
  - Multi-period solving

Context

The challenges continue…

What if there are multiple downstream competing options, complexities, or 'beyond-the-pit' requirements?

- Such as:
  - Incorporating pit backfill
  - Planning for constrained haulage routes
  - Conditional waste delivery or storage options
  - Assessing capital investment for expansion elements

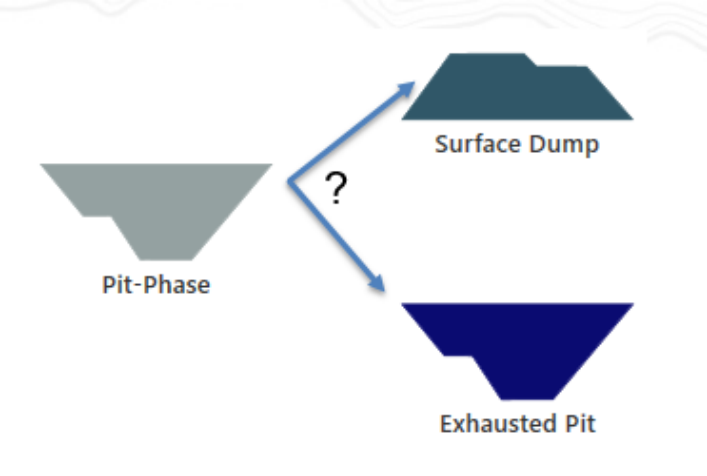
How do we leverage these situations in mine schedule optimization?

Pit Backfill

Pit Backfill - Overview

Modelling aspects to consider (exhausted pit backfill: strategic plan):

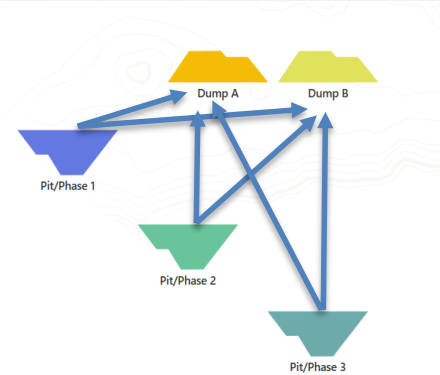
- Looking to solve for waste destinations at the same time as the schedule
- Sequencing-dependent location interaction
- Precedence controls between pits/backfills
- Haulage distance/time differential benefit is likely the incentive



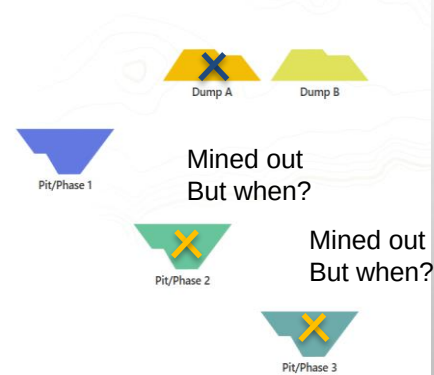
Pit Backfill- Controls

Sequencing and precedence controls

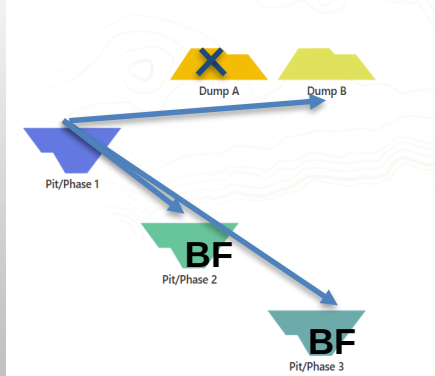
- Discretization of periods – managing release of backfill capacity
  - Consider a LOM plan in annual periods
  - The transition points (when a pit is exhausted, therefore when a pit becomes available backfill) are solved for
  - Ensuring practicality of transition point
  - Conservative vs Aggressive approaches



Period x start



Period x end

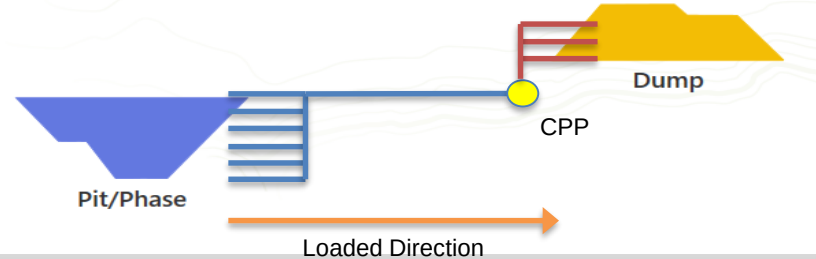


Period x+1 or x+2 start (?)

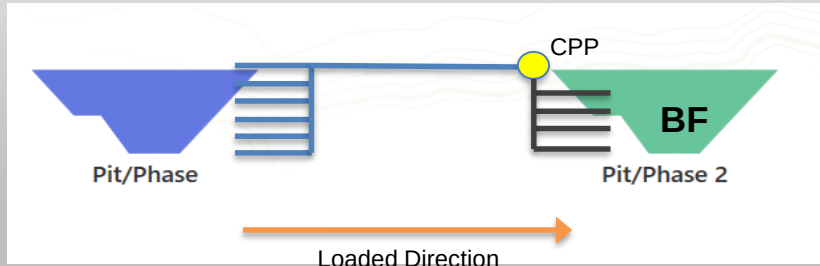
Mechanics of the cost/benefit: Haulage

- When solving for destinations – need to be accurate with parameters
  - Modelling truck hour burden to enable decision-making during solve
  - Cycle time network decomposed to apply explicitly to routes (use of CPP)
  - Consider constraining routes – all trucks on shortest path may exceed traffic capacity

Waste cycle decomposition from pit/phase bench to surface dump



Waste cycle decomposition from pit/phase bench to backfill dump

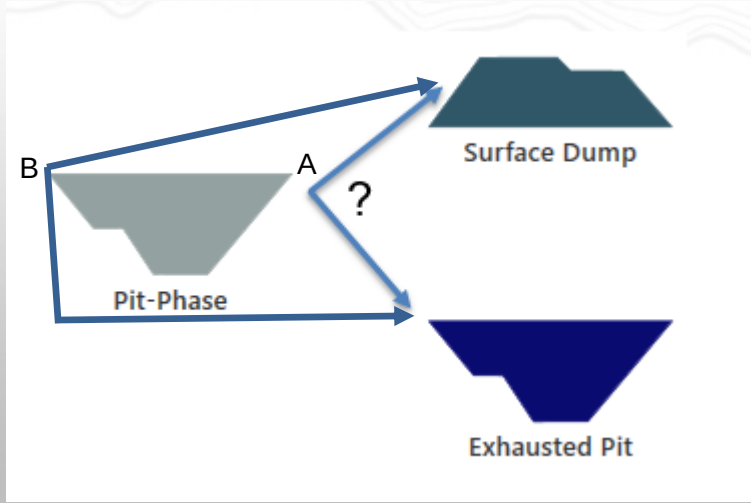


Planning for Constrained Haulage Routes

Planning for Constrained Routes

Context of the problem

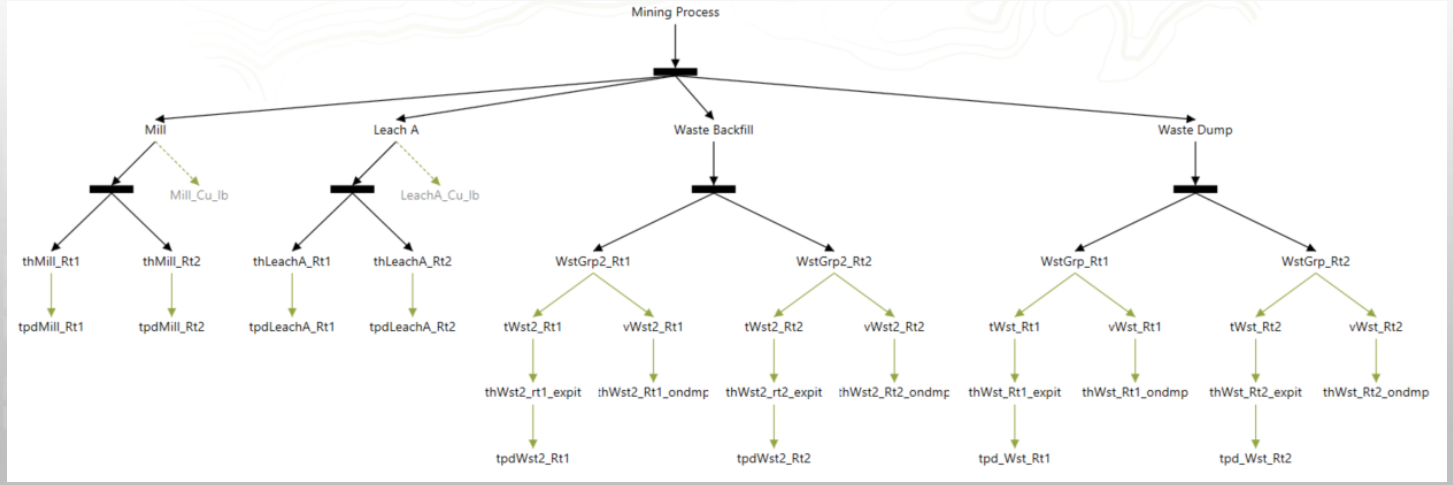
- Seeking lowest cost, most automated scheduling software tends to send all material on shortest route
- All trucks on shortest route may not always be practical or achievable
- As a result, the schedule would be infeasible (under-calling truck requirements and/or ability to deliver plan tonnage)



Planning for Constrained Routes

Modelling aspects to consider (haulage):

- Modelling routes as processes (decisions), units of material can only take one path
- Route availability/capacity modelled as discretized constraint
- Optimization solves for what material on what route
- Combined with haulage fleet capacity constraint (operating in parallel)

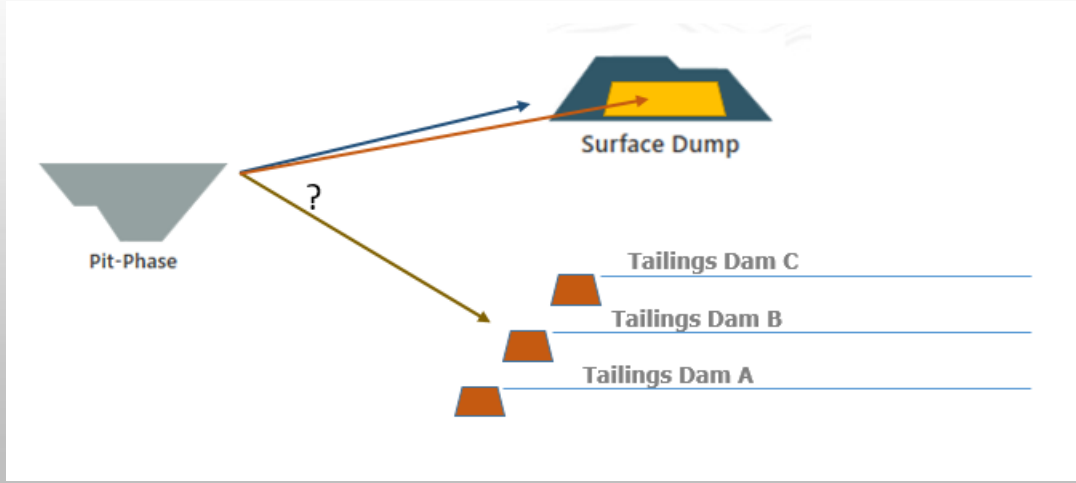


Conditional Waste Storage/Delivery

Conditional Waste Storage/Delivery

Context of the problem

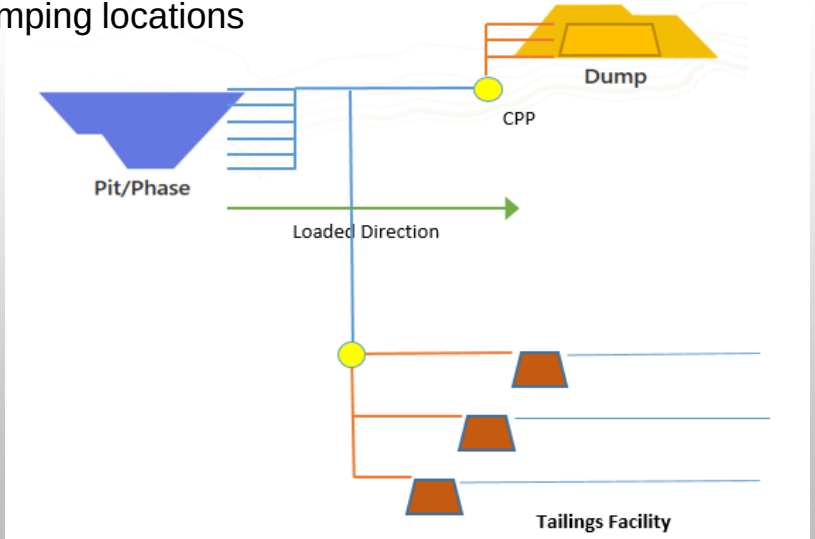
- Destination decisions to be made in multi-dump/multi-cellular situations
- Waste type encapsulation or differential placement
- Mine waste for tailings embankment facilities
- Material availability over time dependent on mining sequence



Conditional Waste Storage/Delivery

Modelling aspects to consider (differential downstream waste)

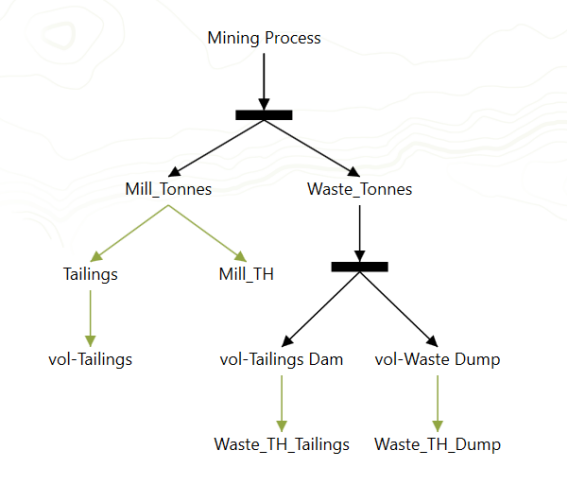
- Precedence controls between dump features
- Relevant qualities must be retained – exercise care if re-binning
- Haulage distance/time differential
- Fixed design capacity at dumping locations



Conditional Waste Storage/Delivery

Modelling tailings dam material delivery

- Certain spec material required over time
- Seeking to avoid/reduce stockpiling and re-handling
- Integrate decisions in optimization model where they can influence mine sequence



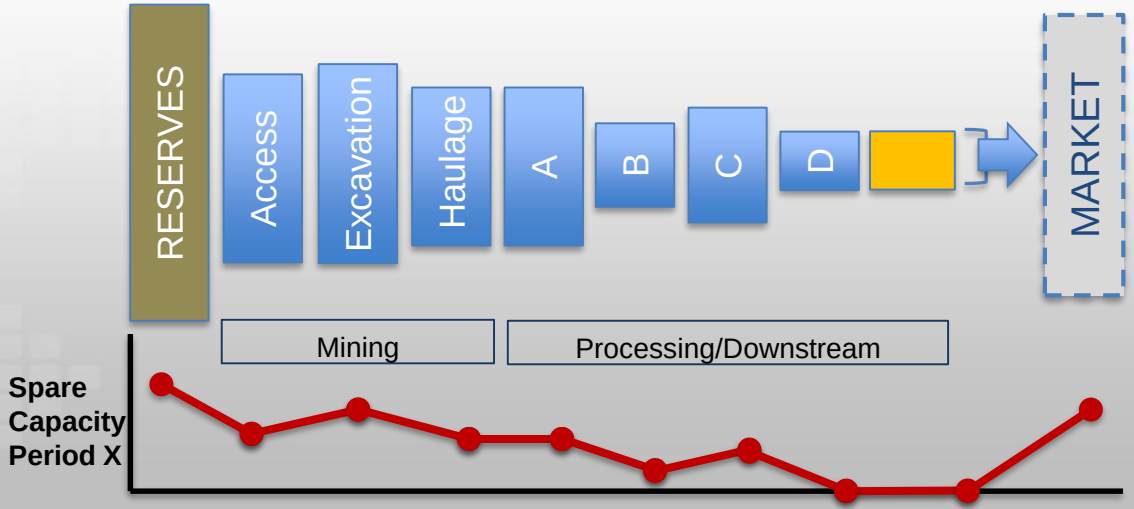
- Revenue from mill is dependent on tailings storage availability
- Volume for tailings dam modelled with specific design capacity
- Design capacity must be accumulated by certain timeline or mill shuts down
- Precedences between tailings dam and tailings storage
- Haulage (truck hours) differential for each waste destination. Unit costs per truck hour.

Modelling Capex within the Sequence Optimization

Constraint-based optimization

Which constraints are binding the mine schedule?

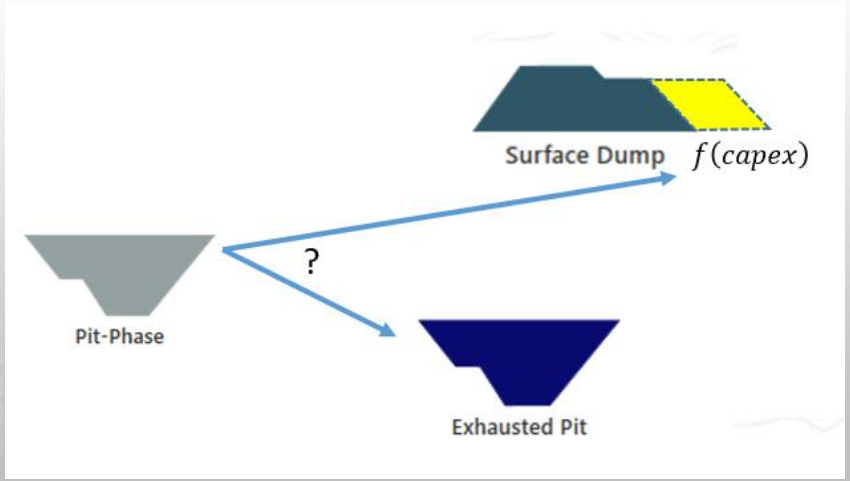
- Likely to vary from period to period, particularly in blending situations
- Certain constraints, such as the bottleneck(s) to revenue generation, should be binding, and tied to heavy capital
- Identify where to apply capex options to evaluate affect on sequence and project value

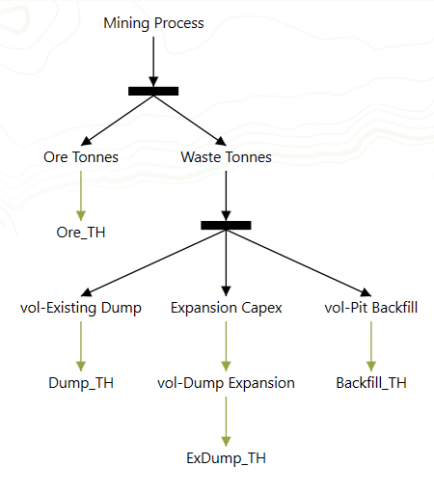


Capex and Pit Backfill

Integration of Capex decision on backfill v surface dump expansion

- Reduction in surface dump footprints if able to integrate backfill early?
  - Approach is modelling capex for incremental dump expansion
  - Additional dump capacity withheld unless investment returns from capex gain in NPV
  - Decision a function of many elements, including haulage differential and timing.





Thank you