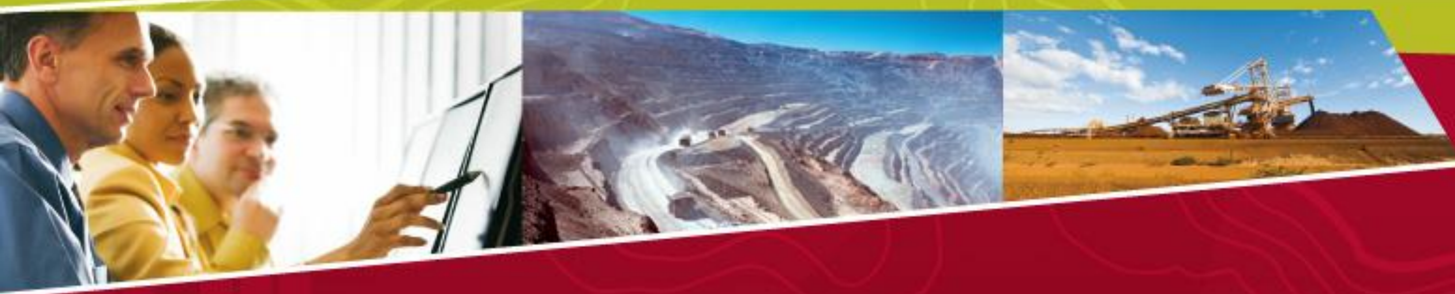

Strategic Mine Planning

An integrated approach to a complicated problem

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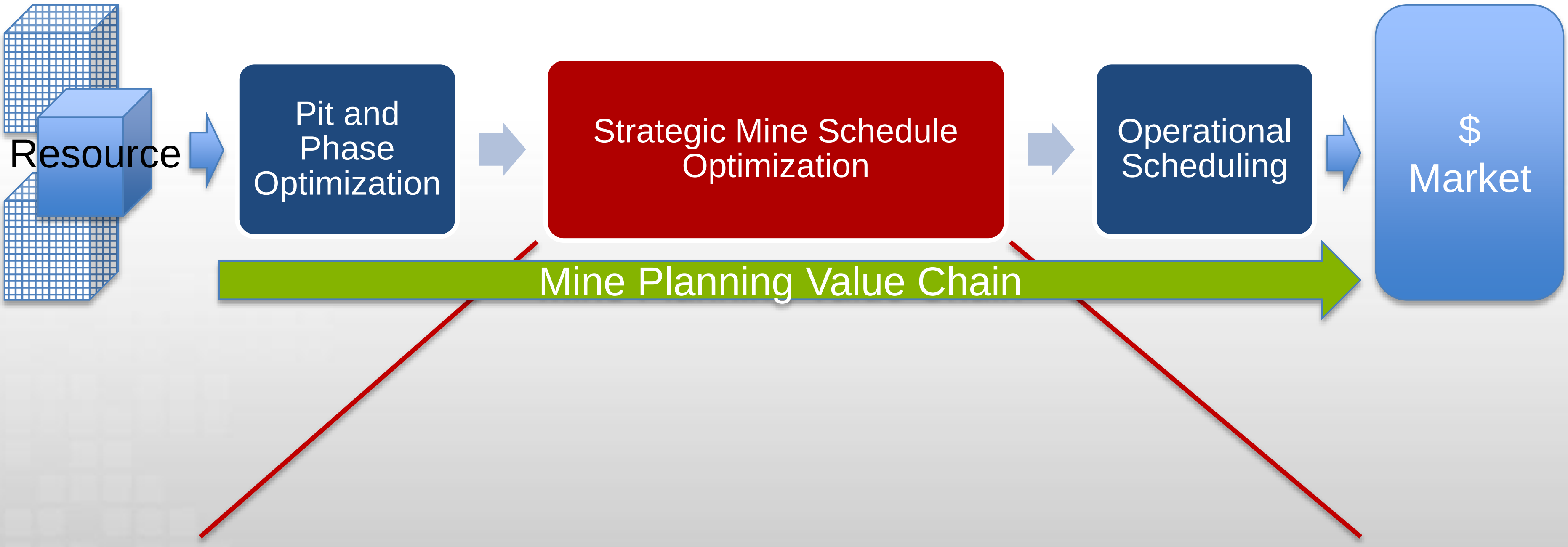
The Mine Planning Value Chain



While the total value of enterprise mine planning includes multiple aspects and functions, the focus of this discussion is the utility of the Strategic Schedule Optimization component of the value chain.

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The Goal of Mine Scheduling

- Integrated strategic mine scheduling should provide answers to the below *while* maximizing Net Present Value (NPV)
  - **Material extraction schedule:** **"If and when a block is to be mined,"** accounting for any possible downstream options.
  - **Cut-off/over policies:** **"Is it ore or waste,"** given all financial inputs including processing costs, haulage costs, recoveries, etc.
  - **Processing Destination:** **"Where to send it,"** accounting for plant constraints, capacities, recovery, and alternative destination/stockpiling options.
  - **Mining capacity:** **"What equipment hours will it take,"** accounting for variable destinations, associated paths and modelled costs.
  - **Waste dump sequencing:** **"Where the block will be placed,"** accounting for selection and practical development precedences.
  - **Decision for new phases or infrastructure expansions:** **"Does it make sense to spend $X, to gain Y units of capacity, and when?"** for decisions that have associated capital expenditure.

The Value in Mine Scheduling

How to calculate the value of a schedule?

In simple terms, the revenue from product minus the costs of production

Given this utility expression, every schedule would have the same value

$$\textbf{Schedule Value} = Rprod - Cm - Cp - Cf$$

where,

$Rprod$	is the revenue from the final product
Cm	is the mining cost
Cp	is the processing cost
Cf	is the fixed cost

In practice, however, money has a time value. This is applied through discounting.

- **We can control revenue and costs with respect to the time period of incurrence**
- **Increasing revenue and decreasing costs in early time periods has a direct impact on schedule value**

$$\textbf{Net Present Value} = \sum_{t=0}^{T-1} \frac{(Rprod_t - Cm_t - Cp_t - Cf_t)}{(1+d)^t}$$

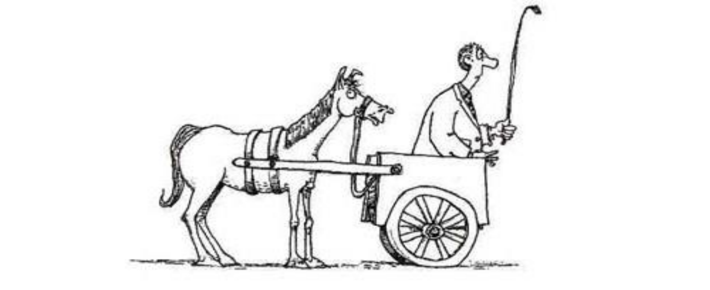
where,

T	is the number of time period
D	is the discount rate

The Traditional Approach

Approach: Simplification. The problem is both daunting and complicated, so measures are taken to reduce the problem to a workable state and/or fit into the limitations of the tools available.

- Aggregations are imposed
- Decisions are made early with regard to material destinations
- Some decisions (equipment requirements, etc) are accomplished through post-scheduling manual calculation
- Schedule is solved one period at a time
- Financial impact of strategic outcomes are known only after physicals from schedule are evaluated post-scheduling



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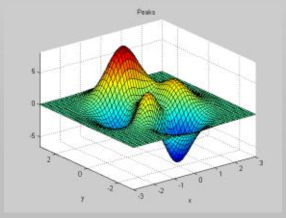
An Integrated Approach

Approach: Leverage optimization technology to find the optimum solution.

- **Set your objective (NPV?)**
- **Define and model all decisions as potential options (outputs)**
- **Demystify and assign driving financial information on a unitized (block) basis**
- **Impose any real physical constraints or practicalities which limit your output**
- **Integrate capital decisions into the solve**
- **Solve the problem globally (considering impact on all periods at once)**

The focus is on deterministic modelling as many possible alternatives as feasible within a single problem, letting the power of optimization solve for your objective.

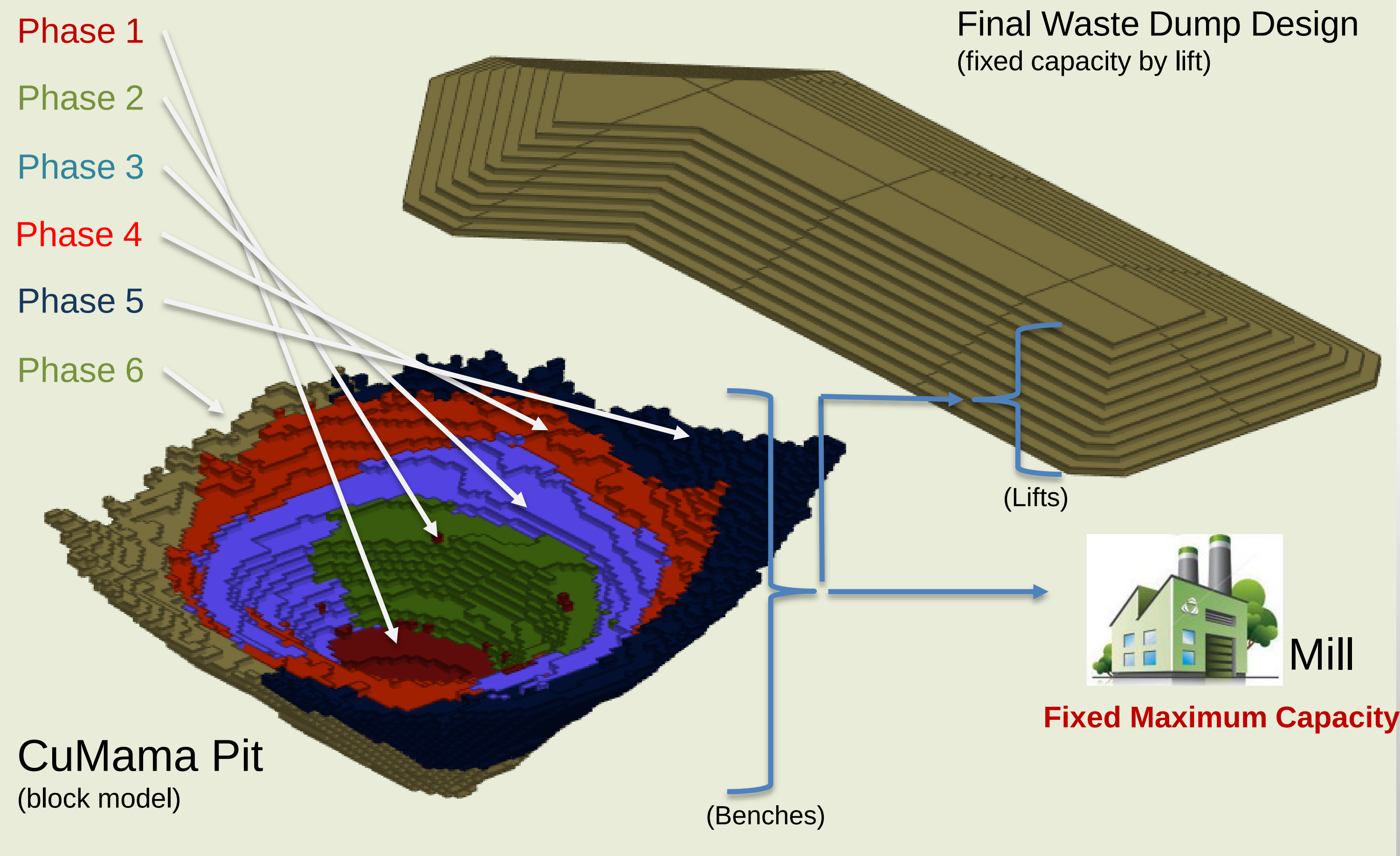


An Example Problem

Mine plans can get very complicated…so let's just consider a simple, deterministic example to illustrate where the unlocked value is:

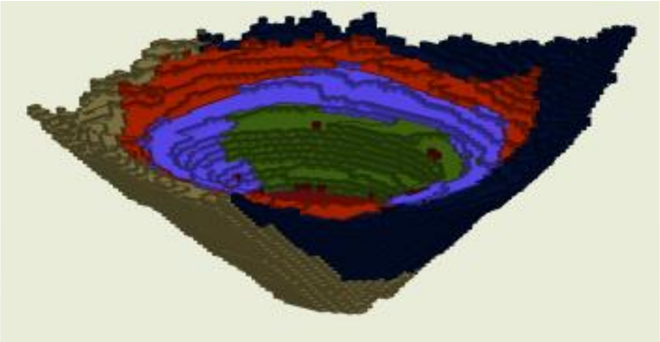
- Single, fully owned open pit mining operation
- Ultimate pit staged in multiple phases
- Single fixed capacity processing plant recovering copper
- Single 'waste' dump location with multiple lifts
- Common truck-shovel fleet with limitation on haulage capacity
- Need to understand if fleet expansion is warranted

CuMama Mine Overview (A hypo)



Formulating CuMama Plan (a hypo)

Requirement: Life of Mine Plan (12 annual periods)

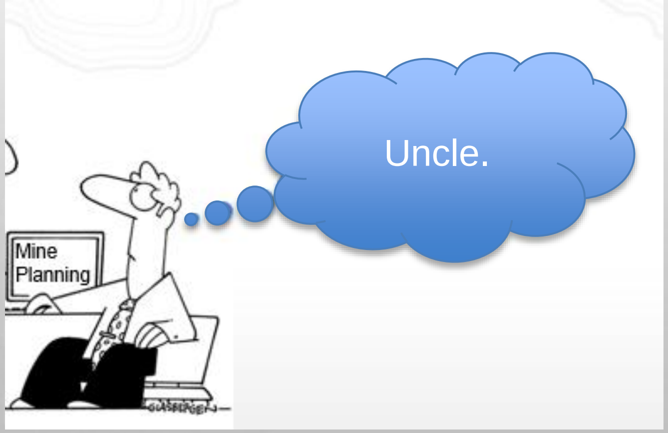


Model Parameters

- Block model containing ~60,000 blocks
- Low-grade Cu deposit, porphyritic, distributed grade
- Design staging: 6 phases with spatial relationship

Mining and Processing Parameters

- Vertical advance restrictions (10 bench max/yr)
- Haulage profiles from each bench to pit exit (rt:minutes)
- Haulage profiles from pit exit to mill (rt:minutes)
- Haulage profiles from pit exit to each WD lift (rt:minutes)
- Existing haulage fleet capacity 240k tkhours/yr
- Max 38mtpy processing rate and imposed min production
- Mill processing Cu recovery 75%*
- No stockpiling capability



Financial Parameters

- All material variable mining cost ($1.75/ton)
- Haulage variable cost ($300/tkhour)
- Processing variable cost ($16.5/ton)*
- Revenue on recovered Cu ($3.30/lb)*
- Annual discount rate at 10%

Deconstructing the Approach

To illustrate the concept and value of this integrated approach, we have generated a mine plan for the CuMama project using 4 different methods of increasing complexity.

1. **Forward Scheduling with Fixed Cut-off grade**
2. **Global Scheduling with Fixed Cut-off grade**
3. **Global Scheduling with Variable Cut-off Grade**
4. **Global Scheduling with Variable Cut-off Grade, Integrated WD Destinations and Capital Expenditure Options**

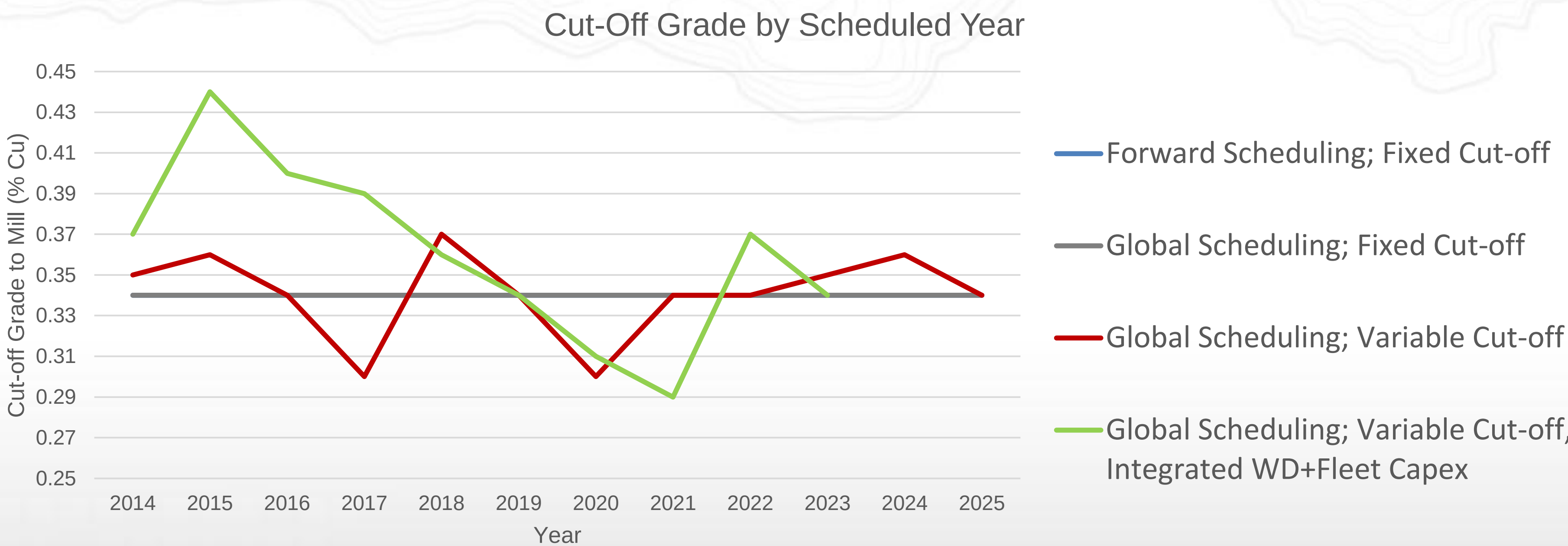
Explanation of Methodology

1. **Forward vs Global Scheduling**
   - **Forward Scheduling** : solving one period at a time
   - **Global Scheduling** : solving all periods simultaneously

2. **Fixed Cut-off Grade vs Variable Cut-off Grade**
   - **Fixed Cut-off Grade** : the destination of each block is pre-determined before the scheduling process (e.g. ore & waste)
   - **Variable Cut-off Grade** : the block destinations are solved for; therefore the cut-off grade is an output resulting from the modelled conditions.

3. **General Destinations vs Integrated Destinations**
   - **General Destinations** : the cycle times to the waste dump are estimated using centroid approach so truck hours are calculated on a coarse level.
   - **Integrated Destinations** : the cycle times to each cell/lift of the waste dump, as well as the lift capacities, are programmed into the decision basis, allowing for detailed destination scheduling.

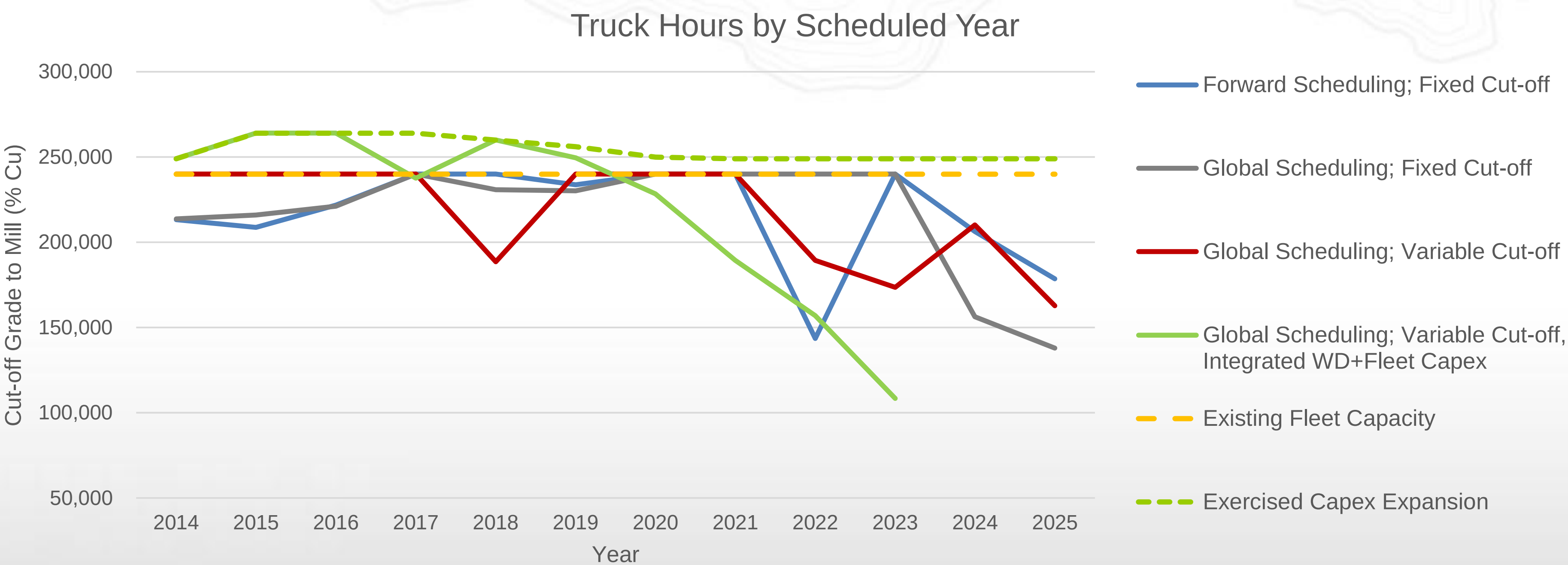
Results: Cut-off Grade Analysis



- As the mill has a fixed maximum intake capacity, increases in the cut-off grade in earlier periods allows for more high-revenue material to be processed earlier in the schedule with less discounting.

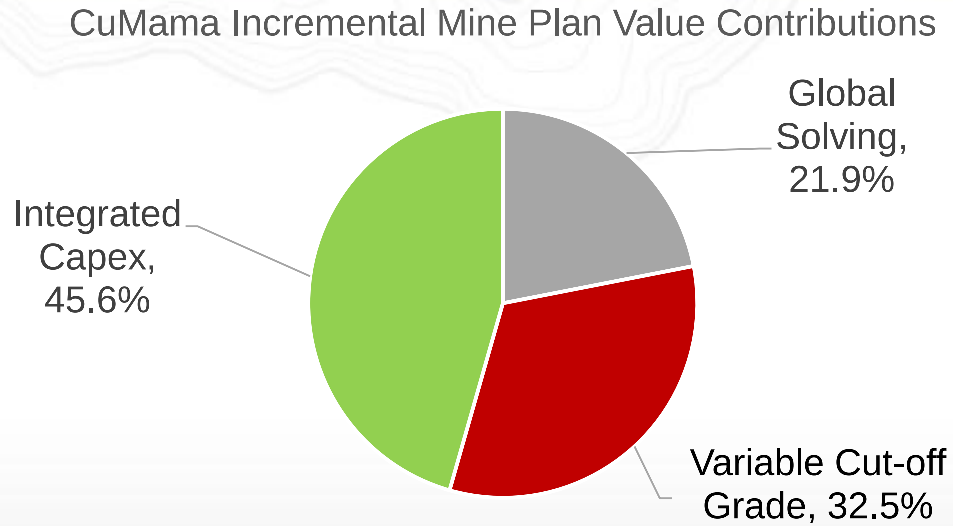
- Further constraints (such as haulage capacity, costing related to truck hours, and in-pit vertical advance) further restrict and complicate the optimum destination decision and therefore the effective cut-off grade.

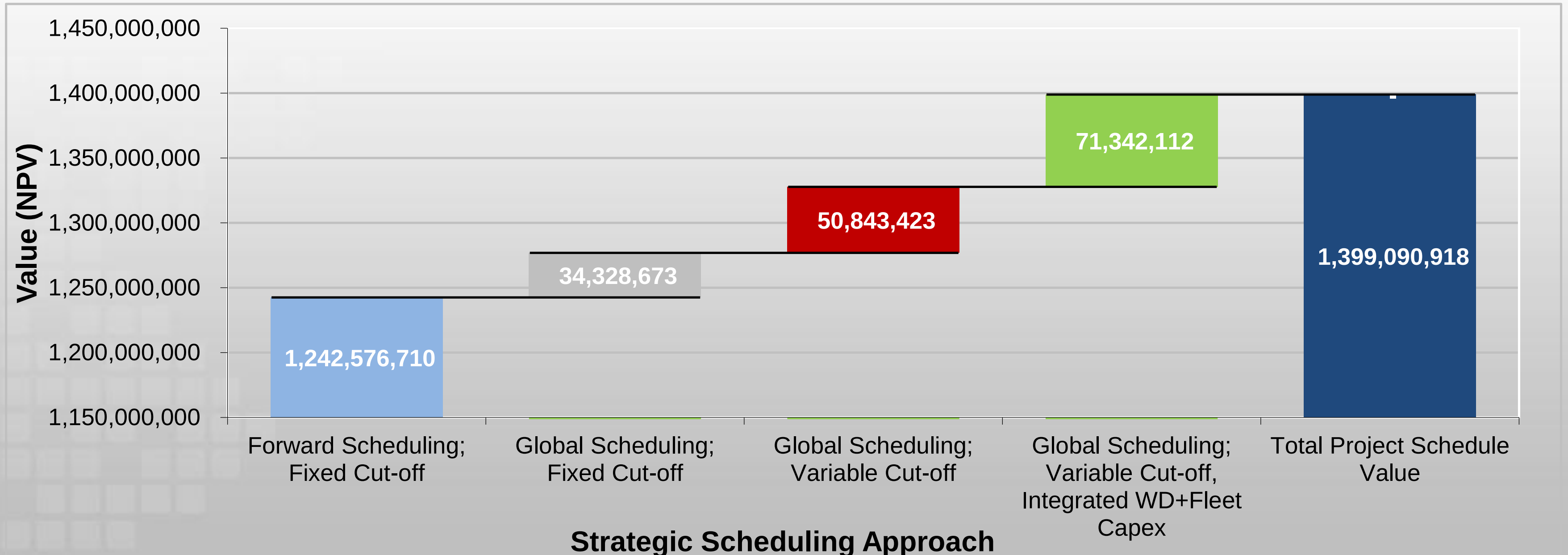
Results: Haulage Analysis



- Solutions reveal that trucking is constrained to the existing fleet capacity (240k truck hours) in the mid-mine life of the first three scenarios.
- Further definition from integrated destination scheduling determines optimal timing for capital purchase ($9M) enabling additional capacity (which ramps and decays as per specified equipment life cycle of additional units).

Results: Impact on Project NPV





Questions?