Capital Expenditure Modelling for Strategic Mine Scheduling

Leon Blackwell
Minemax Pty Ltd

AusIMM SMP 2014
November 2014

minemax
Mine Planning and Scheduling Solutions

Contents

- Introduction
- Modelling properties and relationships
- Application study
- Analysis
- Conclusions
- Questions

minemax
Mine Planning and Scheduling Solutions

Strategic Schedule Optimization

- Longer-term scheduling
  - Simplifications made for technical reasons
- Maximising schedule profitability (NPV)
  - What to schedule
  - What not to schedule
  - When to schedule
  - How to schedule
- Multiple Techniques
  - Heuristic
  - Mixed Integer Linear Programming (MILP)
    - Custom
    - Generic

minemax
Mine Planning and Scheduling Solutions

Capital Expenditure

- Existing modelling often does not consider CapEx
  - Mine site lease
  - Processing plant construction
  - Mining and moving equipment purchase
- Decisions often made before or after scheduling
  - Lost potential for optimal CapEx/schedule

minemax
Mine Planning and Scheduling Solutions

Modelling properties and relationships

- Number Available (Instancing)
  - Multiple instances of the same resource
  - Trucks, excavators, etc
- Limited Lifespan (Expiry)
  - Not all equipment lasts the duration of the mine
  - Particularly important for longer term operations
- Resource Degradation (Decay)
  - Decreased performance
  - Increased maintenance

minemax
Mine Planning and Scheduling Solutions

Modelling properties and relationships

- Settling Periods (Ramp Up)
  - Plant takes time to perfect
  - Operators learning
- Delayed Delivery
  - Construction time
  - Delivery time
  - Purchase cost in the correct period for correct discounting
- Purchase Options (Mutually Exclusive Sets)
  - Different sized ports or plants
  - Alternate options for shipping products

minemax
Mine Planning and Scheduling Solutions

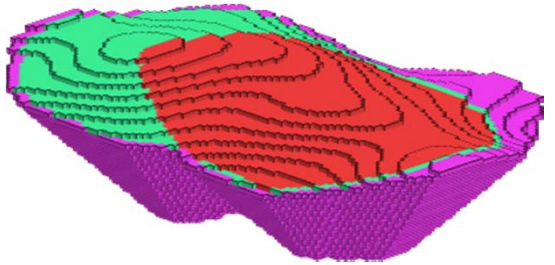
Modelling properties and relationships

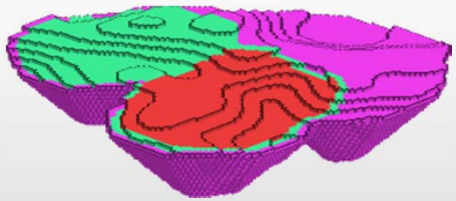
- Order of Availability (Precedences)
  - Rail sequencing
  - Rail before port
- Expansions
  - Additional capacity through extension
  - Step-wise non-linear expansions
  - Precedences can control timing

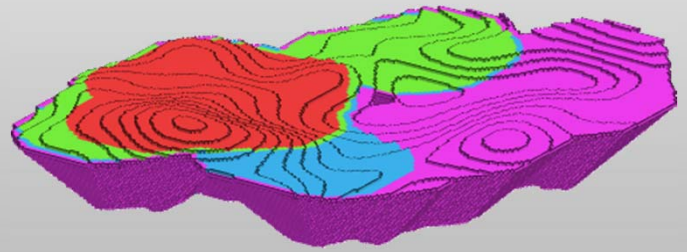
minemax
Mine Planning and Scheduling Solutions

Application study: Setup

- Hypothetical Mining Operation
  - Single element
  - Unrefined
  - 3 pits (Pit A, Pit B, Pit C)
    - Artificial ore body
    - Pit-optimized in Minemax Planner
  - 2 ports (Port X, Port Y)
  - Rail connectivity
  - 12 years of expected operation
  - No existing infrastructure







minemax
Mine Planning and Scheduling Solutions

Application study: Setup

- Trucks

Truck	Cost	Capacity			
		1st	2nd	3rd	4th
Big	$9 000 000	9 000 000 t	10 000 000 t	10 000 000 t	8 000 000 t
Small	$4 000 000	3 800 000 t	4 000 000 t	4 000 000 t	3 700 000 t

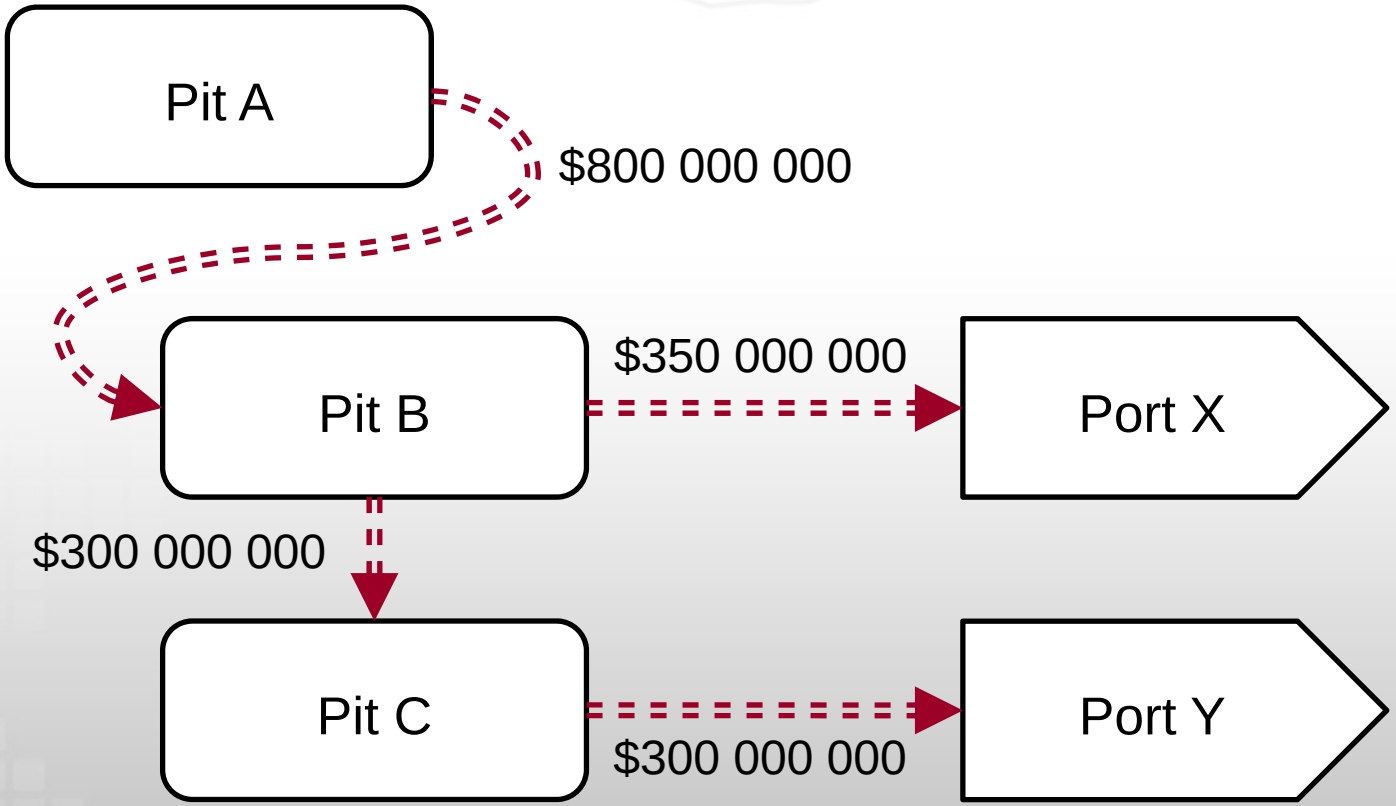
- Port options

Port	Option	Capacity	Purchase Cost
X	X1	2 000 000 t/year	$300 000 000
	X2	3 000 000 t/year	$500 000 000
	X3	4 000 000 t/year	$800 000 000
Y	Y1	4 000 000 t/year	$1 000 000 000
	Y2	5 000 000 t/year	$1 250 000 000
	Y3	6 000 000 t/year	$1 500 000 000

minemax
Mine Planning and Scheduling Solutions

Application study: Setup

- Rail



minemax
Mine Planning and Scheduling Solutions

Application study: Implementation

- Four incremental scenarios
  - Basic
  - Scheduled truck purchases
  - Port purchase options
  - Scheduled rail development
- Optimized in Minemax Scheduler
  - Uses MILP
  - Builds mathematical model for you (generic solution)
- Post-analysis for comparative financials
  - Make best-case assumptions to derive unmodelled costs
  - Combine together to calculate comparable NPV

minemax
Mine Planning and Scheduling Solutions

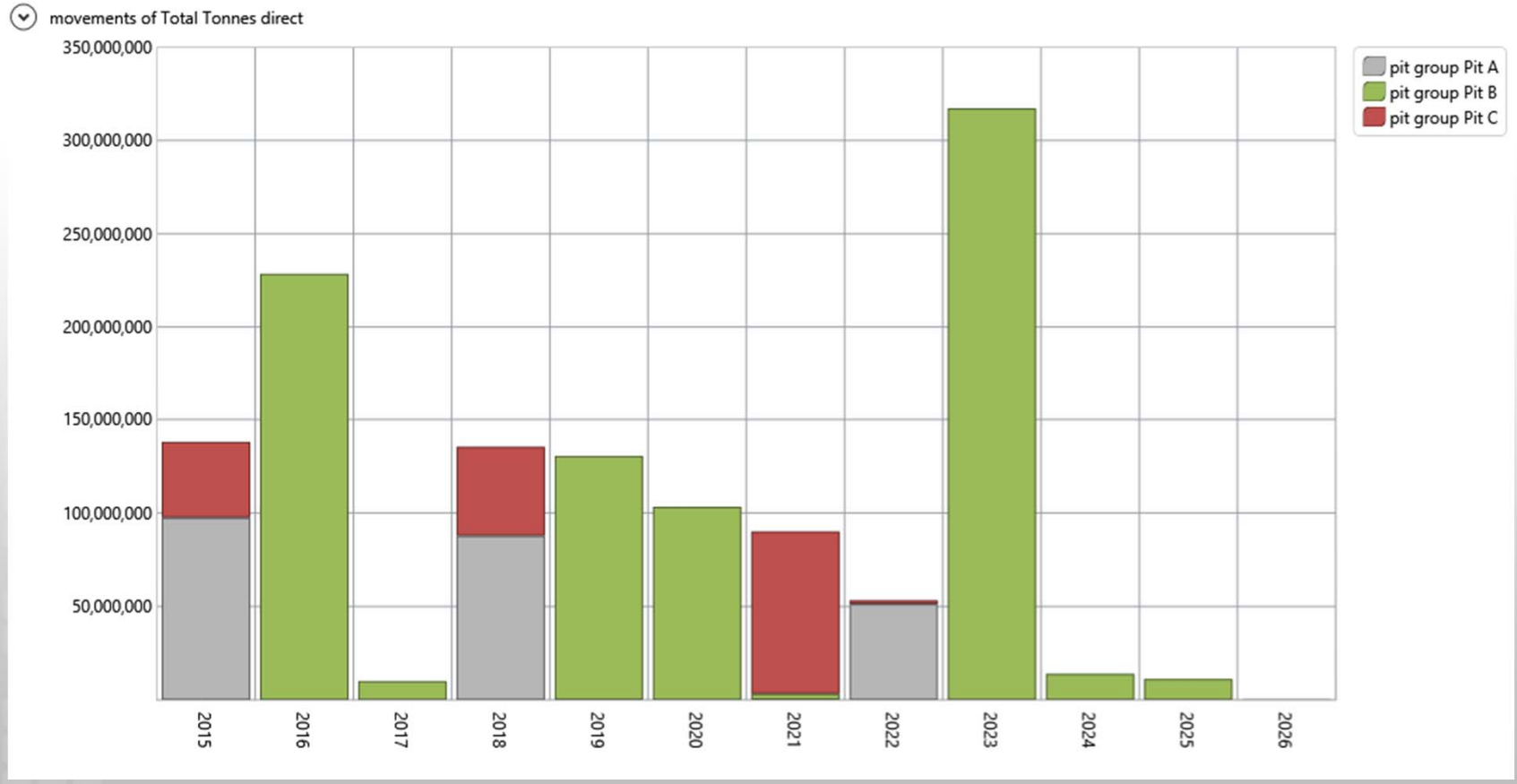
Basic scenario: Setup

- Modelled
  - Ore/waste mining
- Not modelled
  - Truck purchases, so all trucks purchased
    - Provide for 10 000 000 tonnes per period
    - Cost $9 000 000 each
    - Have a 4-period lifespan
  - Port purchases or options
    - Scheduled in first period used
    - Largest option required is selected
  - Rail development
    - Scheduled in first period used

minemax
Mine Planning and Scheduling Solutions

Basic scenario: Results

- Comparable NPV is $2 088 082 935
- Purchases 67 Big Trucks



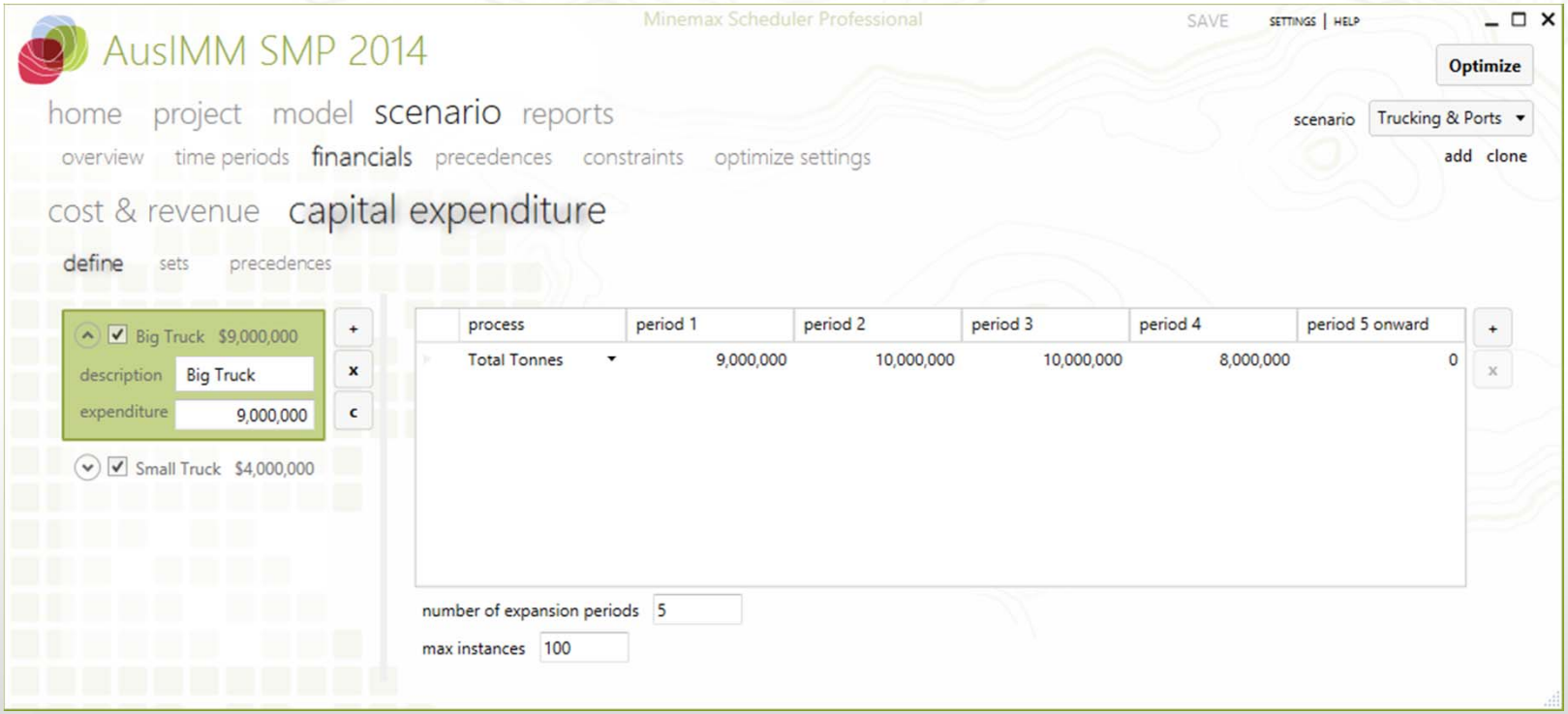
minemax
Mine Planning and Scheduling Solutions

Scheduled truck purchases scenario: Setup

- Modelled
  - Ore/waste mining
  - Truck purchases
- Not modelled
  - Port purchases or options
    - Scheduled in first period used
    - Largest option required is selected
  - Rail development
    - Scheduled in first period used

minemax
Mine Planning and Scheduling Solutions

Scheduled truck purchases scenario: Setup



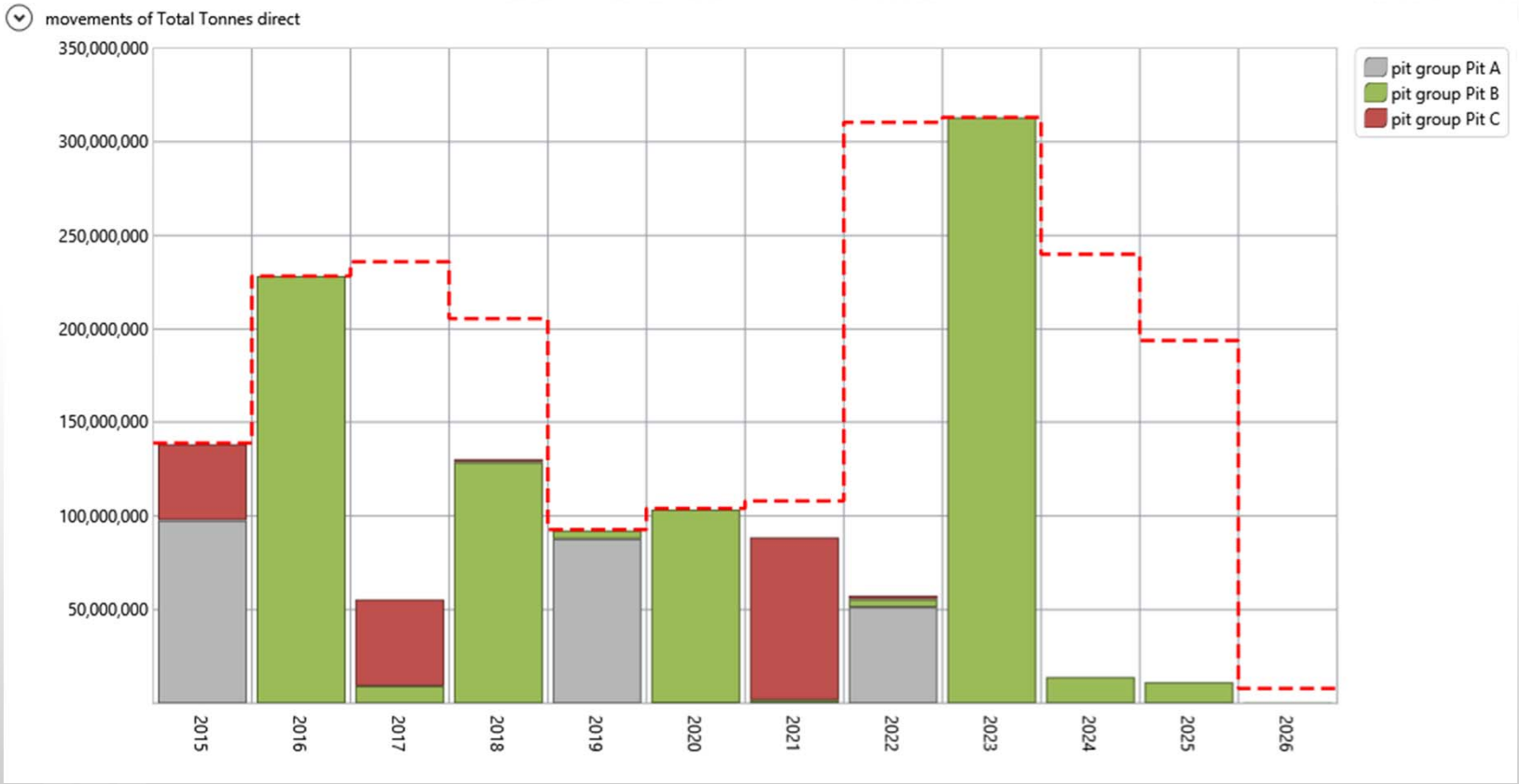
minemax
Mine Planning and Scheduling Solutions

Scheduled truck purchases scenario: Results

- Comparable NPV is $2 117 280 324
  - Increase of $29 197 389
- Purchased 48 Big Trucks and 26 Small Trucks
  - (changed from Basic scenario, which was 67 Big Trucks)
- Changed order of mining pits
  - 3rd period now mines Pit C to make better use of trucks

minemax
Mine Planning and Scheduling Solutions

Scheduled truck purchases scenario: Results



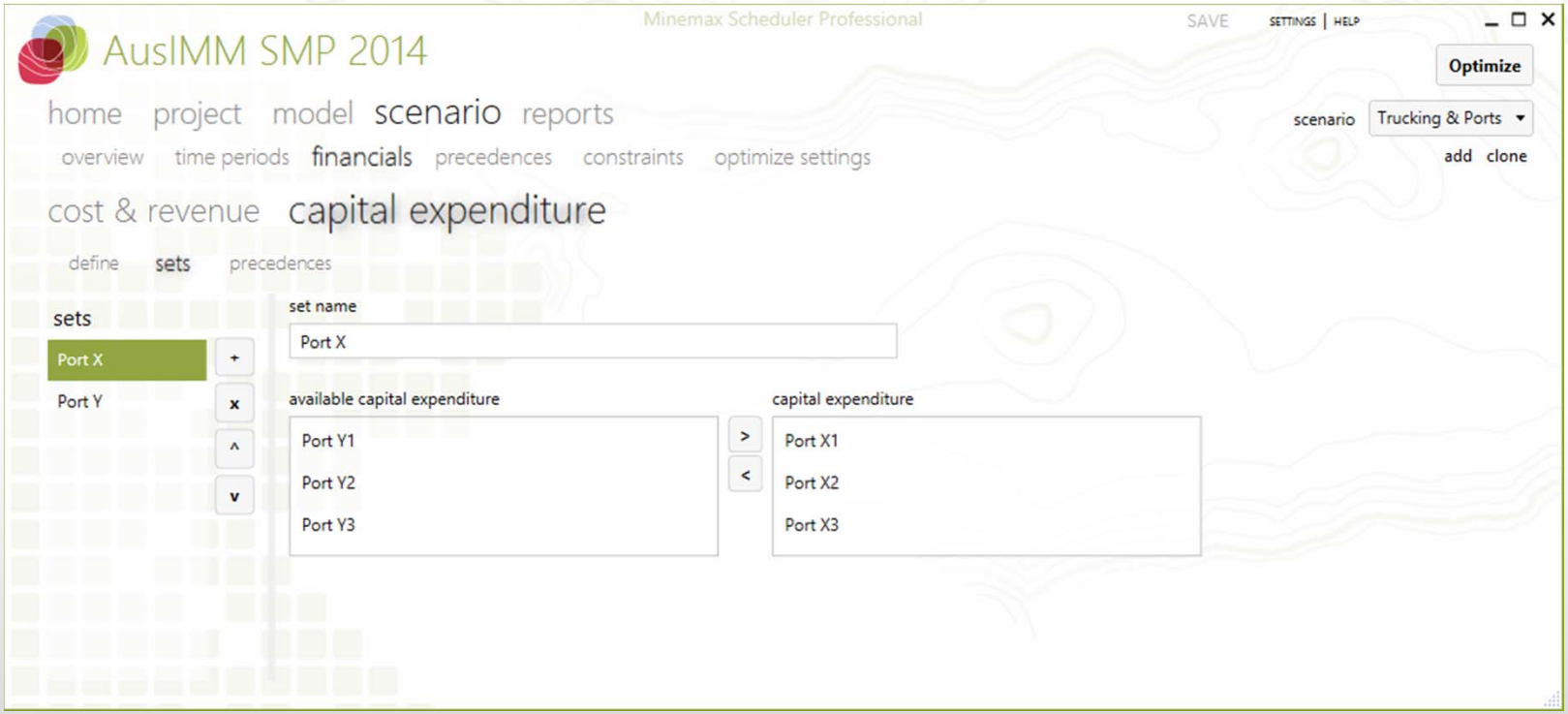
minemax
Mine Planning and Scheduling Solutions

Port purchase options scenario: Setup

- Modelled
  - Ore/waste mining
  - Truck purchases
  - Port purchases and options
- Not modelled
  - Rail development
    - Scheduled in first period used

minemax
Mine Planning and Scheduling Solutions

Port purchase options scenario: Setup



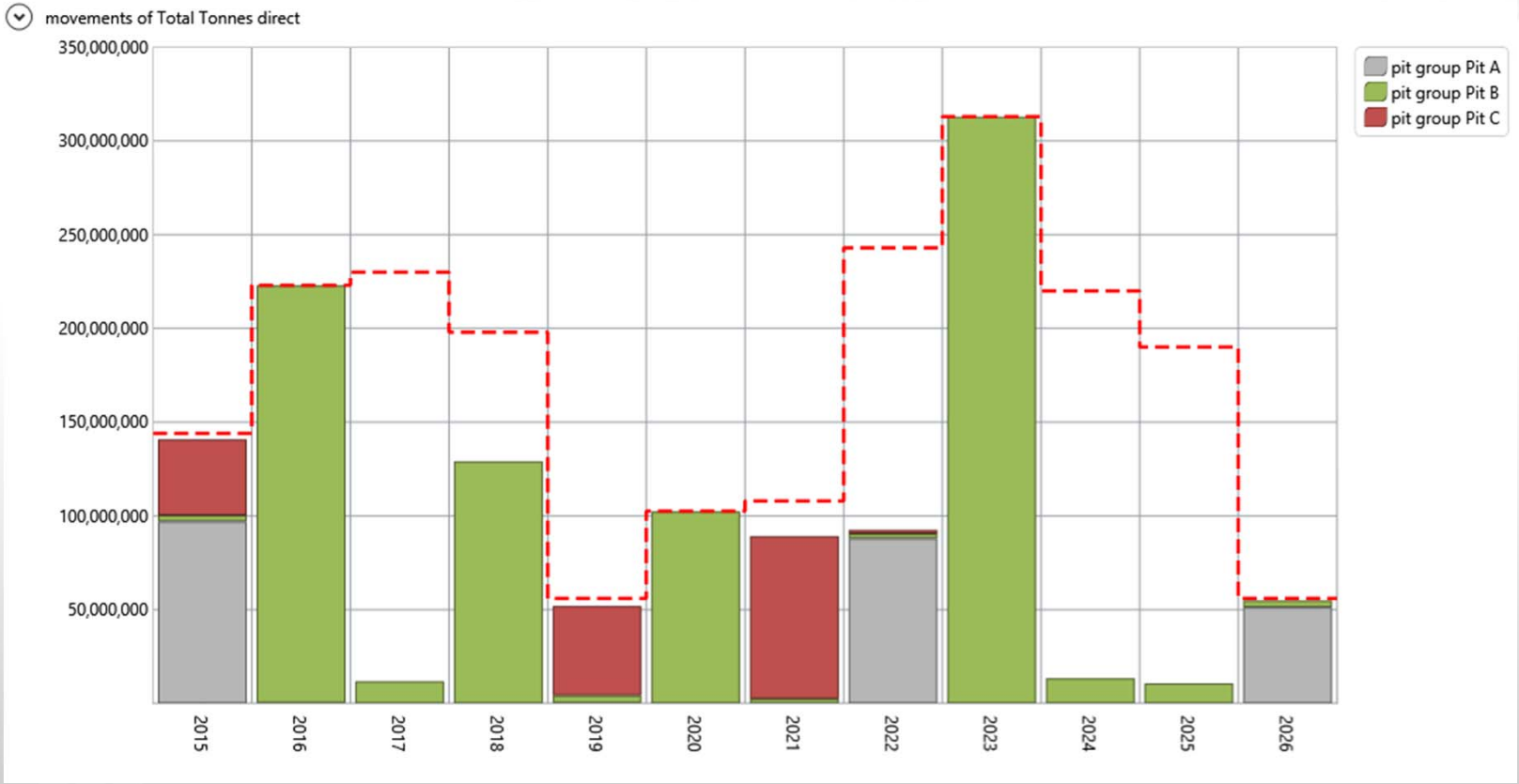
minemax
Mine Planning and Scheduling Solutions

Port purchase options scenario: Results

- Comparable NPV is $2 169 856 428
  - Increase of $52 576 103 over previous scenario
  - Increase of $81 773 492 over Basic scenario
- Chooses one of the smaller options for Port X (X1)
- Now 45 Big Trucks and 27 Small Trucks
- Considerably more mining in final period

minemax
Mine Planning and Scheduling Solutions

Port purchase options scenario: Results



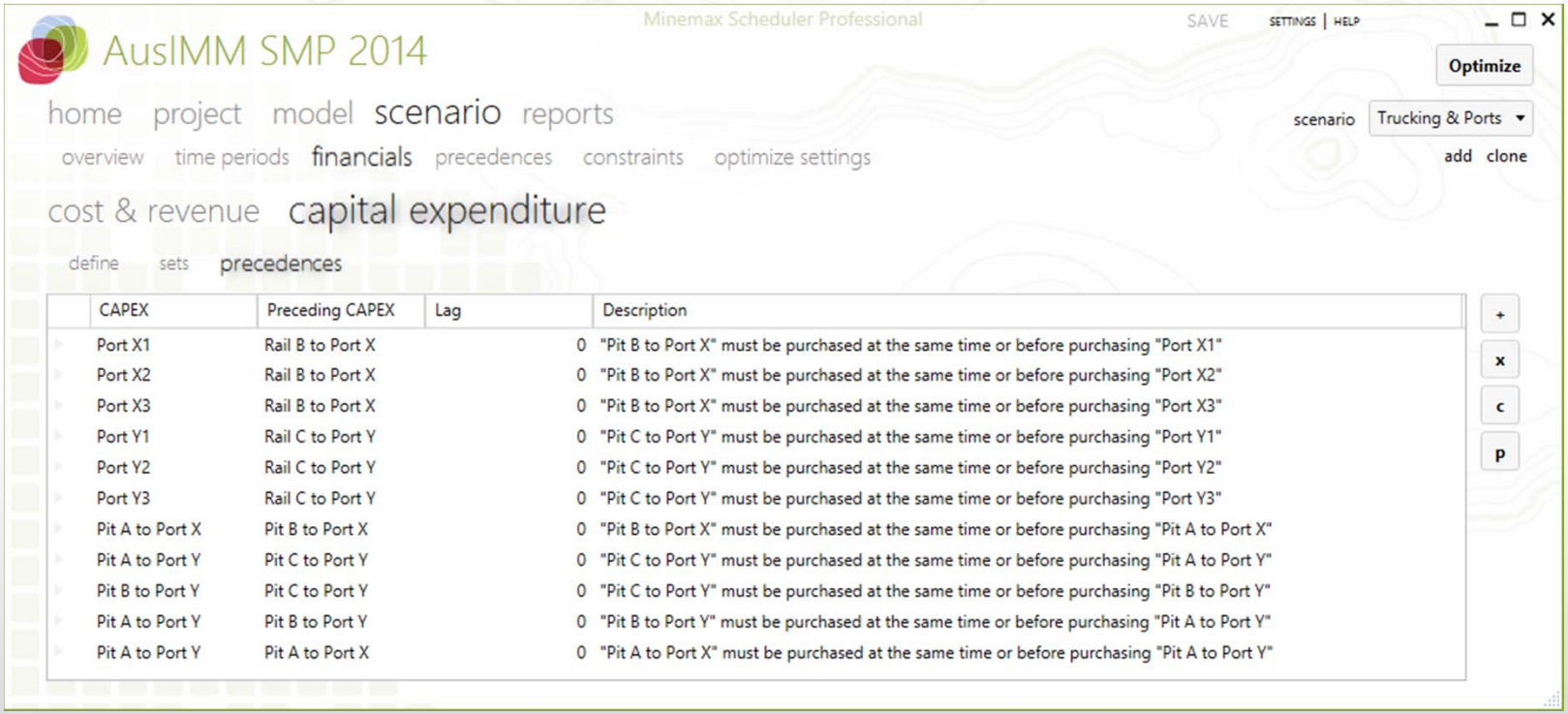
minemax
Mine Planning and Scheduling Solutions

Scheduled rail development scenario: Setup

- Modelled
  - Ore/waste mining
  - Truck purchases
  - Port purchases and options
  - Rail development

minemax
Mine Planning and Scheduling Solutions

Scheduled rail development scenario: Setup



CAPEX	Preceding CAPEX	Lag	Description
Port X1	Rail B to Port X	0	"Pit B to Port X" must be purchased at the same time or before purchasing "Port X1"
Port X2	Rail B to Port X	0	"Pit B to Port X" must be purchased at the same time or before purchasing "Port X2"
Port X3	Rail B to Port X	0	"Pit B to Port X" must be purchased at the same time or before purchasing "Port X3"
Port Y1	Rail C to Port Y	0	"Pit C to Port Y" must be purchased at the same time or before purchasing "Port Y1"
Port Y2	Rail C to Port Y	0	"Pit C to Port Y" must be purchased at the same time or before purchasing "Port Y2"
Port Y3	Rail C to Port Y	0	"Pit C to Port Y" must be purchased at the same time or before purchasing "Port Y3"
Pit A to Port X	Pit B to Port X	0	"Pit B to Port X" must be purchased at the same time or before purchasing "Pit A to Port X"
Pit A to Port Y	Pit C to Port Y	0	"Pit C to Port Y" must be purchased at the same time or before purchasing "Pit A to Port Y"
Pit B to Port Y	Pit C to Port Y	0	"Pit C to Port Y" must be purchased at the same time or before purchasing "Pit B to Port Y"
Pit A to Port Y	Pit B to Port Y	0	"Pit B to Port Y" must be purchased at the same time or before purchasing "Pit A to Port Y"
Pit A to Port Y	Pit A to Port X	0	"Pit A to Port X" must be purchased at the same time or before purchasing "Pit A to Port Y"

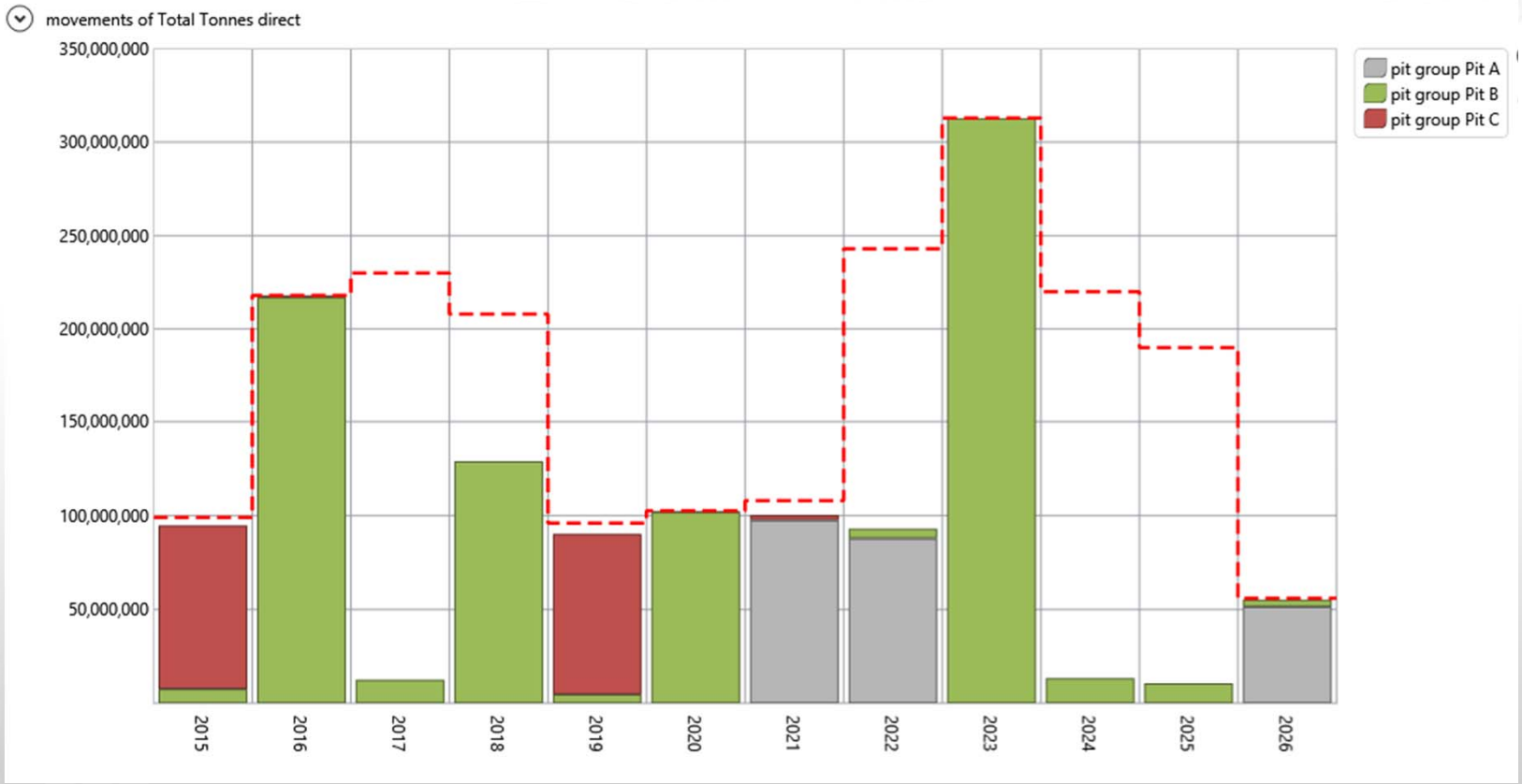
minemax
Mine Planning and Scheduling Solutions

Scheduled rail development scenario: Results

- Optimal NPV is $2 297 393 727
  - Increase of $127 537 299 over the previous scenario
  - Increase of $209 310 792 (~10%) over Basic scenario
- Port X (X1) not purchased until the second period
- Rail link between Pit A and Pit B delayed
- Pit A delayed from 1st period to 7th

minemax
Mine Planning and Scheduling Solutions

Scheduled rail development scenario: Results



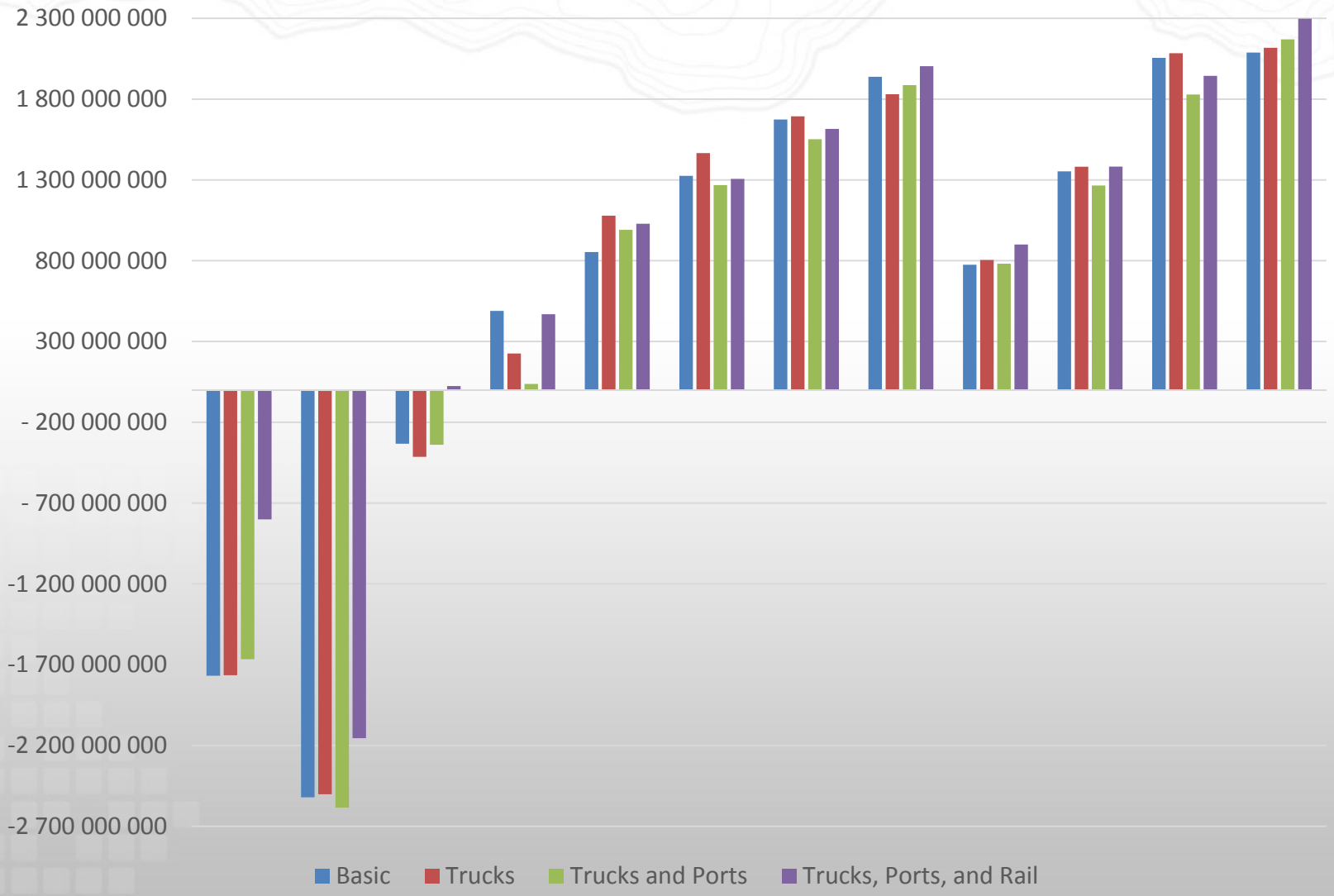
minemax
Mine Planning and Scheduling Solutions

Analysis

- Each scenario changes previous decisions
  - Trucks alter schedule
  - Port options alter trucks
  - Rail alters port
- Each additional CapEx modelled increases NPV

minemax
Mine Planning and Scheduling Solutions

Analysis: NPV over time



minemax
Mine Planning and Scheduling Solutions

Conclusions

- Modelling CapEx isn't difficult
  - Just requires the right framework
- Actually saves time
  - Calculating comparative/correct NPVs is laborious
  - Experimentation is slower
- Each unmodelled CapEx is a missed opportunity
- Additional information makes for additional profit

minemax
Mine Planning and Scheduling Solutions

For more information

- leon.blackwell@minemax.com
- www.minemax.com
- @minemax