Optimal Open Pit Scheduling with CAPEX and Declining Equipment Capacities

Matthew LaBonte
Brian Lambert
Jim Butler

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Problem Statement

- Annual mining rate constraints are based on equipment capacities
- Treating equipment as a fixed-capacity asset unaffected by age will not accurately constrain mining rates due to limited lifespans and declining availability
- We demonstrate the potential impact of this simplifying assumption, and how more accurately modeling equipment life cycles may produce different schedules with different NPVs and identify more realistic timing of replacement equipment

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Modelling Equipment Capacity

- Modelling equipment as a fixed-capacity asset may be appropriate for relatively short time-horizon models (<5 years)

- For longer time horizons (e.g., 10 or 20 years), decreasing equipment efficiency and increasing required maintenance may significantly decrease annual equipment capacity

- For modelling purposes, equipment is categorized as initial or purchased, where purchased equipment is identified as a CAPEX expenditure during the model solve

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Example Scenarios

	Existing Trucks		Purchased Trucks		
Scenario	Unlimited Life	Declining Life	Unlimited Life	Unlimited Life X2	Declining Life
1. UE	X				
2. UE_UP	X		X		
3. UE_UPx2	X			X	
4. DE_UP		X	X		
5. DE_UPx2		X		X	
6. DE_DP		X			X

UE: Unlimited Life Existing Equipment
DE: Declining Life Existing Equipment
UP: Unlimited Life Purchased Equipment
UPx2: Unlimited Life Purchased Equipment w/ indexed price
DP: Declining Life Purchased Equipment

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	Existing Trucks		Purchased Trucks		
Scenario	Unlimited Life	Declining Life	Unlimited Life	Unlimited Life X2	Declining Life
1. UE	X				
2. UE_UP	**X**		**X**		
3. UE_UPx2	X			X	
4. DE_UP		**X**	**X**		
5. DE_UPx2		**X**		**X**	
6. DE_DP		**X**			**X**

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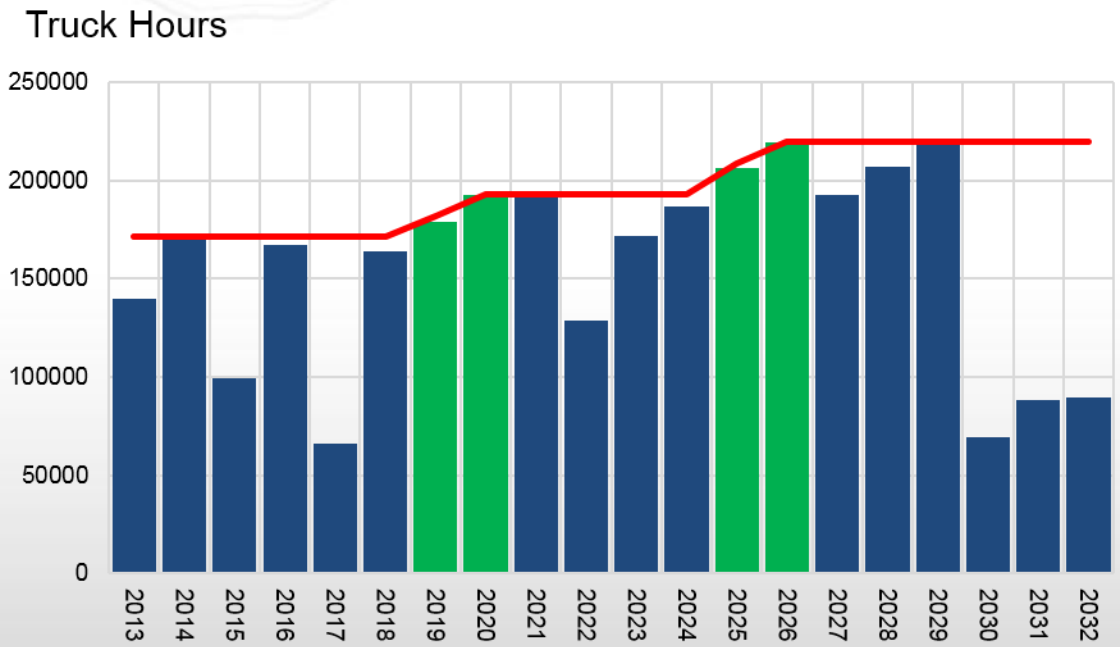
Scenario Examples: Constant Assumptions/Params

- Schedule Parameters:
  - Time horizon - 20 years
  - Processing destinations - Mill with limit of 16.5M tonnes/year
  - Mining limit of 70M tonnes/year
  - Financials
    - Revenue of $40/gram Au
    - Mill recovery of 90%
    - Milling costs of $15/tonne
    - Mining costs of $1.85/tonne ore, $1.75/tonne waste
  - Trucking specific
    - 313 tonne capacity
    - Operation cost of $480/hr
    - Purchase price of $2M

Scenario 2:
Base Case + CAPEX – UE_UP

- (UE_UP) Unlimited life for existing and purchased equipment

- Schedule metrics:
  - NPV $448M
  - Truck Utilization 80.4%
  - Purchased Trucks 9



	2019	2020	2025	2026
CAPEX Cost ($M)	4	4	6	4
# of Trucks	2	2	3	2

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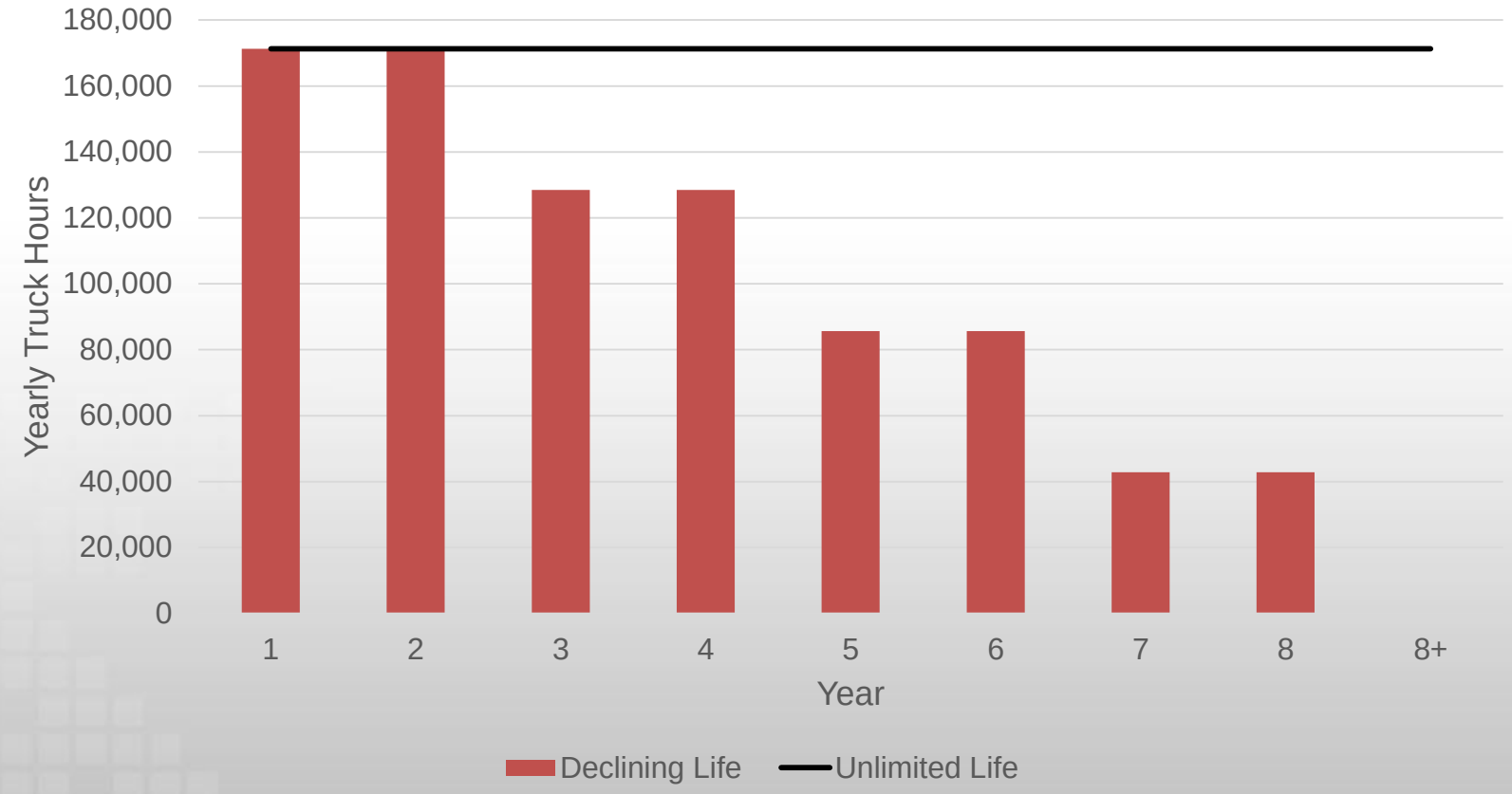
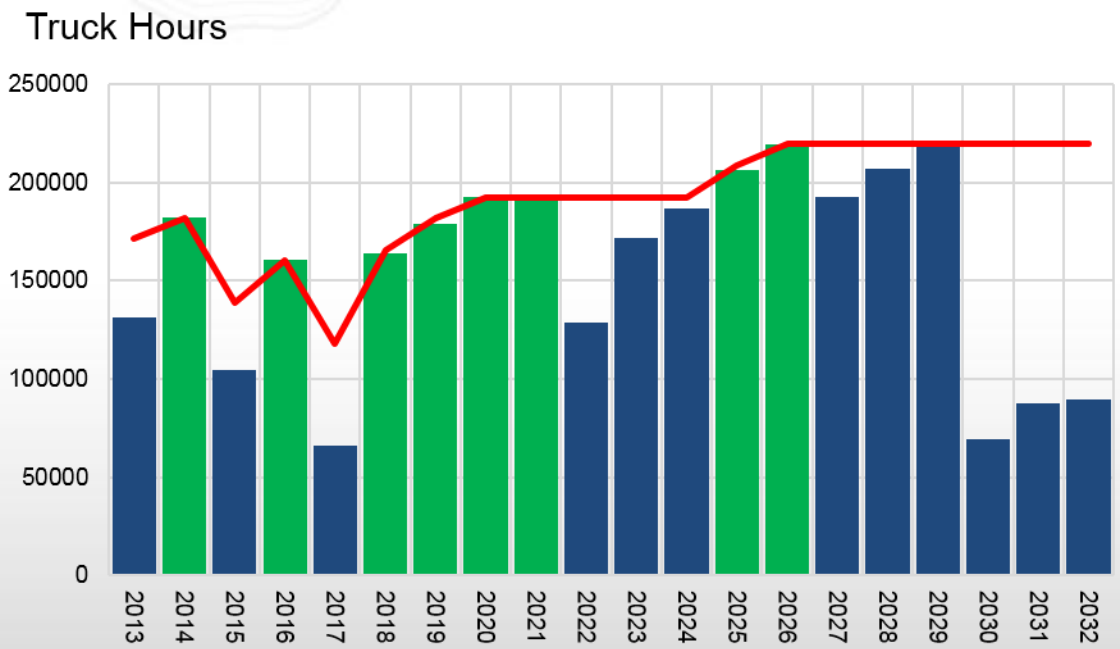
Initial Truck Availability



Scenario 4:
More Accurate Case – DE_UP

- (DE_UP) Declining life for existing equipment, and unlimited life for purchased equipment

- Schedule metrics:
  - NPV $399M
  - Truck Utilization 82.4%
  - Purchased Trucks 41

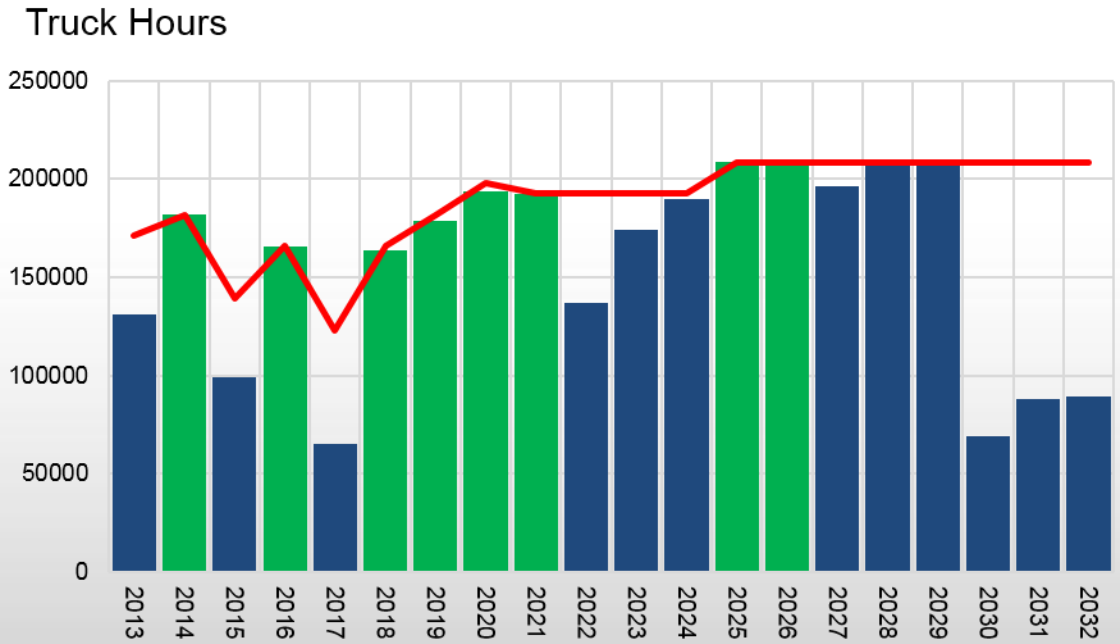


	2014	2016	2018	2019	2020	2021	2025	2026
CAPEX Cost ($M)	4	8	18	22	4	16	6	4
# of Trucks	2	4	9	11	2	8	3	2

Scenario 5:
More Accurate Case – DE_UPx2

- (DE_UPx2) Declining life for existing equipment, and unlimited life for purchased equipment with an indexed price

- Schedule metrics:
  - NPV $360M
  - Truck Utilization 83.6%
  - Purchased Trucks 78 (39)



	2014	2016	2018	2019	2020	2021	2025
CAPEX Cost ($M)	6.7	16.7	26.7	36.7	10	23.4	10
# of Trucks	4	10	16	22	6	14	6

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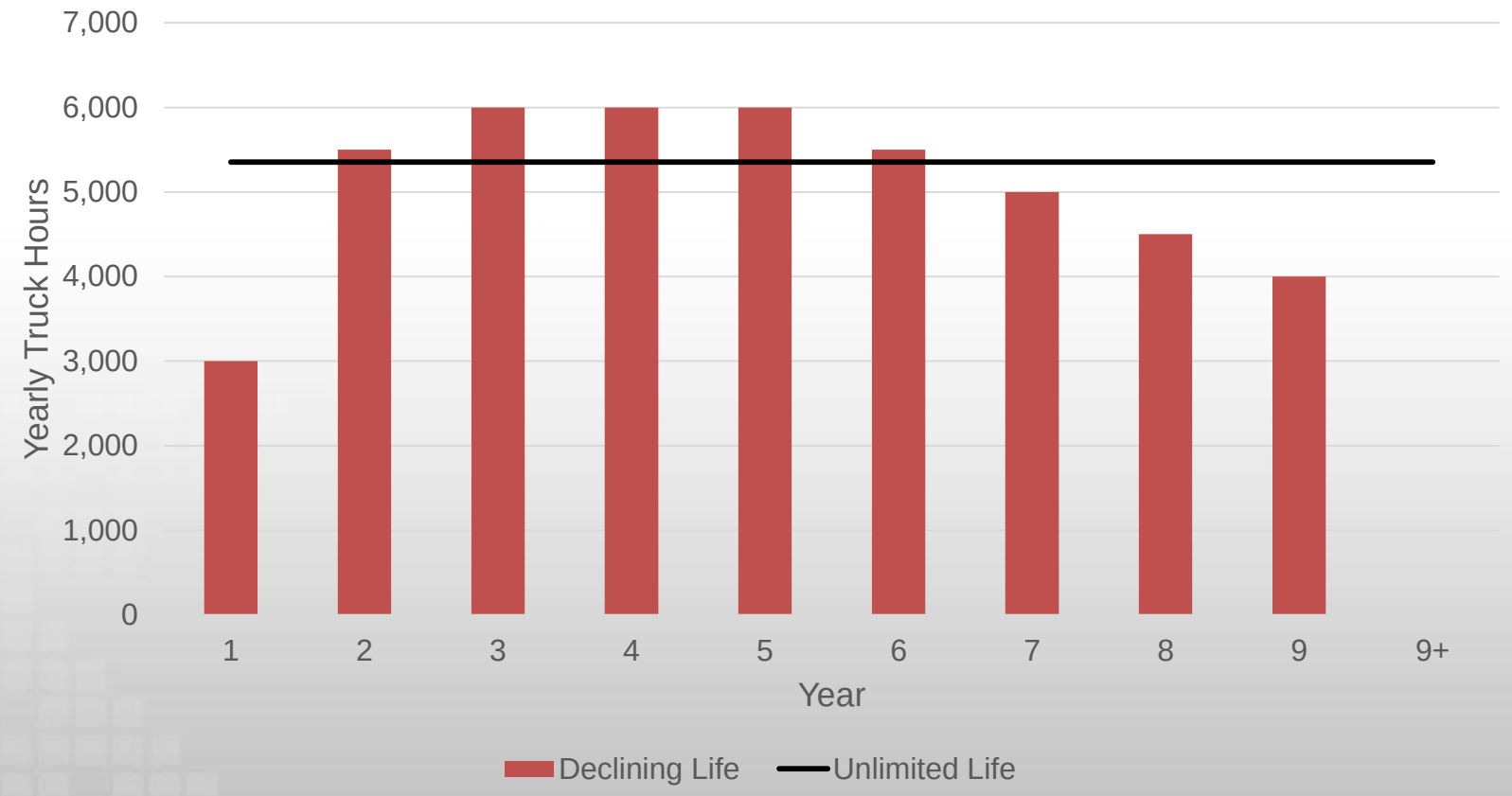
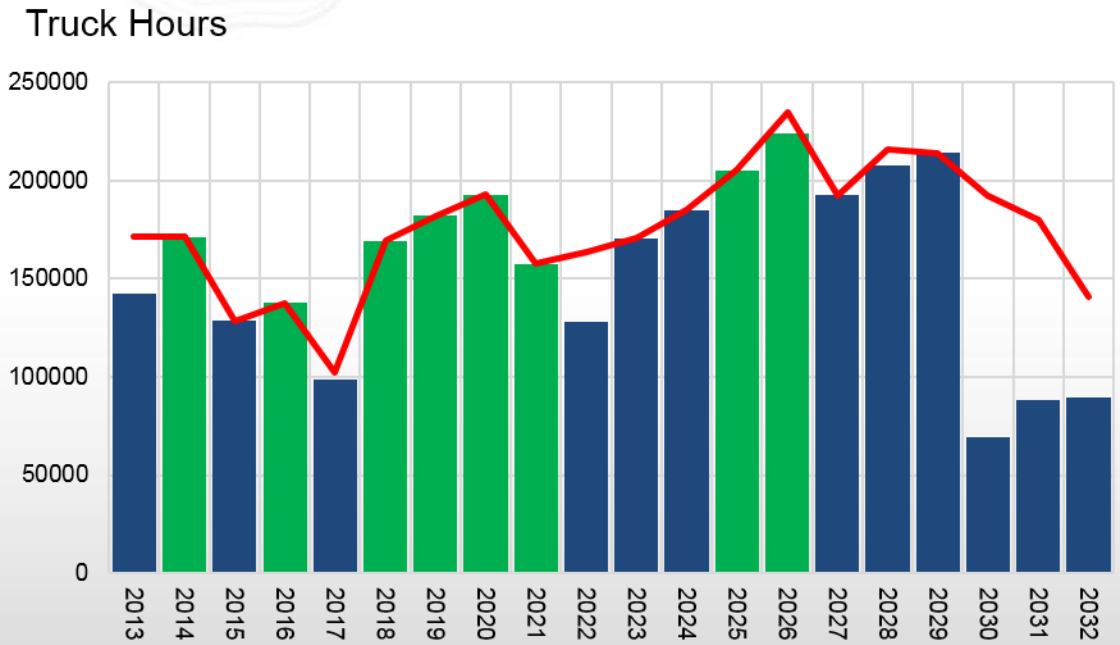
Purchased Truck Availability



Scenario 6:
Most Accurate Case – DE_DP

- (DE_DP) Declining life for both existing and purchased equipment

- Schedule metrics:
  - NPV $372M
  - Truck Utilization 89.9%
  - Purchased Trucks 63



	2016	2018	2021	2023	2024	2025	2026	2027
CAPEX Cost ($M)	6	44	6	12	8	20	10	20
# of Trucks	3	22	3	6	4	10	5	10

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Example Scenarios

	Existing Trucks		Purchased Trucks			Schedule Metrics		
Scenario	UE	DE	UP	UPx2	DP	NPV ($M)	Util. (%)	# Purch.
1. UE	X					393		
2. UE_UP	**X**		**X**			**448**	**80.4**	**9**
3. UE_UPx2	X			X		441		
4. DE_UP		**X**	**X**			**399**	**82.4**	**41**
5. DE_UPx2		**X**		**X**		**360**	**83.6**	**78**
6. DE_DP		**X**			**X**	**372**	**89.9**	**63**

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Take Away

- Schedules created without consideration of equipment life may not be feasible for LOM
- Schedules created without consideration of equipment life will be very different from schedules that do
- This is just one of many assumptions that go into schedule building that needs to be looked at more closely to ensure that models are constructed that yield not only optimal answers, but answers that will be feasible in reality

Questions?

Matthew LaBonte
Brian Lambert
Jim Butler

Level 3, 182 St Georges Terrace,
Perth WA 6000
Australia
Tel (+618) 9226 3288

9137 S. Ridgeline Blvd., St 135
Highlands Ranch, CO 80129 USA
Tel +1.720.287.8250