Materials Handling and Traffic Simulation in an Underground Mine

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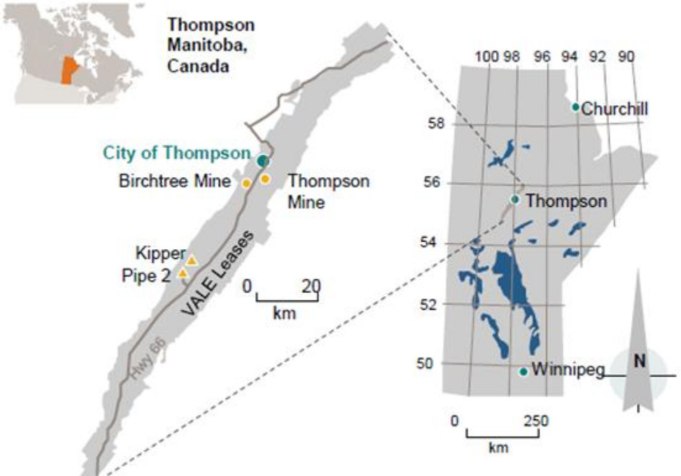
Contents

Context and goals

Overview of the Thompson Mine



Courtesy of Vale

- Underground nickel mine owned by Vale Canada Ltd
  - Mining and refining began in early 1960s
  - Vale acquired assets from Inco in 2007
  - Late 2000s: launch of a study aiming at extracting more ore from deeper levels of an operating mining area

Some facts on this expansion study

- Existing mine that is being mined out
  - Current operations depth: between 3,600 and 4,200 feet
  - Expansion target depth: between 4,300 and 5,600 feet
  - Expansion mine life is estimated at 15 years
- Meeting the production targets is challenging
  - Personnel and supplies: combination of shaft and ramp
  - Ore: trucked on ramp to tram level at 3,600 feet
  - Rock (waste): trucked on ramp to dumping stopes
  - Ventilation constraints can limit trucking capabilities.
- The underground ramp is the life line of the mine!

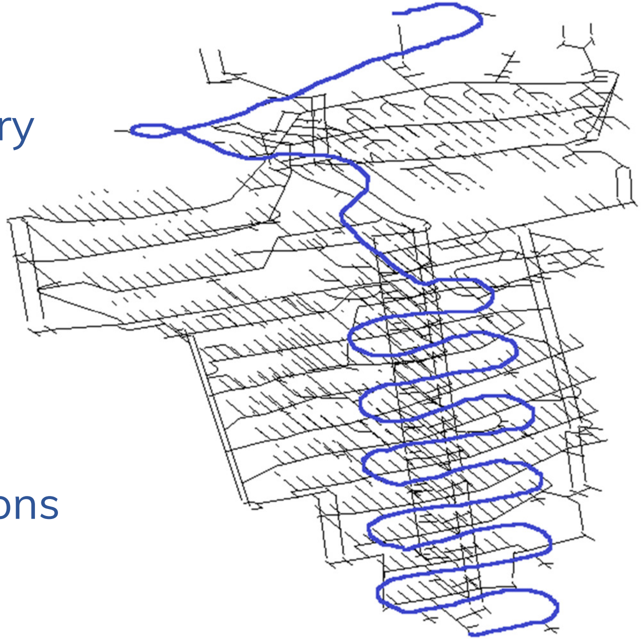
Justification for simulation

- The question of traffic…
  - Lots of movements on the ramp for the next 15 years
  - The more trucks, the more ore, but…
  - Will traffic be the limiting factor?
- Some design points to be addressed:
  - How many trucks are required?
  - Will the mining schedule be feasible?
- Determining the appropriate fleet sizes considering traffic and interferences on the requires a computer simulation

Modelling of operations

Model scope

- Focus on activities generating movements on the ramp
  - Scheduled ore and rock handling
  - Personnel movements and supplies delivery
  - Support services and ramp maintenance
- This simulation is based on:
  - Normal unfolding of a shift
  - Vehicles kinematics and capacities
  - Activities triggered by mine schedule
  - 3D layout for exact dimensions and locations
  - Traffic and ventilation constraints



Handling of ore and rock

- Mining schedule was established a priori
  - Tabulated values of tons/day for each level for each year
  - Materials origins and destinations specified in schedule
- Trucks perform as many haulage cycles as possible.
  - From dumping point to loading point to dumping point
  - Leave the ramp during loading/dumping activities
  - Managed by traffic simulation engine when travelling on ramp
- Cycle times are based on data collected during site visit to Thompson Mine.

Other planned and random events

- Delivery of supplies
  - Boom trucks ensure shaft-to-warehouses delivery
  - Supplies quantities and destinations provided by schedule
- Ramp maintenance
  - Ramp surface must be kept in good condition for all equipment
  - Very slow duty interfering with any faster vehicle
- Service vehicles
  - Account for engineering, geotechnical, supervisors, etc.
  - Fast moving vehicle travelling to randomly chosen destinations

Traffic rules and constraints

- The ramp is a 1-vehicle-wide tunnel.
  - Engage if segment is clear or vehicle ahead is going in the same direction
  - Passing and crossing permitted only at intersections with levels
- Priority to value-added trucks
  - Loaded ore trucks going up must never stop!
  - Priorities set by vehicle type and load status
- Accessing the ramp
  - Number of ore and waste trucks on ramp are limited by ventilation
  - Possible morning start delays due to blast venting
  - Other unplanned ramp closures included in model

Simulation process and strategy

- Simulation software and tools
  - Numeric parameters and statistical distributions in Excel workbook
  - System behaviour and decisional logic implemented in Flexsim
  - Simulation results exported to Excel workbooks
- One simulation run…
  - Repeated execution of a typical working week
  - Results represent fully effective production week
  - Yearly number of operating days can be used for annualization
- Pseudo-random numbers are used! Need of replicates…

Statistics collected during simulation

- For system performance assessment
  - Truck utilization rate: (non-idle time)÷(available time)
  - On-time completion: % of scheduled tasks completed within shift
  - Trucking hours/shift: total travelling, loading and dumping time
  - Ore haulage round trip duration by originating level
- For simulation goodness and validation
  - Main shift events time and duration to validate overall structure
  - Truck mapping in space and time to verify ventilation constraints
- And many more detailed results! Comes with means, confidence intervals, percentiles…

Model calibration and validation process

- Variety of data and information sources
  - Reports from previous studies with updated mining schedule
  - Time and motion study + site visit by simulation and mining engineers
- Model validation and verification
  - Model behaviour firstly review by SNC-Lavalin mining experts
  - Then Client went through exhaustive model examination
- Results analysis and approval
  - Results were challenged by mining experts and Client experts
  - After minor model refinements, final results approved by Client

Simulation results and findings

Determining operations feasibility

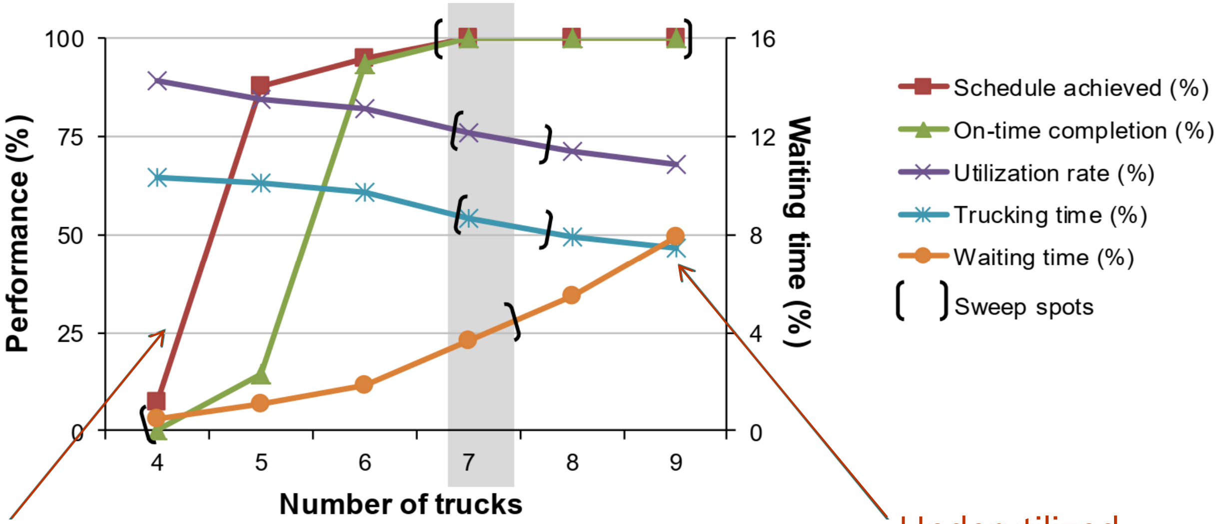
≡ Real-life field requirements

- Meet target tons/day of ore
- Personnel should not be trapped underground between shifts
- Drivers should drive, not "wait for"…
- Trucks must have time left for maintenance

≡ Translation into simulation words

- Schedule on-time completion ≥ 95%
- Truck utilization rate ≈ 75-80%
- Total truck waiting time ≤ 5%
- "Sufficient" resource utilization: $\frac{\text{Trucking time}}{\text{Available time}} \approx$ 50-55%

Determining the right fleet size



Unable to achieve mine schedule

Schedule achieved with sufficient resource utilization

Underutilized resources, too much waiting time

What if design parameters are modified?

- Increasing truck payload
  - Base case: 30 tons. More expensive alternative: 40 tons
  - Trucks required: 10 @ 30 tons, 7 @ 40 tons
- Increasing truck speed
  - Base case: 7km/h. More expensive alternative: 8 km/h
  - Trucks required: 8 @ 7 km/h, 7 @ 8 km/h
- Relaxing ventilation constraints
  - Base case: max 4 trucks on ramp. With more ventilation: 5 trucks
  - Trucks required: 9 @ max 4, 7 @ max 5
- Put this in the balance between CAPEX and OPEX...

Importance of ramp traffic interferences

	Number of trucks	Utilization rate (%)
Recommendations from this study	7	**78.4%**
Study results when ignoring traffic	7	**64.9%**
Ignoring traffic, recommendations would have been…	6	**71.8%**

- In other words:
  - Here, traffic increases truck utilization rate by 13.5%
  - Without considering traffic, there would be 1 truck missing
  - Recall: 6 trucks = 92% of schedule achieved “on the heels”…

Final words

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≡ Benefits of simulation for this study

- Include ramp traffic and interferences in right fleet sizing
- Generation of useful results for mine design calculations
- Low cost test bench to try several design alternatives
- Consensual multidisciplinary teamwork decision making

≡ Importance of client involvement during modelling

- Establish clear scope and expectations at the start
- Dedicate resources to gather required information
- Study team trusts simulation outputs
- Obtain Client early feedback, guidelines and requests
- Final report: conclusions fulfill Client expectations

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