Optimizing Ventilation Design Through Discrete Event Equipment Simulation

BY:

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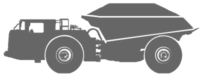
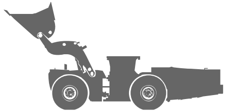
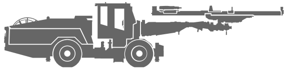
Determining ventilation demand

- For most metal mine ventilation systems, ventilation demand is governed by the diesel equipment in use at the mine.
- Airflow is typically based on a flow requirement per kW of diesel machine.
- To properly model the ventilation system, knowing the number and location of the diesel equipment is required.

Traditional determination of ventilation demand

Airflow Factor *0.08 (m³/s/kw)*

	Type of Equipment	**U/G Fleet Size**	**Diesel (kW)**	**Airflow Utilization (%)**	**Airflow (m³/s)**
	Haul Trucks (40t)	14	300	85%	286
	LHDs	5	110	75%	33
	Drills	5	40	20%	
	Jumbos	8	45	20%	
	Explosive Loaders	6	95	20%	
	Shotcrete Sprayer	7	95	20%	77
	Grader	1	85	30%	
	Miscellaneous	15	80	20%	
	Light Vehicle	12	140	20%	
				Sub-Total	*395*
				Leakage 10%	*40*
				Total	**435**

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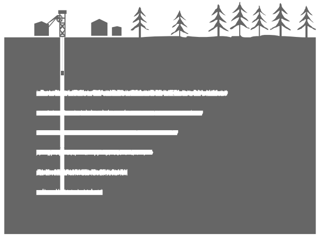
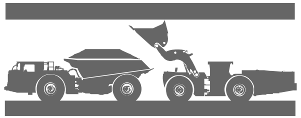
Equipment Fleet Determination

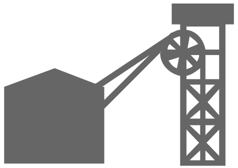
- Equipment fleets are often determined by:
  - Dividing the desired production rate by the diesel truck tonnage to determine the number of trucks required to meet goal (in a day).
  - Evaluate the haulage distance and the speed at which the trucks can operate up and down a ramp or to the crusher location.
  - Calculate the time for the trucks to make the haulage circuit and calculate how many trucks would be required to achieve the tonnage rate.
  - Perform calculation for various production time phases.





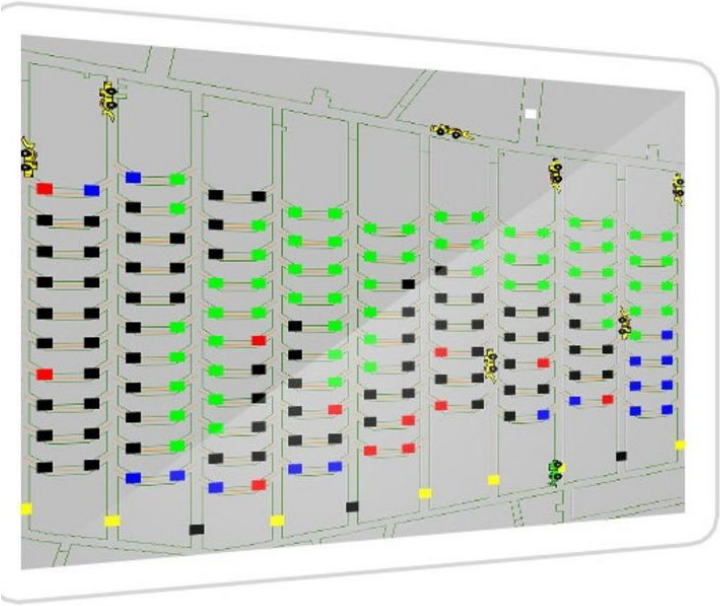
Equipment Fleet Determination

- The challenge is the calculation rarely identifies bottlenecks such as:
  - Interference for trucks hauling up ramp meeting trucks hauling down ramp
  - Congestion around crushers and hoisting shafts
  - Limitations in hoisting capabilities
  - Layout restrictions
  - Development restrictions
- This is where dynamic process simulation comes in.



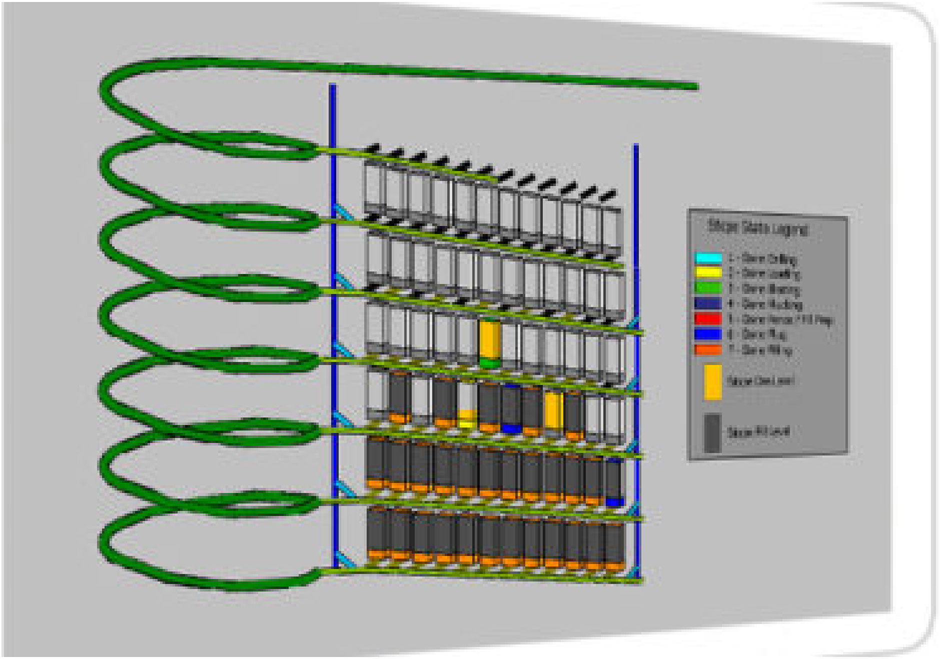
Dynamic Process Simulation

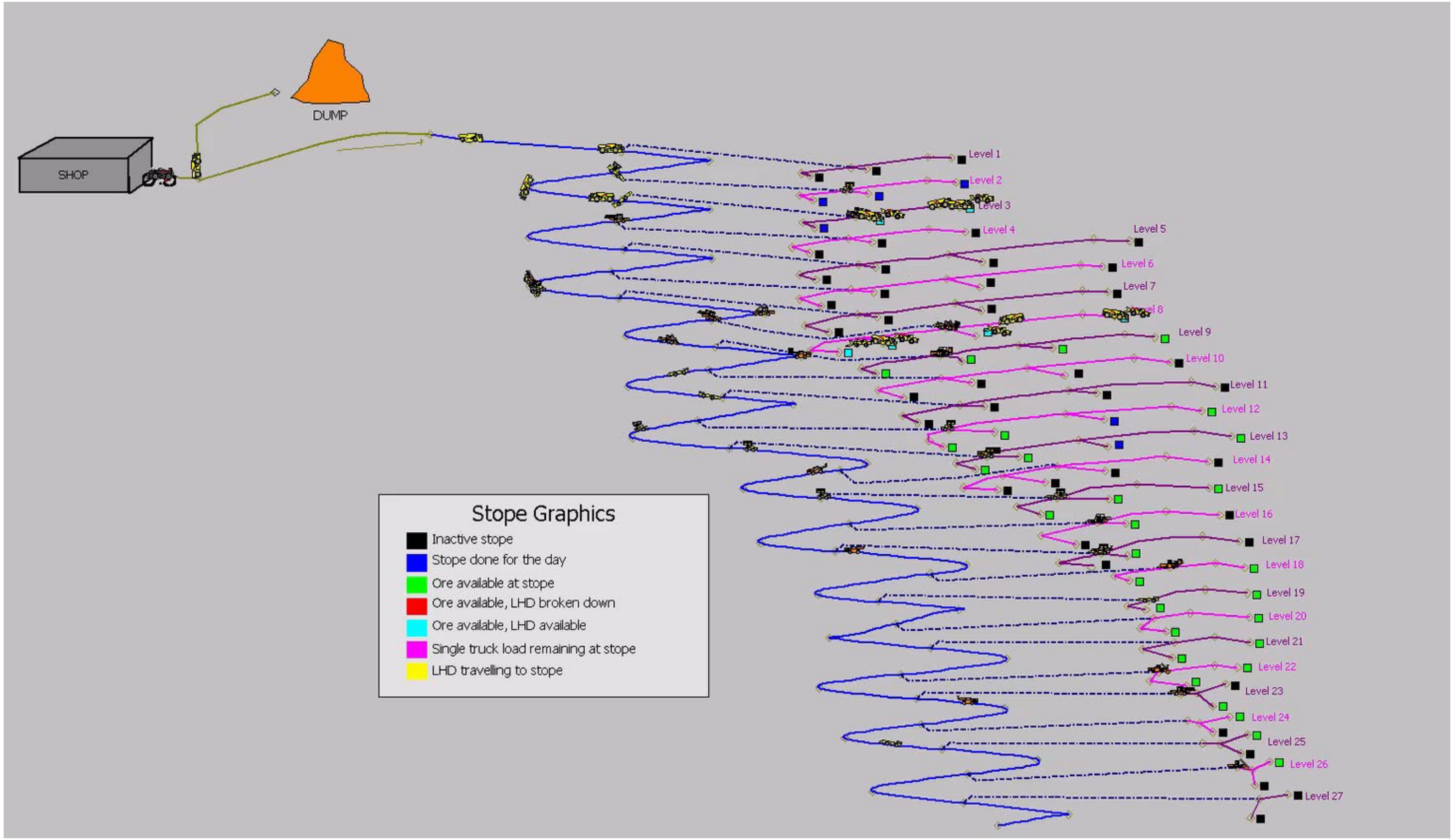
- Dynamic modelling takes a systems approach, with models accounting for interactions and interferences between all of the ore flow systems and mining equipment.
- Most projects involve studying ore and waste handling, lateral development rates, block cave or stope development, construction, production, crusher and skipping capacity, truck ramp haulage and traffic analysis, and bin and storage facility optimization.



Dynamic Process Simulation

- This modeling feeds into mine ventilation designs as the equipment fleet is optimized
  - Both for location of mobile equipment to maximize production and minimizing interferences
  - Size of diesel haulage equipment.





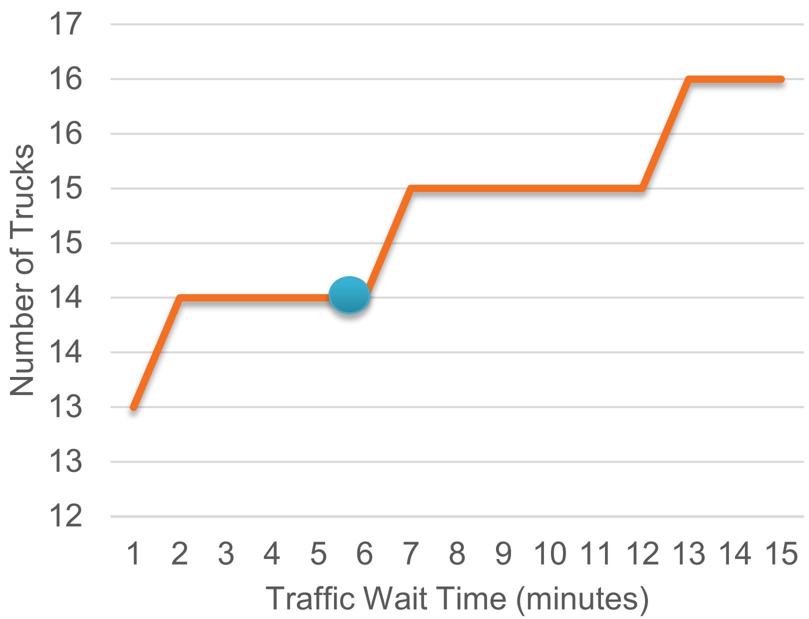
DUMP
SHOP
Level 1
Level 2
Level 3
Level 4
Level 5
Level 6
Level 7
Level 9
Level 10
Level 11
Level 12
Level 13
Level 14
Level 15
Level 16
Level 17
Level 18
Level 19
Level 20
Level 21
Level 22
Level 23
Level 24
Level 25
Level 26
Level 27
Stope Graphics
Inactive stope
Stope done for the day
Ore available at stope
Ore available, LHD broken down
Ore available, LHD available
Single truck load remaining at stope
LHD travelling to stope

Cycle Time and Understanding Traffic

Avg Cycle Times	Minutes
Driving	39.3
Loading	20.9
Wait Dump	0.0
Dumping	2.9
Wait Load	6.9
Level Traffic	1.0
Truck Cycle Time (No Ramp Traffic)	71.0
Ramp Traffic	**??**

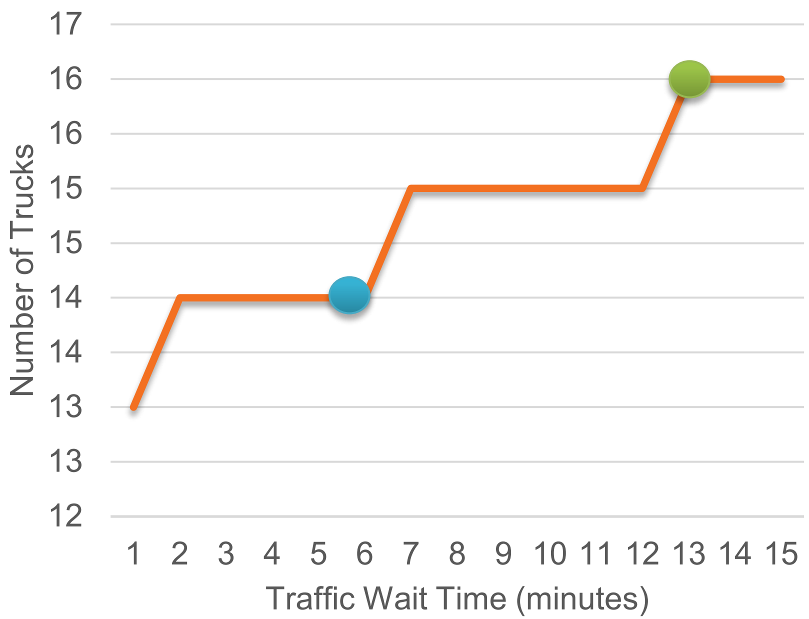
- Cycle times rely on many assumed factors
- Traffic wait time can be difficult to predict.
- Dependent on actual design of the mine and interactions between equipment.

Cycle Time and Understanding Traffic



- Incorrectly assumed 6 Minutes of wait time.
  - 14 Trucks estimated

Cycle Time and Understanding Traffic



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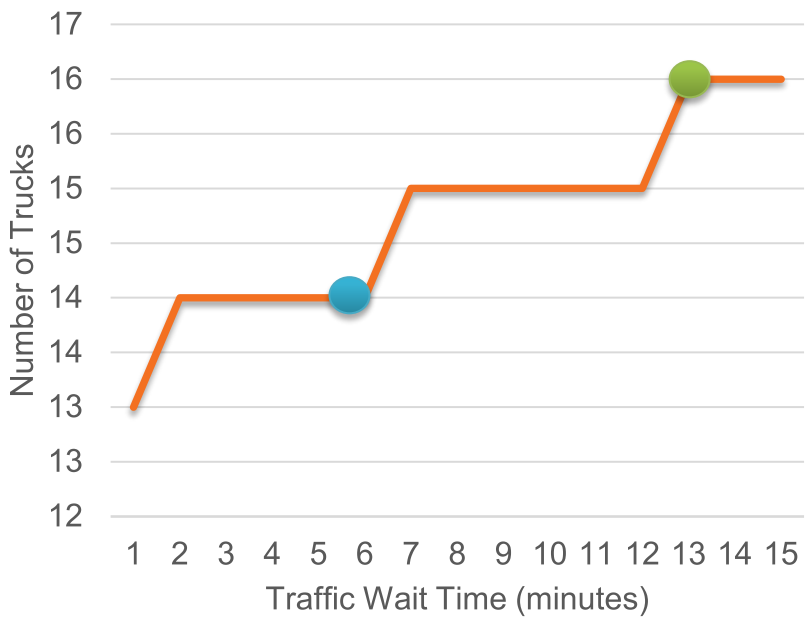
- Dynamic simulation showed more trucks required increasing traffic near 13 minutes.
  - 16 Trucks Required

Cycle Time and Understanding Traffic



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  - 14 Trucks estimated
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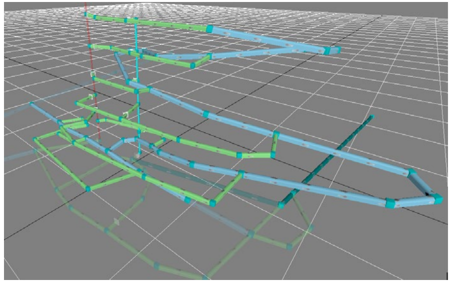
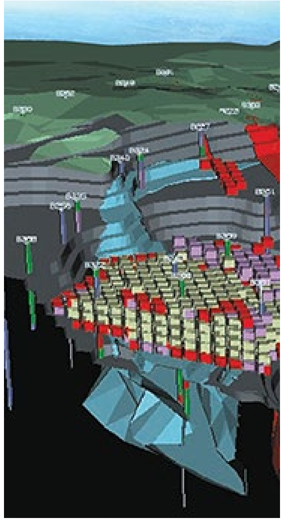
Mine Ventilation Simulation

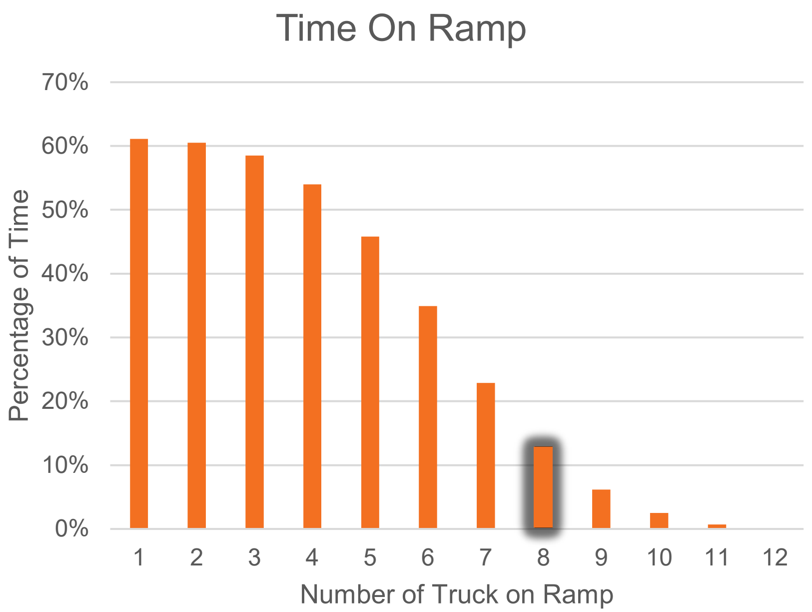
- Once the equipment fleet is optimized, the ventilation engineer can more accurately assess:
  - Ventilation demand based on equipment location.
  - Infrastructure required to support ventilation demand (e.g. ventilation raises, airflow in ramps, etc.)
- The process may iterate based on infrastructure changes for ventilation purposes.

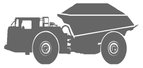


Examples of Modeling Approach



Target Ramp Airflow Based on Trucks





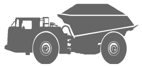
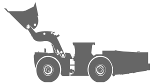
Design airflow for 8 trucks in ramp (13% of time)

192 m³/s Minimum Ramp Airflow

(8 Trucks × 300 kW × 0.08 m³/s/kW)

Overall Maximum Dynamic Airflow

Airflow factor *0.08 ($m^3/s/kw$)*

		Overall Method				Dynamic			
	Type of Equipment	**U/G Fleet Size[1]**	**Diesel (kW)**	**Airflow Utilization (%)**	**Total Airflow (m^3/s)**	Unit airflow[2] (m^3/s)	Number in Ramp	Number on Levels	Total Airflow (m^3/s)
	Haul Trucks	13	300	85%	265	24	8	5	312
	Number of LHDs	5	110	75%	33	9	-	5	44
	Drills	5	40	20%					
	Jumbos	8	45	20%					
	Explosive Loaders	6	95	20%					
	Shotcrete Sprayer	7	95	20%	77	15	-	5	77
	Grader	1	85	30%					
	Miscellaneous	15	80	20%					
	Light Vehicle	12	140	20%					
				Sub-Total	*375*			*Sub-Total*	*433*
				Leakage 10%	*38*			*Leakage 10%*	*43*
				Total	**413**			**Total**	**476**

[1]Fleet size of 14 (1 Truck on Surface)

Overall Maximum Dynamic Airflow

Airflow factor *0.08 (m³/s/kw)*

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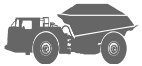
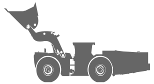
	Haul Trucks	13	300	85%	265	24	8	5	312
	Number of LHDs	5	110	75%	33	9	-	5	44
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[1]Fleet size of 14 (1 Truck on Surface)

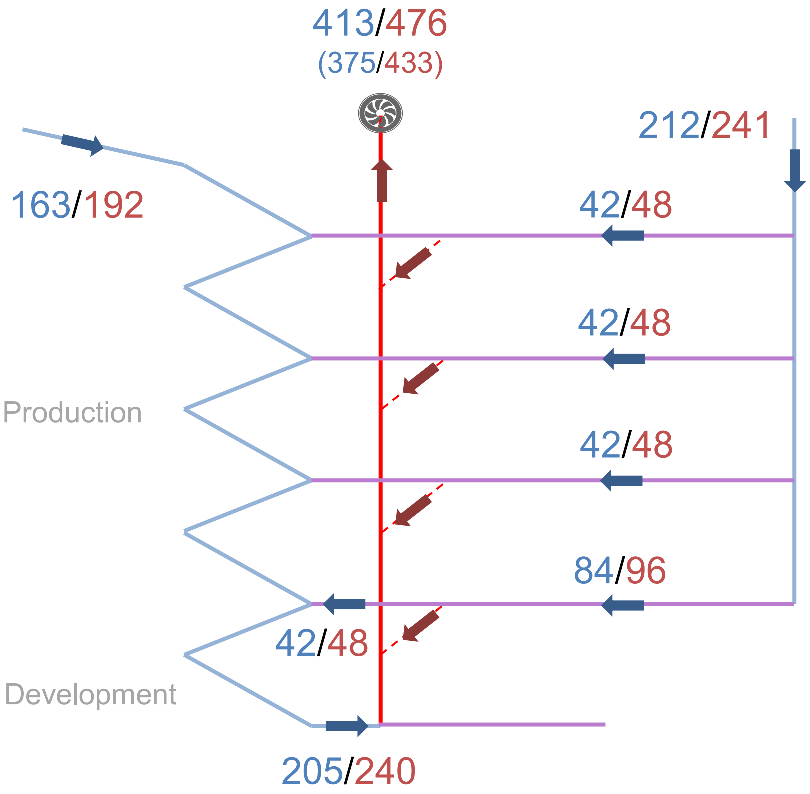
Overall List
$413\ m^3/s$

vs

Dynamic
$476\ m^3/s$

- In this case the Dynamic Simulation is about 15% higher
- Dynamic Simulation provides a higher resolution for distribution of airflow
- Aids in sizing of raises and airway profiles for velocity especially in the ramps.

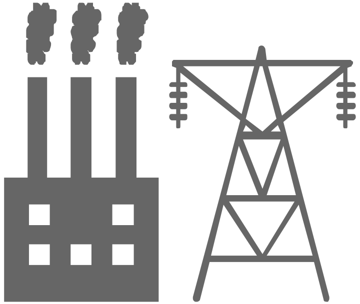
Overall Maximum Dynamic Airflow



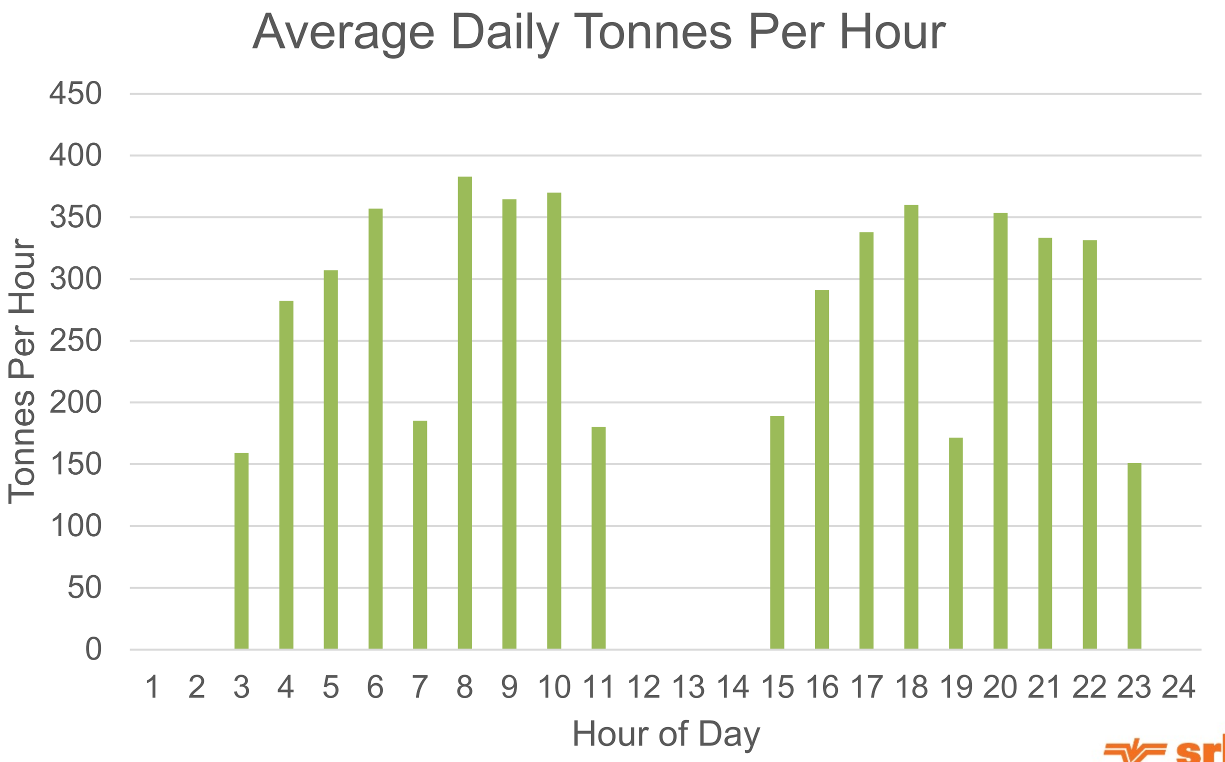
	Overall Method (m³/s)	Dynamic (m³/s)
Airflow in Ramp	163	192
Airflow per Level	42	48
Levels	5	5
Total	375	433
Leakage	10%	10%
Total Mine Flow	**413**	**476**

Dynamic Simulation and Ventilation on Demand

- Dynamic simulations can provide a reasonable estimate for amount on location of equipment throughout the mine.
- Used to better understand the power savings opportunities of VOD



Dynamic Simulation and VOD (Example)



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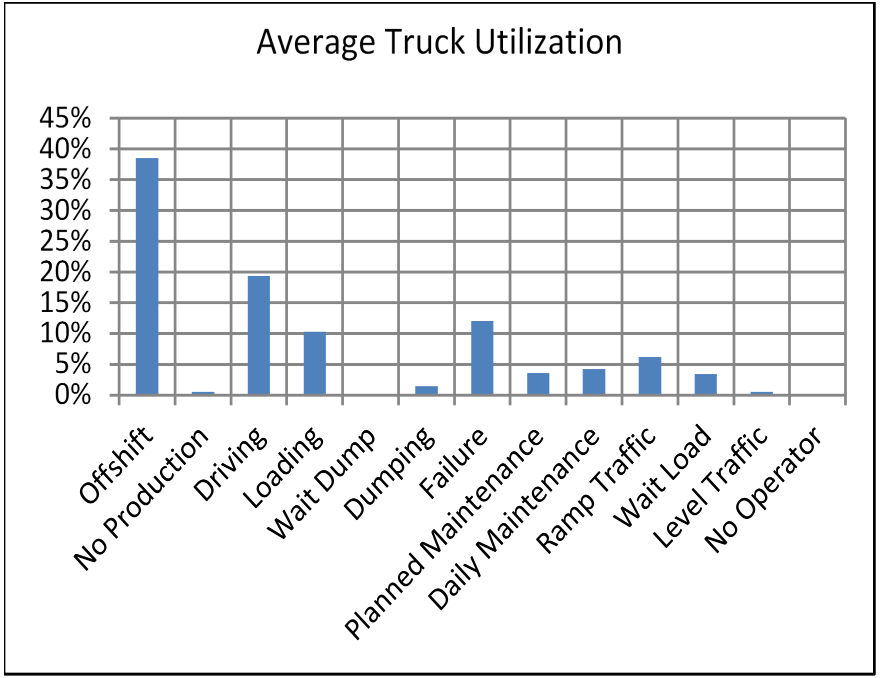
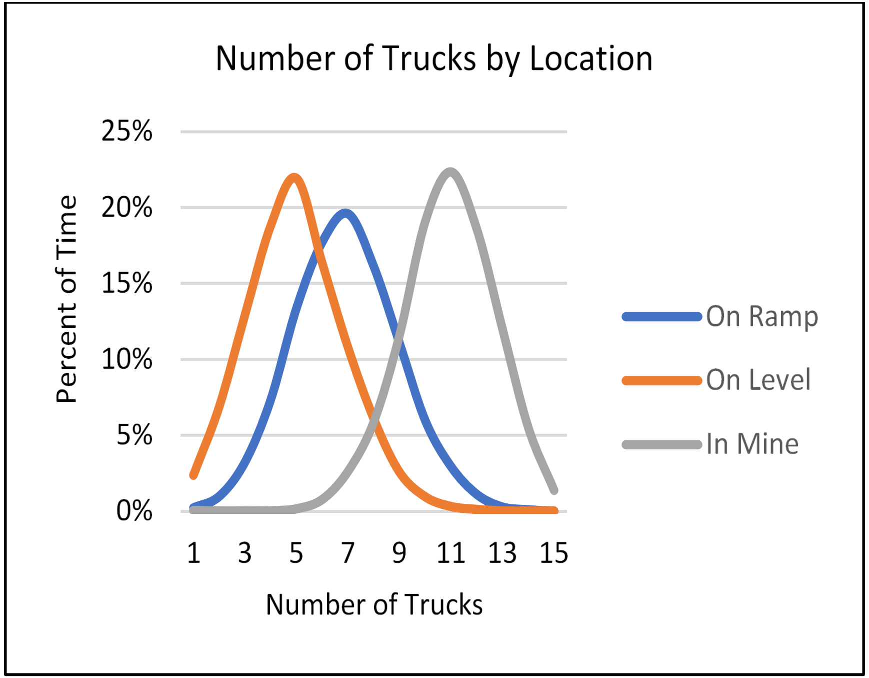
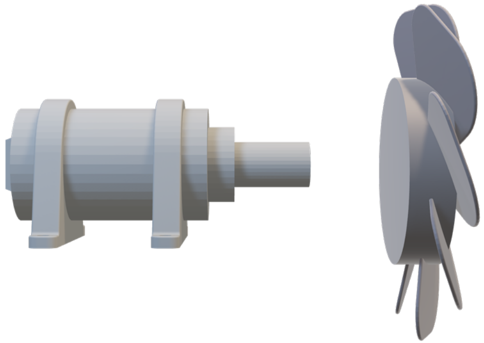


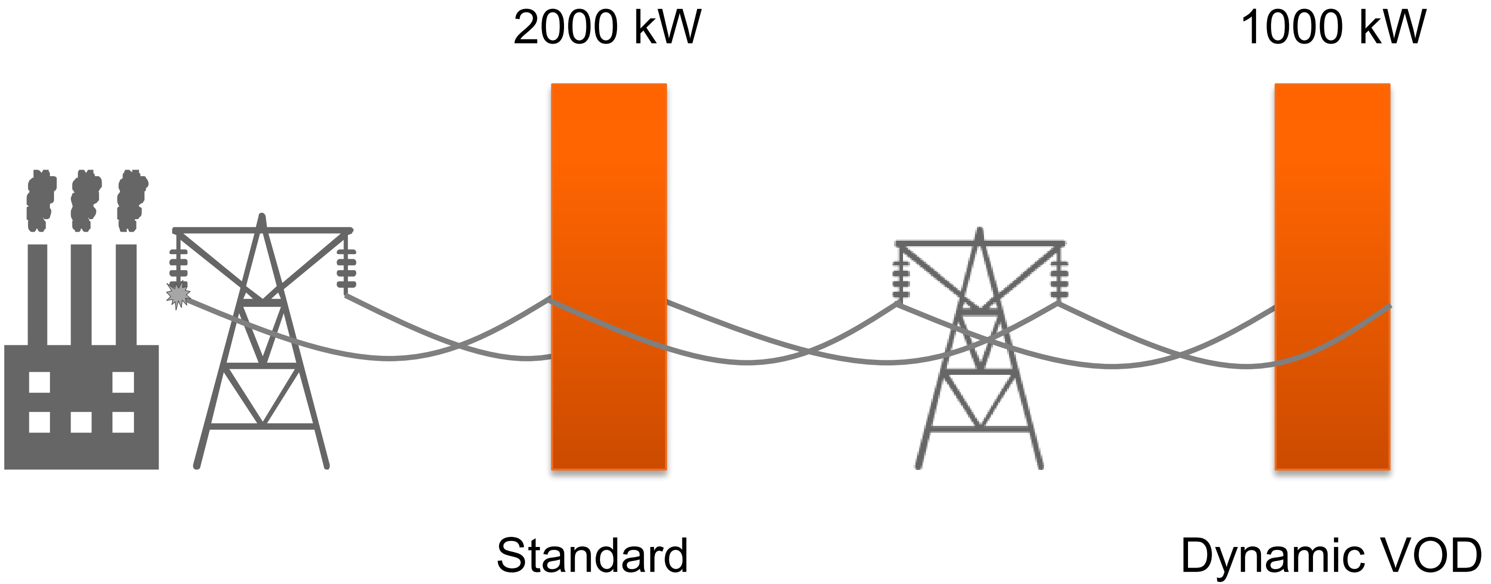


Dynamic Simulation and VOD (Example)

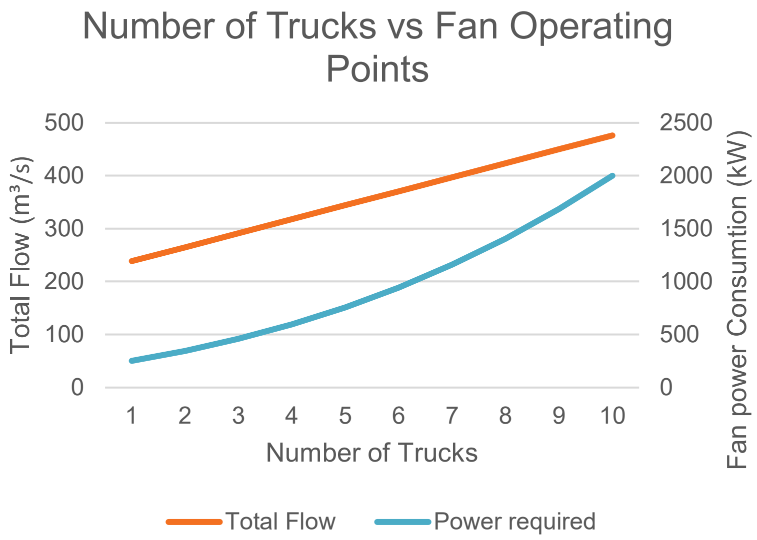


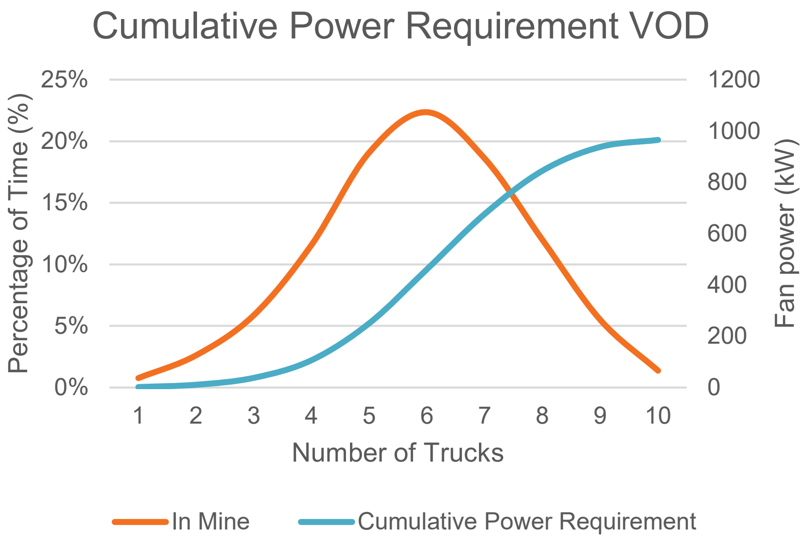
- $Power\ Consumption \propto Fan\ Speed^3$
- Assume Main Power Consumption 2000kW at 476 m³/s
- Basic example of reducing airflow based on number of trucks in the mine.

Dynamic Simulation and VOD (Example)
Average Power Demand Onshift



Dynamic Simulation and VOD (Example) Average Power Demand Onshift





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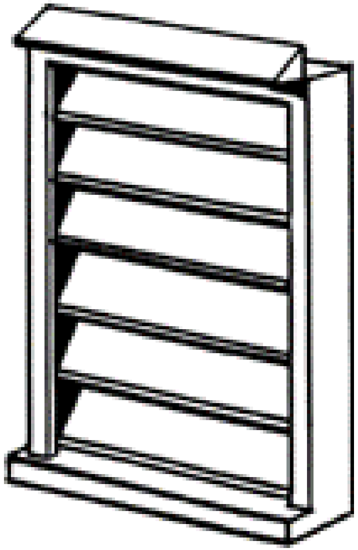
Dynamic Simulation and VOD Caveats



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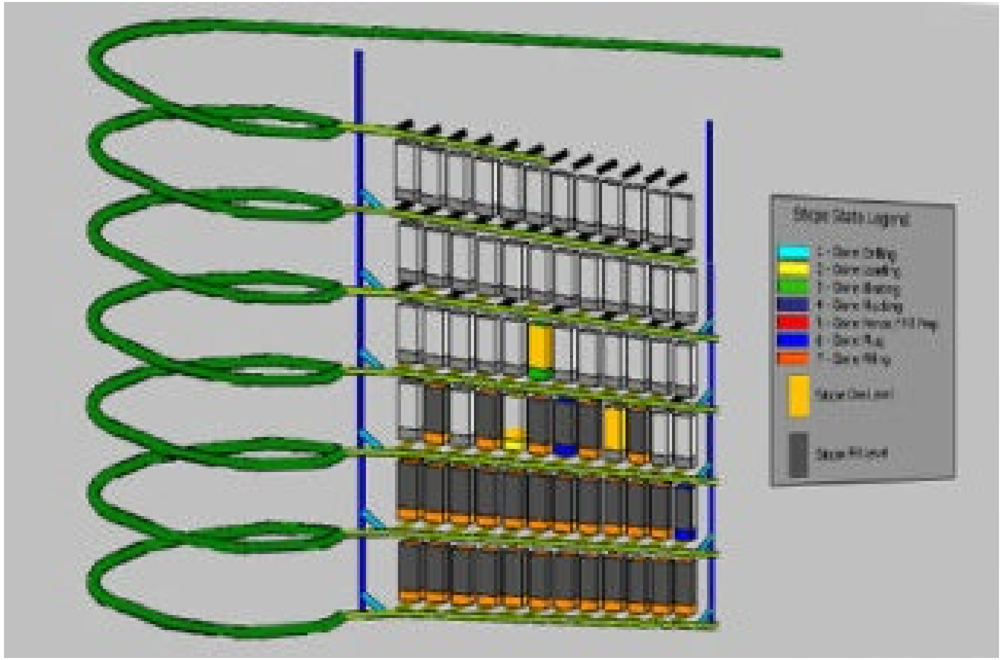
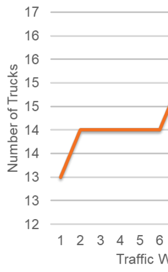
- Simplified example
- VOD is an emerging technology
- Dynamic Simulations can help provide a higher resolution to the potential in power savings.
- Need to always think of operating costs and potential downtime when implementing VOD

Conclusions

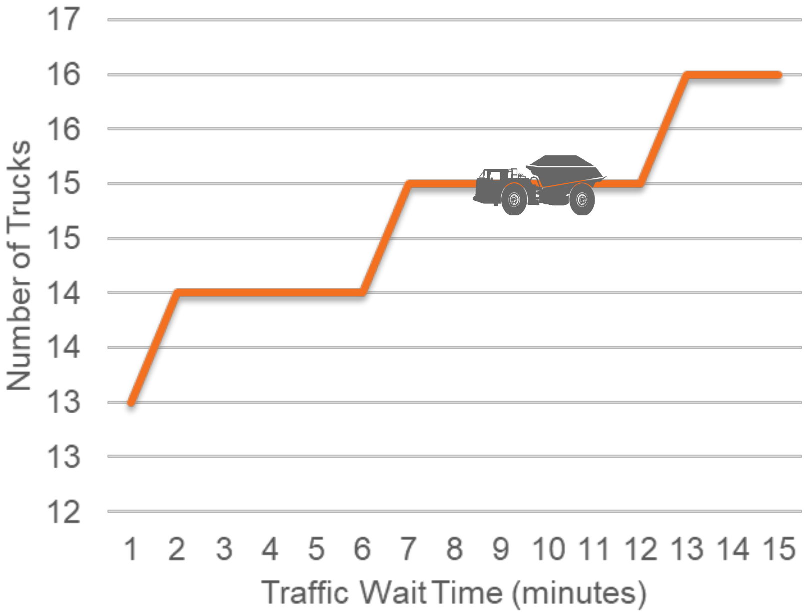
Dynamic modelling provides an accurate approach to interactions and interferences between mining equipment.





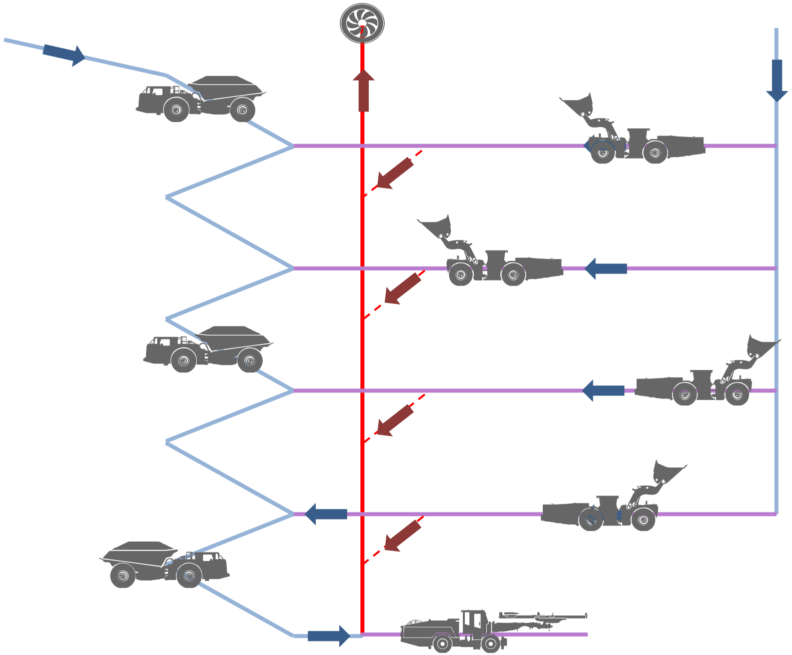
Conclusions

Modeling feeds into mine ventilation designs as the equipment fleet is optimized.



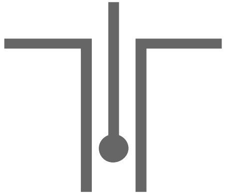
Conclusions

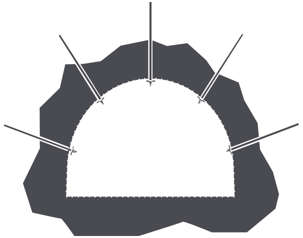
Higher definition on target airflows.



Conclusions

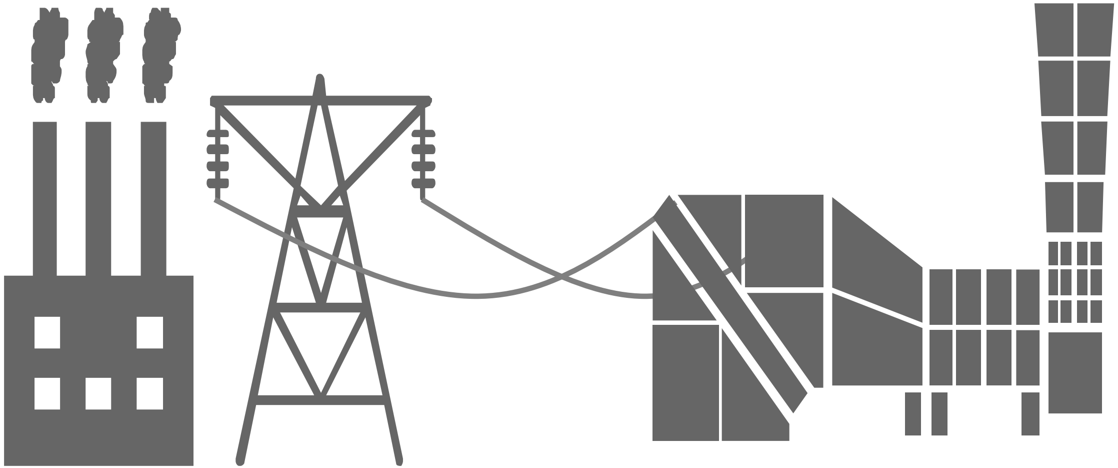
Greater levels of confidence in ventilation infrastructure sizing.





Conclusions

Can be used to estimate at a high level of confidence the potential power savings from using VOD style systems.



Questions and Comment

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