Selection of Shaft Hoisting or Decline Trucking for Underground Mines

By P L McCarthy

Introduction

- The progression from open pit mining to underground mining via a decline to shaft hoisting can be logically determined.
- The economic transition from decline haulage to shaft haulage depends on several factors, particularly the production rate and depth of mining.
- Advances in trucking technology in recent years has extended the depth of changeover from truck haulage to shaft haulage. Future advancements in trucking technology will challenge the current changeover limits.
- This presentation discusses the economic and practical parameters which determine the transition from decline to shaft haulage in underground mines.

Ore handling; decline haulage verses shaft hoisting

Decline Haulage | Shaft Hoisting
---|---
Load Haul Dump Unit | Load Haul Dump Unit
Truck | Truck
Surface Stockpile | Ore Pass
Reclaim Loader | Primary Crusher
Surface Processing Plant | Crushed Ore Storage
BROKEN ORE From Stope/draw point | Conveyor
Loading Station | Skip
Headframe Bin | Conveyer
Surface Processing Plant
Northcote and Barnes 1973

- Decline haulage with 35-40t trucks.
- Truck speed 7kph uphill on an average 1 in 10 grade.
- Mine production less than 1 mtpa.
- 12% discount rate.
- Trucking depth limit 350m if sufficient ore below 350m to amortise shaft over 15 years.

McCarthy and Livingstone 1993

- Decline haulage with 40-50t trucks (Toro 40D and Elphinstone 73B).
- Gradients 1 in 7, 1 in 8, 1 in 9 considered.
- Mine production rates 0.25 to 1.5 Mtpa.
- 10% discount rate.
- Shaft never economically justified within range considered.
- Depth and tonnage limits set by truck performance and ventilation.

Additional cost of hoisting shaft (1993 results)

DYNAMIC MODEL RESULTS
COST PENALTY FOR RAISEBORED SHAFT

![Graph showing the additional cost of hoisting shaft for different tonnages (250,000 TPA, 500,000 TPA, 750,000 TPA) over the years of commissioning the shaft.](image-url)
Moser 1997

- Survey of about 50 mines.
- Former open pits developed as declines to 600m depth and 600,000tpa.
- New mines less than 300m depth and less than 400,000tpa then decline only.
- New mines more than 400,000tpa or more than 300m deep have a hoisting shaft.


Cannington Study
Recent Truck Studies

- Callie Project (Normandy).
- Kanowna Belle Project (North).
- Ridgeway Project (Newcrest).
- General confirmation that a hoisting shaft is difficult to justify economically to depths of 800m or more and mining rates to 1.5Mtpa.
- New truck technology will potentially extend these limits or further improve the advantage of trucking over hoisting.

Haulage Options

Single Decline Truck Haulage.

- Multi-Purpose, cost effective particularly for short life operations.

Twin Decline Truck Haulage.

- Similar to above with minimised trucking delays.
- Larger possible fleet sizes and higher production rates.
- In some instances where shaft hoisting is not economically feasible, and where a single decline limits production capacity, there is an economically justifiable case for twin decline haulage.

Shaft Hoisting.

- Provides high production rates particularly from deep operations.
- High initial capital outlay.

Haulage Method Selection; Influencing Factors

- Ore reserve, production rate, mining method & ground conditions.
- Depth of orebody below surface/portal.
- The need for a decline for service access.
- Development schedule and planned mine life.
- Vertical and lateral advance rates and coverage required with respect to the size and shape of the orebody and production rate.
- The type and condition of existing infrastructure (ie exploration shafts/declines) and their potential utilisation.
- Haulage distances to the shaft.
- Ventilation requirements/capacity.

Trucking Technology

- 50 tonne payload capacity diesel trucks have become the benchmark for high production underground mining operations.
- These trucks are capable of reliably hauling up a 1 in 7 decline at approximately 9 km/h.
- Computer management systems for engines and drivelines and other advancements have;
  - Reduced fuel consumption and emissions, whilst increasing power outputs.
  - Reduced down time, increased servicing/rebuild intervals and lower operating costs.
- Future trucking improvements will include greater payloads (60 to 80t), more powerful fuel efficient diesel engines, greater ramp haulage speeds, lower down times, increased service rebuild intervals and better ergonomics.

New Generation Trucks

Representative makes and models:

<table>
<thead>
<tr>
<th>Truck Type</th>
<th>Model</th>
<th>Engine</th>
<th>Nominal Capacity</th>
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</thead>
<tbody>
<tr>
<td>Rigid Body Diesel</td>
<td>Elphinstone 73 D</td>
<td>509kW</td>
<td>52.2t</td>
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<tr>
<td>Articulated Body Diesel</td>
<td>Wagner MT5000</td>
<td>485kW</td>
<td>50t</td>
</tr>
<tr>
<td>Articulated Body Electric</td>
<td>Kiruna K1050E</td>
<td>410kW rms</td>
<td>50t</td>
</tr>
<tr>
<td></td>
<td></td>
<td>650kW (30min)</td>
<td></td>
</tr>
<tr>
<td>Diesel Ramp Truck</td>
<td>Tanrock</td>
<td>1000kW</td>
<td>80t</td>
</tr>
</tbody>
</table>
Decline Gradient

- No advantage flatter than 1 in 8.
- Modern trucks comfortable on 1 in 7, but rear-wheel drive trucks cause more road damage in difficult floor conditions.
- Articulated trucks capable of up to 1 in 5 without adverse cycle times.
- Truck maintenance costs increase steadily with increasing gradient.
- Road maintenance becomes more difficult and costly with increasing gradient and may become impractical at steep grades with water inflows.
- Safety hazard may increase with gradient.
- Some states apply shaft rules at steep gradients.

Operating Costs

Direct operating costs from first principles for fleet hauling from 550m below portal

<table>
<thead>
<tr>
<th>Make</th>
<th>Model</th>
<th>$/t</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wagner</td>
<td>MT5000</td>
<td>3.4</td>
<td>Low profile</td>
</tr>
<tr>
<td>Elphinstone</td>
<td>73D</td>
<td>3</td>
<td>Additional decline capital required</td>
</tr>
<tr>
<td>Kiruna</td>
<td>K1050E</td>
<td>2</td>
<td>Retard problems at this duty. Cost assumes very cheap grid power.</td>
</tr>
<tr>
<td>Tamrock</td>
<td>Ramp Truck</td>
<td>1.7</td>
<td>In development</td>
</tr>
</tbody>
</table>

Practical Constraints on Shaft Decision

- Environmental issues (carbon, energy etc).
- Occupational Health and Safety.
- Option for increased mining rate and depth with further discovery.

Simulation Modelling

- AMC has developed a multi-use simulation software, which is capable of modelling ‘real life’ circumstances including truck and shaft haulage systems.
- The simulation allows dynamic interaction and modelling of the entire ore handling system from the stope to the concentrator and beyond if required. Some parameters modeled are:
  Fleet size, type, performance characteristics, loads, speeds, break downs, maintenance, utilisation, delays, passing, loading, availability of ore, other traffic
- The simulation allows evaluating and quantifying of alternative mine layouts, passing bay distances, location of ore sources, ore/waste/fill tipping and sources, impact of surge capacity, instantaneous handling rates required and queuing of LHD’s.

Simulation Modelling

- Simulation allows the optimisation of each haulage function to operate on the system availability/capacity rather than its individual. Hence significant cost benefits and increased outputs can be achieved by identifying and alleviating limiting factors.
- Similarly, shaft hoisting, including any trucking and conveyor components can be simulated for optimisation of output.
Screen captures from within “Areana” a software-modelling package
Daily Ore Tonnes Hauled

Truck Fleet Availability and Utilisation