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SURFACE MINING TECHNOLOGY

MANAGING THE PARADIGM SHIFT

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Mining is essentially a materials management process where materials are classified, excavated, moved to a desired location, processed at a cost and sold for a price and hopefully, generate a profit. 'How much is that cost and can it be reduced?' is the age-old question. The requirement for a paradigm shift with regard to materials movement in search of low cost production has not just happened by chance, but rather, has been driven by agents of change that include mining companies, c ons u l t ant s , gov e r n m e n t s and equipment suppliers.

Throughout the past 100 years of mining, surface mining technology has involved humans with hand tools, humans with machinery and unmanned automated equipment. In the past 50 years, surface mining technology has evolved and now takes the form of trucks and loaders (TL), in-pit-crushing conveying (IPCC) and autonomous haulage equipment (AHS).

Trucks and Loaders

The conventional system of trucks and loaders is common in approximately 95 per cent of surface mines around the world due to strong reliability, good performance and large opportunities for economies of scale at all levels. The system is

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based on a digger unit that takes the form of a loader, excavator or shovel at the mining face loading a truck within four to six passes, that then transports material to a desired location.

The safe operating limits of trucks are determined by consideration of climate, rock properties, haulage profiles and tonne kilometres per hour (TKPH) limits. TKPH is a value based on load, speed, ambient temperatures and distance travelled. It is common practice to monitor TKPH via a dispatch system where if the TKPH value is exceeded for ten minutes, the truck will be automatically limited to a configurable top speed that allows the tyres to cool down. When the tyres return to a safe operating TKPH, a speed limiter device will disengage and allow the truck to resume its normal maximum speed.

Common practices for safe working limits of trucks are 25 km/h loaded and unloaded when travelling on ramps and around corners, 35 km/h on-bench and up to 45 km/h on flat haul profiles.

The TL system is accustomed to prolonged operational delays that include: incorrect haulage routes followed by operators, human errors with driving over windrows and production delays due to slippery roads during heavy rain or snow.

Autonomous Haulage Equipment

AHS is a technology that has advanced within the past 20 years. The concept is based on trucks operated remotely via a control system with no driver in the cab, hence equipment autonomy. The system is dependent upon an operator within the digger unit loading unmanned haul trucks which are controlled by global positioning systems (GPS) following preconfigured haul routes. For safety considerations, an over-ride mechanism is installed to allow for the remote control system to shut down a truck at any time.

Autonomous haulage trucks are equipped with a control system, a high-precision GPS, an obstacle detection system and a wireless network system that is operated and controlled via a management system enabling the trucks to be unmanned. Information on target course and speed is sent and received wirelessly from the management system to the driverless truck, while the GPS is used to ascertain their position. When loading, the trucks are automatically guided to the loading spot after computation of the position of the bucket of the GPS-fitted digger unit.

AHS technology incorporates a fleet control system that prevents collisions with other dump trucks, service vehicles or other equipment at the mining site. In the event that an obstacle detection system detects another vehicle or person inside the hauling course while under the autonomous operation, the vehicles will reduce speed or stop immediately, making the system safe and reliable.

In the case of Rio Tinto´s Australian iron ore operations; they currently have two mine sites using this technology at Yandicoogina and West Angeles operations. 290 t trucks are controlled 24 hours a day from a remote operations centre located more than 1000km from the mine site. All data from the trucks in use at the mine, including information on the location of the vehicles and their running status, can be verified via the management system. Each mining fleet within the AHS system is limited by the productivity of the digger unit, with current operations achieving up to 6500 tph.

This system is most common for mining regions accustomed to large scale bulk mineable commodities such as iron and coal that are exposed to high operating costs: such as Australia (limited skilled labour); Chile (high diesel emissions due to operating in high altitudes); and Africa and Brazil (rising material and consumable costs). There are a number of sites around the world that are currently using this system including Australia, Brazil and Chile with high production haul trucks of 230, 320 and 400 t capacity. Performance to date for AHS systems has resulted in the following advantages:

- Increased truck effective utilisations of up to five per cent
- Improved speeds within operational and safety limits (50 kilometres per hour)
- Optimised truck TKPH levels associated with increased tire life (+7000 hours)
- Reduced labour requirements (no labour for trucks, overall 35 per cent decrease in mine labour)
- Reduced safety incidents on haul roads.

In-pit-crushing Conveying Systems

In-pit-crushing conveying technology has been around for the past 35 years and is based on IPCs that have fixed or mobile locations. Fully mobile IPCC system (FMIPCC) is a system that is based on track mounted crushers or sizers. This method is suited to soft rock and often requires 30 MW of power per system.

Semi mobile IPCC (SMIPCC) employs mobile crushers that are located as close as practicable to the workface and is fed by haul trucks. Two to three benches are operated simultaneously to feed a crusher to allow for material flexibility. The haul truck distance for this system is generally within 2.5 km.

A fixed IPCC system (FIPCC) is based on permanently installed crushers. The crushers are large and have a high capacity (above 15000 tph). Crushing units feed a single conveyor that carries material out of the pit from several conveyors at once. In-pit-crushing conveying systems are inherently high capital expenditure systems and have lower operating costs due to lower energy requirements, including power and diesel emission reductions. Large haul cost reductions for this type of system often outweighs the additional crushing and conveying cost.

Conveyors for IPCC systems vary with material properties and production scales but generally allow for up to 400 mm top size material with lower sizes at conveyor transfer points. A major advantage of conveyors is that they can generate power on downhill runs, therefore reducing power requirements and inherent energy costs.

Case Study

The key drivers for surface mining technology include the following:

- Annual material movement at required product specifications
- Ore blending requirements
- Labour availability and costs
- Rock strengths
- Energy efficiency
- Safety
- Truck cycle times
- Initial truck installation is nearing end of operational life
- Minimise fleet size.

Table 1 details the primary operational parameters for TL, AHS, SMIPCC and FMIPCC systems.

A case study of a 180 Mtpa iron project based on 20 year mine life comparing TL, AHS and IPCC systems resulted in up to 33 per cent reduction in operational mining costs. Table 1-2 outlines the economic comparison of the four mining systems.

Figures 1 to 3 detail the capital and opex comparison by principle cost drivers, mining activities and life of mine expenditure.

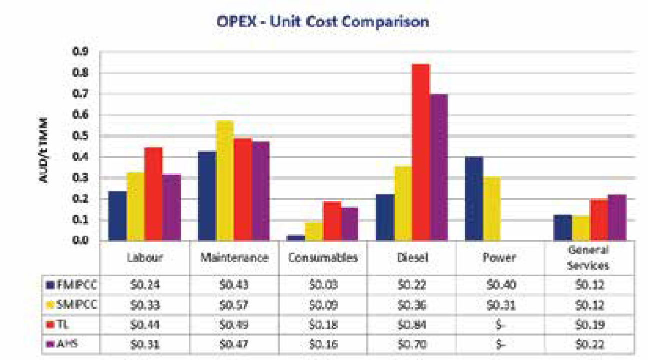
In the aforementioned case study, the annual total material movement is 180 Mtpa per annum. The economic viability for each system resulted in the following:

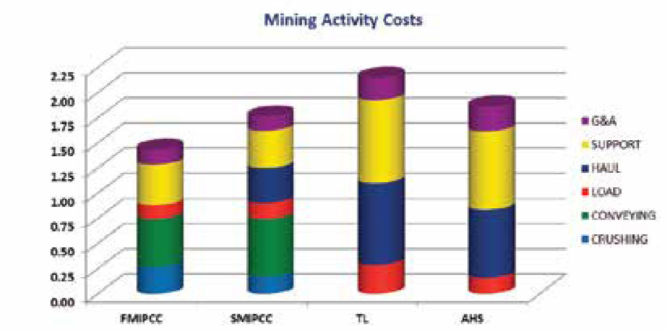
- Autonomous trucks greater than 8 year mine life.
- FMIPCC greater than 10 year mine life.
- SMIPCC greater than 12 year mine life.
- IPCC system requiring an installed power of some 60 MW, with an average consumption of 35 MW during peak operation for the case study.
- Truck cycle times below 18 minutes resulted in uneconomic application of IPCC technology.
- OPEX savings indicated potential of up to 33 per cent cost reduction using FMIPCC technology.
- overall 22 per cent total mine expenditure savings with AHS and IPCC technology
- 26 per cent energy cost reduction equivalent to 0.22 $/t TMM.
- 48 per cent reduction in manpower.
- 40 per cent reduction in ancillary fleet requirements
- initial CAPEX for IPCC and AHS systems are 20 per cent higher in comparison to TL system.

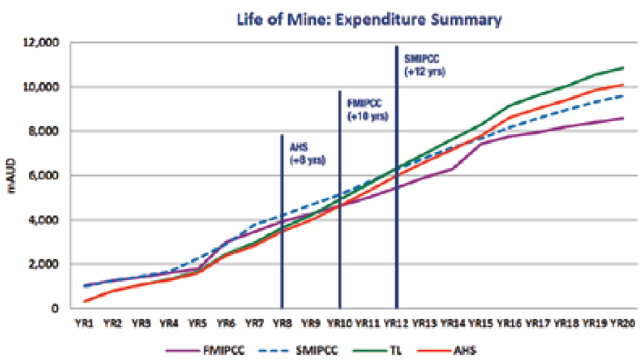
In general, for operations with annual material movement lower than 100 Mtpa, autonomous trucks and IPCC systems are more economically viable after year 15, based on current market prices and material costs.

Table 1: Surface Mining Technology Comparison

Parameters	Units	TL	AHS	SMIPCC	FMIPCC
Common SMU1	Xm x Ym x Zm	5 x 25 x 15	50 x 50 x 10	25 x 25 x 15	100 x 350 x 15
Operating Widths	m	25	50	25	100
Ramps Grades	%	8% - 10%	10%	10% - 12% - allow for truck flexibility	16% - 20%
Major Maintenance Intervals (every 10,000 hours)	Days	3	4	14	21
People per system	Qty	6	2	8 per 10km conveyor length	10 per 12km conveyor length







Risks

As part of any mining application study, a thorough risk evaluation is imperative to ensure that all risks for the project have been identified, analysed and mitigated to acceptable levels. Key risks for technology systems are:

- Operations: the ability to achieve operating hours and relocate systems in nominated timeframe I s critical to success.
- Plant: failure to achieve throughput due to rock hardness, saprolite or clay issues
- Blasting: blast damage due to flyrock. A common practice is a minimum distance of 350 m for mining equipment depending on blast and rock properties.
- Power: Supply risk for IPCC such as determination of load flow, fault and harmonic studies and branch power factors.
- GPS: network of signal technology required, further strengthened by horizontal deposits with high satellite visibility.
- Operational equipment manufacturer: supplier risks that are inherent to specific regional mining history. Current support of IPCC systems in Australia is limited and likewise for autonomous mining equipment in Africa.

For both autonomous and IPCC systems, an annual production of 20 Mtpa and above is required to achieve economies of scale.

IPCC and AHS systems are generally capex neutral over a 25 year mine life when compared to traditional TL systems whereas upfront opex savings are often realised earlier in the project, resulting in a reduced payback period.

Conclusion

Surface mine technology is consistently evolving as our industry encounters deeper deposits, mining in harsher climates, diluted grades with ever-changing rock-types and properties and is further complicated by tighter economic conditions. Managing the paradigm shift in search of operational improvements and lower cost has required many companies to retool and approach projects from a different direction with different assumptions. This difference has been enabled by surface mining technology to ensure that the 'right tonnes are delivered to the right place at the right time'.