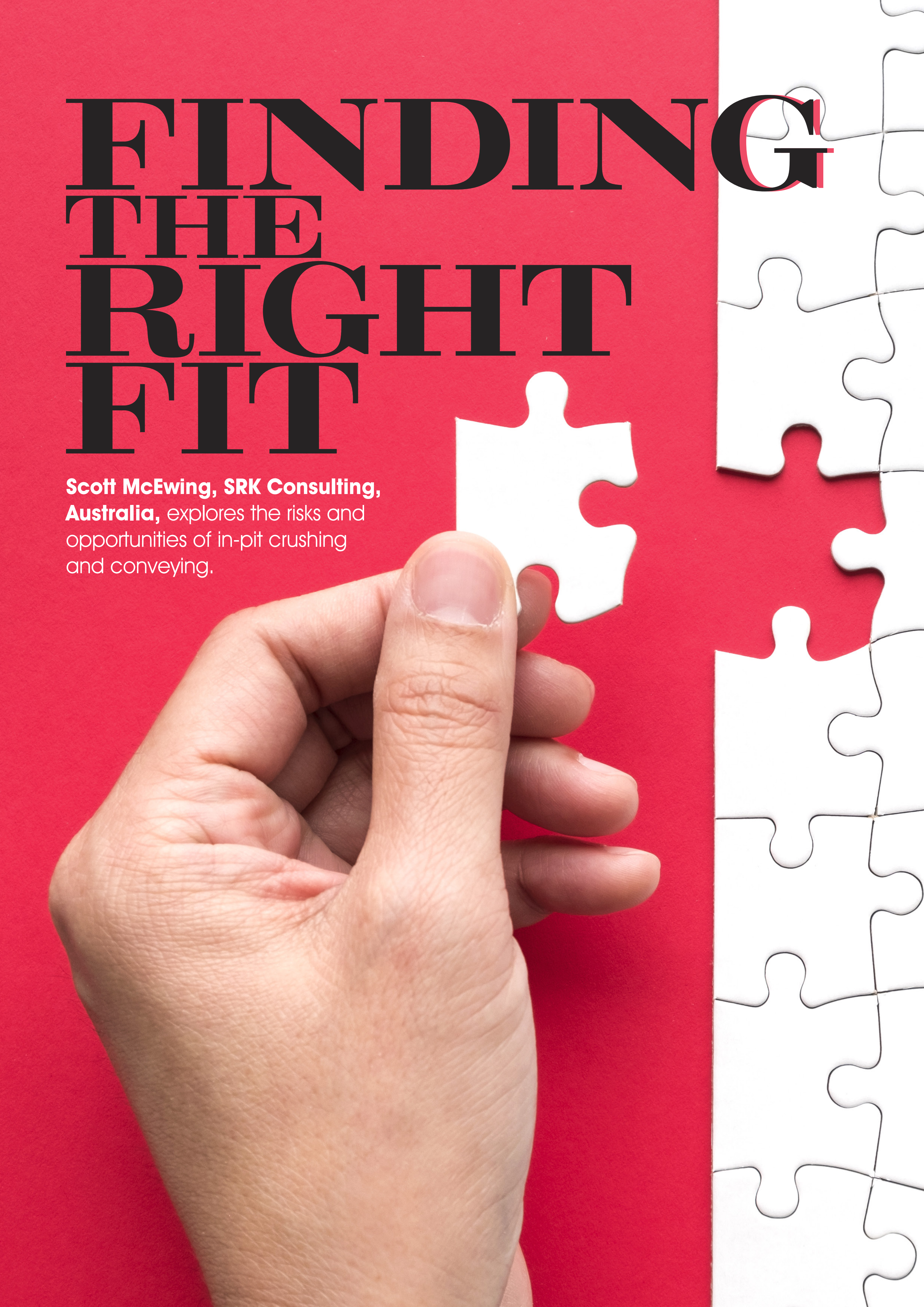
FINDING THE RIGHT FIT

Scott McEwing, SRK Consulting, Australia, explores the risks and opportunities of in-pit crushing and conveying.



In suitable mining projects, in-pit crushing and conveying (IPCC) can provide operating cost reductions to the tune of 20 - 60% savings, depending on project specifics.

For this reason, IPCC systems have been in use around the world for decades.

IPCC systems consist of a primary crusher installed in-pit, close to the active mining areas. The crusher is used to crush mined material to a suitable size for transportation via a downstream conveyor system. The conveyor then transports the crushed material out of the mine.

Material haulage is recognised as a significant contributor to both the operating and capital cost components of mining projects. In a conventional mining operation, mine haul trucks carry all the mined material within the ore pit up and out of the mine for either stockpiling, feeding directly to the processing plant, or for stowing in a waste facility.

IPCC systems allow the mine to utilise lower cost electricity and an efficient conveyor transportation system to reduce the haulage costs.

IPCC systems can be used in a range of commodities, and can be configured to suit a wide range of mining scenarios from long hauls in near surface tabular deposits, such as bauxite, coal or iron ore projects, to deep, long-life mines.

Examples of IPCC configuration include:

- Ore or waste – engineering the system to transport ore or waste, or in specific instances, both.
- Scale – applications can range in size from small-scale to suit low production quarries, or very large-scale to provide economies of scale to large-scale mining operations.
- Relocations – fixed, semi-mobile or fully mobile crusher options can be considered.

As mine trucks operate at their slowest speed on upslope/uphill ramps, the largest cost savings are usually found by minimising the vertical height that a mine truck travels. IPCC has also been used in strataform deposits, where long conveyors offer significant haulage cost savings over flat hauls beyond the efficient operating hauls of mine trucks.

Potential benefits of IPCC systems

Having an IPCC installed close to active mining areas allows the conveyor system to provide the majority of the material haulage. Consequently, a single truck carries more tonnes per hour, and fewer trucks are needed to meet the required production rate. Typically, the larger the vertical distance between the IPCC installation location and the delivery location, the larger the operating cost saving per tonne of transported material. However, there is a sweet spot where declining inventory by pit depth is offset by the savings potential.

The financial benefits associated with IPCC systems are primarily derived from the reduction in the cost of hauling material out of the pit, hence directly related to the use of electric conveyors over diesel powered mine trucks.

Additional benefits that may be realised using IPCC systems include:

- Mine operating costs decrease as the mine truck fleet size is reduced through a shorter haul. This equates to fewer operators and maintenance personnel, mechanical maintenance requirements and reduced road maintenance.

- The dependence on diesel fuel is substantially reduced with related reduced carbon emissions, depending upon how the electricity is generated at the operation.
- Potential to use renewable energy to supplement the total energy requirements.
- The systems are not generally influenced by weather conditions.
- Reduced external noise by decreasing the number of mine haul trucks operating out of the mine pit area.
- Reduced dust generation from the mine haul roads.
- Reduced water consumption by minimising the dust control required on mine haul roads.
- Additional intrinsic benefits such as improved safety and reduced environmental impact.

A key point of note is that opencast optimisation software uses the Lerchs-Grossman algorithm (such as Whittle), which only considers operating costs. Therefore, the reduction in operating costs may be sufficient to allow an open pit optimisation of the operation to support an increase in the total ore reserves.

The reduction in the number of trucks required to meet the production targets using an IPCC system leads to reductions in the number of people required onsite, from the truck operators and maintenance crews, to supervision and management roles. The mining camp can have a smaller physical, financial and environmental footprint.

Potential risks of IPCC systems

IPCC does however have downsides. For instance:

- IPCC systems can require a significant upfront capital investment, which often does not align with minimising the overall project capital.
- Detailed mine planning and operational management is required to maximise the potential benefits. This reduces operation flexibility and can work against maximising net present value (NPV).
- In-pit infrastructure footprints can be large and result in additional stripping costs, and can interfere with future cutbacks.
- The utilisation of an IPCC system can be relatively low where stockpiling and reclaim is not possible.
- System downtime results in a complete loss of production.
- It is often difficult to present a commercially viable alternative case for IPCC systems against an advanced project when limited to using the pre-selected infrastructure and mine planning.
- IPCC systems are not ideally suited to operations which are mining from multiple locations.
- The basis for operating cost savings is dependent on access to a cost-efficient and adequate supply of electrical energy.
- Sweet spots between production rates and capital costs do not necessary align with other project objectives.

Capital cost

Often, the greatest challenge in considering an IPCC system is the upfront capital cost. The capital costs of mining projects are often scrutinised in the feasibility study stages as owner's target capital cost minimisation strategies and aim to improve the projects payback and NPV.

This often works against IPCC considerations, which usually require significant upfront capital as part of a longer-term investment. IPCC infrastructure can be designed for a 20 year operating life.

Key IPCC capital cost centres include:

- Mechanical infrastructure.
  - Crushers.
  - Conveyors.
  - Stackers.
  - Electrical (transformers and electricity reticulation).
- Earthworks/civils.
  - Crusher pockets.
  - Reinforced rock walls.
  - Foundations.
  - Footprint of the crushing area to allow for turning and dumping areas for trucks and maintenance services in-pit.
  - Earthworks required for the conveyor routing.

Depending on the planned use and configuration of the IPCC system, a proportion of the capital cost can be offset by other cost reductions. For example, in an ore-focused IPCC system the crushing component of the IPCC may be viewed as a relocation of the primary crusher into the mine.

A further offset exists with the reduction in capacity required from the mine truck fleet. Depending on project specifics, significantly fewer trucks may be required with an IPCC system.

Mine planning requirements

A range of infrastructure and associated configurations need to be considered as part of an evaluation. Due to the range of options that need to be considered, as well as the cost implications, the best time to consider IPCC is at the feasibility stage of a project.

It has been noted that the flexibility of a conventional drill/blast, load and haul mining operation can often mask poor planning practices. For IPCC systems conversely, a robust and relatively rigid mine plan is required. IPCC systems are inherently less flexible than the well proven mine haul trucks used in most operations. This lack of flexibility can negatively impact the ability to meet the changing operational requirements of a mining project, such as blending at the mine face to meet a product specification. IPCC installation locations, mine development and progression need to be examined in detail. If incorporated into the design, IPCC installations can be relocated to maximise the haulage benefits in an advancing mine, but must be planned well in advance.

IPCC systems often favour large, deep and long-life pits with extensive hauls, although this is dependent on site-specific factors. An exception to this guidance occurs with quarries, where a long-life quarry utilises a small-scale IPCC system to reduce the operating costs over an extended project life. Mining from multiple discrete locations is not an ideal use of IPCC, which typically favours one source of material and one material destination.

Operating costs

The potential cost savings from IPCC are largely based on electrical energy being cheaper and more efficient than diesel fuel, and the related reduced dependence on mine haul trucks.

Conveyors are more efficient than trucks, in that a truck needs to move the mass of the truck when both loaded and returning empty. The conveyor only moves the belt on low friction pulleys and the material on the belt.

The operations' labour requirements are also reduced with fewer operators, maintenance crew and related roles in an IPCC scenario. The IPCC and related infrastructure will require additional personnel, including operators and maintenance personnel, but the total project labour costs typically reduce.

Ore or waste haulage?

The majority of IPCC systems operating around the world are using ore systems. As noted previously, in this scenario the primary crusher can often be considered as relocated from a location adjacent to the process plant to installed in-pit, avoiding the expense of an additional primary crusher. If this approach can be developed as part of a mine before the commissioning, the capital cost of the IPCC is lower as the primary crusher was always needed.

Conversely, when designing an overburden or waste-focused IPCC system, the crushing plant is designed to minimise the operating cost of the combined IPCC system, i.e. the waste is crushed only to a size suitable for the conveyor. A limited number of operations are utilising IPCC systems in this way to deliver a low operating cost waste stripping solution. These operations are generally high strip ratio operations.

As conventional truck haulage operations do not need to crush the waste, in the context of an IPCC system, additional capital and operating cost are invested in the waste with the view of total project cost minimisation. Amortising the capital cost of a primary crusher for the waste haulage slows the payback and could potentially reduce the NPV.

Crusher relocations

The primary crushing system can either be a mobile, semi-mobile or a fixed installation, depending on the required frequency of crusher relocations:

- Fixed crusher location, where the location is set for the life of the operation.
- Semi-mobile crushers can be relocated infrequently closer to the mining face to maximise haulage savings.
- Fully mobile crushers are loaded directly by the production machines.

In the case of a fixed or semi-mobile installation, material to be transported out of the mine is delivered by a traditional mine truck and shovel fleet from the operating face in the pit to the crusher. The material is then dumped from the mine trucks into the crusher where it is broken, before being transported out of the pit by a single conveyor or sequence of conveyors.

Fixed and semi-mobile crushers benefit from the flexibility of having the truck fleet between them and the mining face. The operation largely retains the ability move production and blend as needed.

Fully mobile IPCC systems can eliminate the mine truck fleet altogether by allowing material excavated by the excavator or shovel directly into a hopper that feeds the IPCC system. The mobile crushers are usually installed with a track undercarriage and are connected to a main conveyor system with a network of mobile conveyor components, such as mobile conveyors, belt wagons or a mobile bridge conveyor.

Excavator or shovel moves need to be well planned for this type of application to work in practice. Fully mobile systems can only mine what is available to them, and have reduced flexibility to move if production requirements change. The potential operating costs savings are maximised as the number of mine trucks are reduced.

Crusher configuration

The function of the crusher in an IPCC system is primarily focused on reducing the product size to that suitable for conveying. In the case of an ore-focused system, the crusher may also be the primary crusher for the processing plant, and hence be set-up to produce a fraction size suitable for the downstream mills.

The type of crusher selected for an IPCC system depends on a number of factors, including:

- Required production rate.
- Material properties including hardness and abrasiveness.
- The required crushed product size.
- Mobility.

Different crusher configurations offer different challenges to relocating the crusher and suitability to crushing certain material types.

The largest and highest throughput crushers for harder materials are gyratory crushers. These require large installations and are correspondingly more complex to relocate. Gyratory crushers are not considered suitable for fully mobile applications, but can be engineered to be relocated with appropriate foundations and modular installations.

More compact crushers, such as small jaw crushers, are often used in small capacity, fully mobile systems.

Modern crusher designs, such as double roll and mineral sizer type crushers, benefit from smaller dimensions and higher throughput. There are compromises in material suitability however, and hence are not ideal for all material types. The new crushing technologies offer potential for large-scale, fully mobile IPCC systems with production rates in excess of 6000 tph.

Conveyor configurations

The conveyor configuration can create significant logistical challenges. A fundamental rule of thumb for conveyors is to keep them as short and straight as possible. The number of discrete conveyor sections should be kept to a minimum, as each introduces its own mechanical availability factor that in turn lowers the systems combined mechanical availability.

Typically, there is a main or incline conveyor, the longest conveyor that transports the broken material out of the mine. There are likely to be several shorter conveyors connecting the crushing plant to the incline conveyor.

The conveyors can be aligned to either follow an existing haul road, or have a steeper alignment to minimise conveyor length. Conventional conveyors can operate at angles approaching 20˚, but as this is flatter than typical pit walls, it introduces the need for additional earthworks to create an alignment. This can take the form of a conveyor slot or cutback.

Alternatively, a conveyor tunnel approach moves the incline conveyor largely underground and out of the operating pit. The conveyor can then be installed on the backs of the tunnel or on conventional frames to the floor.

High angle conveyors (HAC) are a relatively new development that provide an interesting alternative to conventional incline conveying systems. There are a range of solutions including sandwich and bucket style conveyors that allow the conveyor to operate up steep slopes. A HAC can mitigate the need for the earthworks associated with providing a flatter slope to install a conventional conveyor.

HACs do, however, face limitations of scale and capital costs. The current HAC technology cannot meet the production rates possible with conventional conveyors, but this constraint should improve as the technology matures.

With a fully mobile conveyor system, more conveyor components are often required to link the crusher to the incline conveyor. There are many approaches to this, and these can reduce the mechanical availability.

Discharge systems

Once the crushed material is delivered to the pit crest, the next consideration is stacking or other discharge systems. These systems add additional capital and operating costs and operational complexity. Systems can range from simple conical stackers to crawling slewing stackers. The choice of system will be influenced by the need for stockpiling of ore ahead of the plant, or in the case of waste handling, the need for rehandling or direct disposal with a crawling stacker.

Conclusion

The key value drive for IPCC considerations is the reduction in haulage costs due to electrification of the conventional haulage by using the conveyor systems. The relative price of electricity is an important aspect in accessing the financial viability of IPCC systems.

The reduction in operating costs may be sufficient to allow reoptimisation using the Lerchs-Grossman algorithm, resulting in material increases in the ore reserve estimates and subsequent project life.

The key risks deriving from the upfront capital costs, the loss of operation flexibility and the relatively low utilisation hours expected from an IPCC system must be taken into consideration.

The range of scale options and applications for IPCC is broad, but successful IPCC implementation relies on a relatively long project life to amortise the capital costs. Analysing the relationship between capital costs and production rates is also key to identify potential sweet spots where targeted production requirements align with infrastructure and capital or operating costs.

The ideal time to consider an IPCC system is at the early stage of project development. This does not mean that an operating project will not benefit from IPCC, but often there are additional challenges that need to be overcome in established operations and mine plans.

IPCC systems are best suited to projects over a long life, those requiring long hauls of >7 km flat or >150 m deep, and those with production rates between 2 - 50 million tpy. There are, of course, notable exceptions and each application needs to be considered against site specific requirements. GMR