Abstract

With the rapid increase of fuel prices in the last two years, there has recently been reconsideration of the application of crushing and conveying in open pit mines. This presentation examines their potential role in hard rock base metal and gold mines.

The fundamentals of pit development are considered and comparative cases examined relative to conventional shovel-truck operations. The application of fully mobile in-pit crushing systems is analyzed in terms of bench operations and their impact on mining costs and mine development. As an alternative, semi-mobile crusher options are compared.

The presentation identifies the applicability and economics of in-pit crushing and conveying systems in large open pit pushbacks and discusses alternative layouts and configurations.

About the authors

David Tutton is a mining engineer with 33 years mining experience in open pit operations with an emphasis on mine planning. Willibald Streck is a mining engineer with 50 years experience in surface mining materials handling technologies. Both are independent mining consultants based in Germany.

Introduction

Since the early sixties, there has been optimism that trucks in large open pit mines would be replaced by belt conveying systems, resulting in improvements in terms of economics and, more recently, carbon emissions. In the last five years, these developments have become more interesting due to the highest oil price in history, and this has led manufacturers to design a number of alternative systems. Consequently, there has been a "new focus on IPCC (in-pit crushing and conveying) systems" and this is one of the focal areas of this congress.

Despite this increased interest, in-pit crushing has had limited or no success in deep, hard rock open pit mines, and trucks have continued to find application as they get larger and pits deeper. While ore crushing has been used in specific conditions, few mines have successfully and economically implemented waste crushing.

The authors of this presentation come from two different directions: one from the planning of deep, hard rock open pit mines, which are specifically targeted here, and the other from the design and application of continuous mining systems. The presentation revolves around these two counter-view points and will attempt to stimulate discussion on how the industry can plan conveying systems in deep, hard rock open pit mines while at the same time maintaining the primary objective of maximization of Net Present Value (NPV) and returns to the stakeholders.

Transportation costs

Transportation costs have always been a significant part of large open pit mining capital and operating costs. This is illustrated in figures 1 and 2, which are typical open pit project capital and operating cost distributions for a large deep open pit mine using conventional shovel-truck mining methods. Transportation costs are very variable depending on pit configuration and geographical location, but the haulage component is almost always above 45% of operating costs on a life of mine basis and about 40-50% of capital costs.
If we examine the transportation cost component further and focus on those costs associated with moving material uphill, it can be seen that typically the uphill represents 40-50% of overall haulage costs. It should be noted that these examples from mines and projects in North America and Chile are based on 2009 conditions and mine capacity is in excess of 500,000 tonnes per day using ultra class haul trucks of 300 to 360 metric tonne capacity.

The key cost drivers impacting transportation costs in these operations are fuel, equipment and parts costs, tyres and labour cost as shown in the break-up in figure 2. Fuel represents over 50% of total haulage costs. These costs have increased rapidly in the last five years as can be seen in figure 3, which shows relative inflation for key cost drivers in Chile.
Electrical power costs have also increased substantially in a number of countries, with a tendency to follow, but lag behind oil price increases. Fuel price has tripled since 2000 and that of electrical power has doubled. In the same period, relative total open pit mining costs have increased by 125%.

The conclusion of this simple cost analysis is clear: there is a strong motivation to look to more energy- and cost-efficient transport systems, specifically in the vertical haul component.

Development of large open pit hard rock mines

To comprehend how more energy-efficient haulage systems can be applied in this type of mine, one needs to understand the way they are developed. NPV is the primary objective, and the economics of large open pit hard rock mines is driven by two key phrases – “mine the next best ore” and “delay waste as long as possible”.

On this basis, most large open pit mines are developed as a series of phases or pushbacks (also called expansions), which initially develop the most economic material and then expand outwards as a series of phases showing incrementally lower economics. Each of these phases will generally have its own access system or will link to the access system of a previous phase. In addition, it will have adequate width and length to support the productive capacity of the phase. This is standard practice in large porphyry copper mines, gold operations and many others. If open pit operations were not developed in this way, many would be uneconomic.

Large open pits may be developed in 10 to 20 phases. Some examples of typical phase mining are shown in figures 4 to 6. At any point in time, a mine’s production may come from three to five active pushbacks with typically one pushback well established in ore, a second in a mixture of ore or waste, and the others in different stages of phase development. This is illustrated in figure 4.
With large capacity mines using electric rope shovels of >50m³ capacity, typical widths of pushbacks are two to three loading widths or 120 to 200m. Vertical development is frequently high (depending on the orebody configuration) with typically five to ten benches exploited per year in an individual pushback. This often results in short pit wall permanence and a strong interaction between pushbacks. Ore exposure and the balance of the mine plan are critical, with any waste backlogs strongly impacting available ore, i.e. a policy of “just in time” is frequently applied to waste development.

As can be seen in figures 5 and 6, it is not uncommon that one mining pushback may include three or four loading machines.

![Figure 5 - 200m ~300 kt/d pushback at Escondida. (Photo by author - 2002) In this case a shallow inter-ramp slope results in limited phase interaction. Three shovels are deployed with spare loading positions.](image1)

![Figure 6 - Palabora south pushback - Four shovels deployed (5 in photo) (Photo by author - 1983) In this case a steep inter-ramp angle results in strong phase interaction and mining is configured so as to minimize spillage.](image2)

Such equipment deployment requires high levels of efficiency, has limited flexibility and requires strict short-term mine planning. In many cases, there are both conflicts between activities and competition for bench area with respect to the drilling, loading and hauling processes. What can be seen clearly from the figures above are the conflicts of “real-estate” and the flexibility required in haul road access. This is discussed further below.

With large open pits often mining in excess of 700m depth, the lateral extents become large and phase development moves spatially with time. A good method of examining this trend and the potential benefits of in-pit conveying systems are “bubble plots”, showing for example ore tonnes times vertical
meters; the larger the bubble, the greater the IPCC potential. This is illustrated in figure 7 where bubbles are colour-coded to represent time.

The centre of gravity of the pushback moves significantly with time and often most potential benefits occur late in the mine life or routine relocation of any system would be required.

By mining phases at a lower development rate (i.e. two shovel deployments or reduced production rate), NPV is reduced. To illustrate this, the ore/waste distribution of a typical phase in a large copper mine is taken as an example, with simplified scheduling comparing four full shovels deployed and two shovels in initial stripping. To illustrate NPV, simplified and typical economic parameters are assumed. This is shown in figure 8.

In these illustrations, ore is shown in orange, waste in green, shovels deployed are black, and the sinking rate is blue. The lost value by the reduced shovel deployment and sinking rate is 46% less than the four shovel case, i.e. this example is used to show that in a typical ore/waste configuration, if phase development rates are impeded, value will be lost.

Figure 7 - Bubble plot analysis of ore tonne vertical meter for two typical large copper open pit mines

Figure 8 - Evaluation of the impact of shovel deployment (and sinking rate)
The challenge

So what does the mine development require from an alternative transport system?

- A reduction in vertical transportation costs
- A reduction in carbon emissions
- Maintenance of the general philosophy of phase/pushback design
- Potentially high vertical development rates
- Potentially high pushback productivity, and, most importantly,
- The maintenance of mining flexibility such that
  - Blending constraints can be achieved, and
  - Excavated material can go to a number of destinations for both ore and waste.

Alternative crushing systems

Conveyor transport requires a smaller size distribution than truck haulage. While some marginal ores may be processed by dump leaching without crushing, the majority of ore mined for conventional processing generally requires crushing. On this basis, it is logical to consider that the primary crusher may be located in the pit in order to condition ore for conveyor transport.

Waste, on the other hand, does not require crushing for truck transport, but does require a size reduction for conveyor transport, and this is an additional cost burden of waste conveying.

The major emphasis of this presentation is the conveying aspect, but a short description of alternative crushing systems is provided in figure 9. Major differences are mobility, feed hardness and capacity, with fully mobile units generally having lower capacity and feed hardness capability.

<table>
<thead>
<tr>
<th></th>
<th>High capacity</th>
<th>Typically gyratory/jaw crushers</th>
<th>Rarely relocated</th>
<th>Commonly associated with transport tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi-Fixed</td>
<td>High capacity</td>
<td>Typically gyratory/jaw crushers</td>
<td>Relocations every 3-5 years</td>
<td>Commonly associated with transport tunnel or wide truck ramp</td>
</tr>
<tr>
<td>Relocatable</td>
<td>Medium capacity</td>
<td>Typically Twin roll crushers or sizers</td>
<td>Relocations every 6-18 months</td>
<td>Multiple crushing stations with conveyor ramps and conveyor distribution point</td>
</tr>
<tr>
<td>Movable</td>
<td>Medium - low capacity</td>
<td>Typically Twin roll crushers or sizers</td>
<td>Relocations as required to follow shovel</td>
<td>Commonly feeds onto bench conveyor or conveyor bridge</td>
</tr>
</tbody>
</table>

Figure 9 - IPCC crushing systems
A key parameter to mobility is material hardness, and this can prevent application in hard rock open pit operations.

**Alternative conveying systems**

The conveying system has most impact within the open pit environment due to the space required for installation, its permanence, low mobility and its impact on other unit operations. While fixed conveying systems are frequently with fixed crusher installations, more mobile systems have found limited application in large hard rock open pits, and a greater emphasis is put on this type of system in this analysis. A comparative list of conveyor types that could be considered is shown in figure 10.

<table>
<thead>
<tr>
<th>Type</th>
<th>Typical capacity (t/h)</th>
<th>Typical speed (m/s)</th>
<th>Typical width (mm)</th>
<th>Comments</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed</td>
<td>5-12</td>
<td>4-6</td>
<td>1800-2400</td>
<td>Tunnel, covered or open, No Flexibility</td>
<td></td>
</tr>
<tr>
<td>Relocatable</td>
<td>5-12</td>
<td>4-6</td>
<td>1800-2400</td>
<td>Poor flexibility, High relocation costs, Stoppage of on month for relocation</td>
<td></td>
</tr>
<tr>
<td>Shiftable</td>
<td>5-12</td>
<td>4-6</td>
<td>1800-2400</td>
<td>Portable or crawler mounted drive stations. Medium flexibility but impact on other unit operations. Frequent downtime for conveyor shifting</td>
<td></td>
</tr>
<tr>
<td>Crawler mounted Piggy-back</td>
<td>2-4</td>
<td>3-4</td>
<td>1200-1800</td>
<td>Fewer relocation times, multiple systems, interruptions at transfers. Common in leach operations</td>
<td><img src="image1.png" alt="image" /></td>
</tr>
<tr>
<td>Tyre mounted Piggy-back</td>
<td>0.5-2</td>
<td>3-4</td>
<td>1200-1800</td>
<td>Application in quarries. Good floor conditions required</td>
<td><img src="image2.png" alt="image" /></td>
</tr>
<tr>
<td>Skid mounted Piggy-back</td>
<td>2-4</td>
<td>3-4</td>
<td>1200-1800</td>
<td>Common in quarries and leach operations. Fewer relocation times, multiple systems, interruptions at transfers, support equipment to relocate</td>
<td><img src="image3.png" alt="image" /></td>
</tr>
<tr>
<td>Crawler mounted Mobile Bridge</td>
<td>5-7</td>
<td>3-4</td>
<td>1800-2400</td>
<td>High investment cost and medium flexibility</td>
<td><img src="image4.png" alt="image" /></td>
</tr>
<tr>
<td>Crawler mounted Belt Wagon</td>
<td>5-12</td>
<td>4-6</td>
<td>1800-2400</td>
<td>Used with shiftable conveyors. High cost, short length (60-80m)</td>
<td><img src="image5.png" alt="image" /></td>
</tr>
</tbody>
</table>

**Figure 10 - Alternative conveyor systems for IPCC applications**

In large soft-soil mines, the standard and proven transportation method is by belt conveyors with conveying offering a number of advantages compared to trucking:

- Operating costs per tonne-kilometer are low
- Electric power is used instead of the ever-rising diesel price
- No exhaust gas is emitted into the environment
- Labour requirements are reduced
- Operational safety is better.

The disadvantages of belt conveying are:

- High investment costs require a reasonable write-off period
- The layout of the conveyor system and periodical re-locations must follow the progress of mining
- Blasting in the vicinity of conveyors must be restricted
• The loading efficiency of the shovel is affected by the interlinked down-stream units.

Milestones in IPCC applications

In-pit crushing plants started to be used in German limestone quarries in the 1960s when they replaced rail haulage and trucks could not be used due to poor footwall conditions.

During the 1980s, ore in-pit crushing and conveying systems were installed in some of the large open pits of the world, including Chuquicamata, Highland Valley and Bingham Canyon, just to name a few. Again, this transition was primarily associated with the change from rail haulage to conveyor haulage. The crusher units were in fixed locations with associated tunnels, declines or surface ramps. The structures could be considered fixed with relocation on a project basis.

In 1992, Chuquicamata also installed a waste crusher and associated conveying facility to crush and transport waste from lower benches to a waste dump located approximately 11 km from the crusher installation. This is one of the few examples of waste crushing in hard rock open pit mines.

The use of mobile crushing units developed from their first use in quarries throughout the second half of the last century. Initial plants were crawler-mounted and had a throughput capacity of only 300 to 600t/h. They had crawlers, a standard hopper, apron feeder, single or double roll crusher, and slewable discharge conveyor boom. Thus, they differed only in throughput and size from the current types of mobile crusher units which are now considered for the application in large open pit mines. Since that time, there has been a continuous development to larger size and throughput and greater mobility.

Probably the biggest breakthrough in mobile crushing units for large open pit mines was the development of the mineral sizer by MMD in the early 1990s, which subsequently showed that fully mobile units could achieve high throughputs in certain types of material and pit configuration. Today, fully mobile, crawler-mounted in-pit crusher plants loading directly onto a belt conveyor are mostly used in quarries and mines which advance fast laterally and have straight benches. Their medium to hard rock material is diggable by shovel without the need for blasting (or with light fragmentation blasting). Examples can be found in mines in China, Canada and Australia where units are in this operation mode with throughput capacity of approximately 10kt/hr. A typical example is shown in figure 11.

Figure 11 - Large rope shovel feeding mineral sizer linked to bench conveyor at Goonyella coal mine (Photo – MMD)
Shiftable and relocatable conveying systems are well proven and are standard techniques in the transport of coal, ore and waste at large shallow mining operations that are mined with lateral development.

Fully mobile systems are of interest to mining in deep open pits with pushback operations, specifically piggy-back systems and mobile bridge conveyors as shown in figures 12 and 13.

![Piggy-back conveyor system at Ulan coal mines](Photo - Krupp)

Figure 12 - Piggy-back conveyor system at Ulan coal mines (Photo - Krupp)

![Mobile pit bench conveyor](Photo by author in 2007)

Figure 13 - Mobile pit bench conveyor - 7kt/h self leveling and aligning unit tested at Suncor oil sand operations. This unit has 300m length and has a maximum travel speed of 6m/minute. The unit was used in combination with a large rope shovel (Photo by author in 2007)

**Pushback operation**

Mining in pushbacks in hard rock mines involves a detailed process of scheduling of individual mining activities. Apart from the loading activity, other processes include: drill mark-out, drilling, blast charging, blasting, loading, wall and crest loading/scaling, hauling and bench clean-up. All of these use “real estate” or bench area within the pushback. In addition, inventories of drilled and blasted reserves are required to ensure continuity of operations and these, together with bench access roads, also use real estate. An example of these conflicts of real estate is illustrated in figure 14.
The interaction of individual phases can also impact pushback operations with mining on a higher pushback managed so as not to impede operations or access to an active phase below. This will often mean modified blasting practices and loading operations in crest areas.

Typically, pushbacks are mined with two to four shovels with production rates of 200 to 400 kt/d. It is not uncommon that blasting within an active pushback would occur one to two times per week and sometimes more in complex operations. Blasting strongly impacts mining efficiency with the requirement to locate equipment at a safe distance from blasts (typically 100 to 150m depending on configuration). Depending on the amount of electrically powered equipment, equipment downtime associated with a blast can be 60 to 120 minutes. In addition, equipment at a greater distance (500 to 600m) will be affected due to safe clearing distance requirements for personnel.

Typical mine operations with large shovels (54m³ class) utilize bench heights of 15 to 18m (15m most common) with operating widths of 70m. This implies that at a dig rate of, say, 100kt/d, bench advance will be approximately 40m/day.

When considering a bench conveyor in a hard rock mining pushback, the system must incorporate the following aspects:

- It must be commensurate with typical bench activities (not just loading and transport)
- It must not tie up excessive “real estate”
- It must allow for simple transport crossovers (truck over conveyor or vice-versa)
- Systems must be advanced fast (equivalent of shovel)
- It must be robust enough to remain close to blasting activities (equivalent of shovel)
- Quick repairs in case of blast damage (equivalent of trolley line)
- It must consider non-primary activities of loading unit (primary loading production is commonly only 50-60% of calendar time).

Figure 14 highlights the issues of getting crusher and conveyor combinations to the loading face. This is further illustrated in figure 15 showing the conflicts in “real estate”, i.e. blasting close to crusher installations, the need to have conveyor-truck intersections, and the amount of room tied-up by a conveying system.
Potential applications of IPCCs in large deep, hard rock open pits

As described above, the application of mobile crushing of waste material or ore and waste in deep, large hard rock open pits is more problematic than current applications. The primary issues hindering their application are associated with flexibility, interaction with other activities and, in particular, the speed of phase development.

The application of fixed in-pit ore crushers is applied on an opportunity basis and will be used when the configuration of the pit allows, i.e. wall permanence.

Potential applications, where conveyors are mobile and advanced to the loading area, face a number of issues including:

- The crusher type – it must be mobile and therefore sizer or twin-roll
- There are limitations on material hardness
- The impact of blasting is significant – typically 100 to 250m clearing of equipment depending on blast configuration is required; it must be less if system to succeed and choke blasting is required
- Maximum of two shovels on a single pushback bench.

If one looks at, say, 250 to 300m pushback width, the following could be envisaged to advance the crusher plant as fast as the shovel:

- Three to four belt wagons would be required – excessive cost and transfer points
- Five to six piggy-back flights – excessive cost and transfer points
- Single mobile bridge conveyor on crawlers – high capital cost.

In order to evaluate the potential application of a fully mobile crushing system, it is compared to a typical high production shovel-truck pushback as shown in figure 16, where four shovels are deployed in a pushback of approximately 200m width. Blasted material and loading faces are represented by brown shaded areas and active drilling areas by blue areas. This is similar to the illustrations shown earlier.
In order to deploy a fully mobile crushing system with a crusher for each loading unit, the phase width would have to be increased to an adequate width of approximately 250 to 300m. The access ramp would need to have extra width to accommodate both truck and conveyor haulage lanes (50% increase in ramp width). Ramp conveyors, transfer points and conveyor crossover points would be established.

Single benches with two shovel/crusher/bridge conveyors can be developed. In order to establish a bench, a box cut needs to be developed with conventional methods while the crushing and conveying equipment is withdrawn and parked in a safe location. Blasts would then follow into the box cut and relocation of equipment could occur. Estimation times for relocation of different systems into the start-up position are:

- Belt wagons four to six hours
- Piggy-back conveyors four to six hours
- Bridge conveyor 72 hours
• After 250 to 300m slew of bridge conveyor to final wall, establish bench conveyor – 72 hours.

Due to multiple transfer points, excessive capital and low overall system availability, piggy-back systems and belt wagons are not applicable.

After box cut establishment, typical blast times would involve two to three hours to retreat the shovel, crusher and conveying bridge, one hour for blasting followed by two to three hours for clean-up and system advance into the loading position. For bench conveyor extension 48 hours are required, and for ramp conveyor extensions 72 hours. Figure 17 shows a schematic representation of a bench development using two shovels with associated bridge and bench conveyors. Choke blasting would be essential in order to minimize damage to equipment; however, this and the full bench width of blasting would likely cause pushback wall damage due to excessive vibration.

Figure 17 - Schematic illustration of bench development with two shovel/crusher/bridge conveyor systems

This example demonstrates that an operation with moveable crushing and conveying systems is uneconomic on pit development grounds:

• Wider phase development necessitates a significant anticipation of waste mining (from later phases)
- Average bench extraction is at a rate of 145kt/d with two systems rather than 400kt/d with four shovels in a shovel-truck schedule
- Significant system under-utilization occurs due to space constraints and system interaction.

The authors believe the concept of fully mobile crushing systems is not appropriate with respect to pushback operations in large hard rock open pits. While the approach finds application in horizontally developing surface mines, the option should not be a focus in deeper open pits.

**Where next?**

As stated in the introduction, the key area of potential savings through conveyor haulage is in up-hill hauls. Replacement of conventional truck haulage on in-pit horizontal hauls offers limited cost advantage and impedes mine plan flexibility and, in particular, loading efficiency.

A direct comparison of a 250kt/d haulage system on a 10% ramp (with $0.70/l fuel and $0.10/kWh electric power) shows that total costs of ownership for truck haulage with 360t class trucks are $0.18/t.km compared to $0.06/t.km with a conveying system. This excludes crushing and ex-pit cost components. The break-even for conveying benefits is when the fuel to power (diesel ($/l)/electricity ($/kWh)) is above approximately 2:1. On this basis, the challenge remains of how to incorporate such systems without impeding mine development. Two approaches come to the fore, one that has already been applied in several situations, and the other that requires further assessment by suppliers and operators.

The concept of the crushing station or series of crushing stations on a conveyor ramp slot has been practised in the past at Chuquicamata and Carmeaux. This is shown in figure 18, and the concept is also applied to the earlier pushback configuration in figure 19. This requires a pushback modification to accommodate the system with a significant anticipation of waste mining (from future pushbacks). This is costly and difficult to develop, and a tunnel option may also be considered if geotechnically and economically supportable. Two relocatable crushing stations are envisaged with a minimum of two ramp conveyors allowing distribution of material to different destinations. Relocation would be anticipated every six to twelve months to allow mining using conventional shovel truck operations from four to six benches. Issues with such a development are: anticipation of waste mining costs associated with slot, the impact of blasting above the conveyor/crusher installations, and potential under-utilization of the system if material is preferentially hauled using conventional truck transport.

![Figure 18 - Examples of a conveying slot and associated waste crushing facilities (left and middle, Chuquicamata 1997 (Photo by author 1997) , right Carmeaux)](image-url)
A further option is the hybrid operation where more mobile crushing stations are considered. The issues here are that trucks, crushers and conveyors do not mix in that we are faced with the problems of:

- Conveyor-truck crossovers and vice-versa; i.e. how to accommodate both truck road and conveyor track in the mine design
- How to design a crushing station for large trucks which is regularly relocated
- How to simplify the feed arrangements of relocatable crushers
- How to simplify the site preparation for relocatable crushers.

These are the challenges which are presented to mine design engineers and suppliers. Let us dream further. Is a large 360t capacity truck the best vehicle for bench haulage and short truck haul cycles? Would autonomous 150 to 250t autonomous shuttle vehicles provide the best option for bench operations?

The authors consider that relocatable systems rather than mobile systems are the preferred way forward in IPCC technology and illustrate this by means of a multiple crushing station operation in a coal mine in India developed in the 90s. In this operation, four relocatable twin-roll crushing stations were used with associated bench conveyors, conveyor distribution point and ex-pit conveyors and spreaders. Three systems were dedicated to waste and one to coal with the conveyor distribution point providing the ability to route each crusher to any destination. Truck haulage on the bench was an integral part of the system with conventional haulage over distances of up to 1000m and two to three benches. The impacts on mine planning are significant and these need to be adequately considered in the conceptualization process. This is illustrated in figure 20.
Discussion

In this presentation, we have targeted primarily the copper and gold open pit mining industry with high capacity deep mines. The conclusions of this analysis raise the following points for discussion.

- Large, hard rock, deep open pit mines are driven by NPV relating to metal-rock presentation.
- Phase design creates value, IPCC creates efficiency – value is more important!
- Conventional shovel-truck systems allow this to be optimized.
- Current crushing-conveying technologies strongly impact mine design and plan flexibility, thus reducing NPV.
- Mine planners must seek opportunities through phase design to make use of crushing and conveying systems to reduce the impact of vertical transport costs.
- Discard the concept of “all-conveying” and target to ramp conveying with quickly relocatable truck dump and ramp conveyor line.
- Instead of fixed and steep conveyor ramp, locate the ramp conveyor along the truck exit ramp 10:1.
- With regard to energy consumption, the length of the ramp conveyor line is much less important than the lift and energy consumption is the main cost driver for conveyor haulage.
- Design pushback walls in straight lines rather than curves to accommodate the conveyor line with few transfer points.
- Use a transport crawler for moving truck dump/crusher plant as well as conveyor drive head stations.
- Relocate the ramp conveyors as frequently as the truck ramp when required for a new pushback.
- Relocation of the truck dump/crusher plant must not cause more than three to four days interruption of conveying and this should be achieved through clever design and site preparation.
- The ramp conveyor is extended or relocated during truck dump/crusher plant relocation, no additional lost time.

Acknowledgements

The authors wish to thank the management of Codelco, Minera Escondida, Rio Tinto and Suncor for their permission to include illustrative photographs from their operations. Additional photographs are from the websites of or provided by Thyssen-Krupp, Rahco and MMD.