Cost Considerations for In-Pit Crushing/Conveying Systems

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Summary

This article focuses on continuous materials handling systems used in the hard rock open-pit mining industry. Guidelines for mine planning with continuous systems are outlined. Key parameters affecting capital and operating costs are identified. Commonly encountered trade-offs between operating and capital costs are discussed. A typical range of costs is presented based on average operating conditions.

1. Definitions

Because in-pit/crushing/conveying is relatively new to the industry, the vocabulary used is still in a state of flux and causes considerable confusion at times. The following definitions will be used in this discussion:

Near-Pit Crusher: Crusher located outside the pit but adjacent to the perimeter, e. g. Duval Sierrita's 60 inch gyratory waste crushers, Gibraltar's 54 inch gyratory ore crusher.

In-Pit Crusher: Crusher located within the past or future influence of the ore body, e. g. Anamax Twin Buttes' 54 inch gyratory waste crusher and Cyprus Bagdad's 60 inch gyratory ore crusher.

Mobile Crusher System: Crusher and feeder with integral propelling mechanism such as walking pads or permanent crawler, e. g. Palabora's 54 inch gyratory ore crusher.

Portable Crusher System: Crusher and feeder with independent propelling mechanism such as crawler transporter, e. g. Duval Sierrita's 60 inch gyratory ore crusher.

Movable Crusher System: Crusher/feeder with independent propelling mechanism such as crawler transporter and with relocation costs from 10% to 15% of capital costs for site preparation and dismantling, e. g. proposed Utah Mines Island Copper 54 inch gyratory ore crusher and Iscor 60 inch gyratory waste crusher.

Conventional Crusher System: Crusher and feeder housed in reinforced concrete structure which is typically located in large, flat area of pit (e. g. Smoky Valley Round Mountain 42 inch gyratory ore crusher and Chuquicamata 54 inch gyratory ore crusher) or sloping pit wall (e. g. Anamax Twin Buttes 54 inch gyratory ore crusher).

Conveyor Flight: Length of conveyor between transfer.

Relocatable Conveyor: Conveyor that has temporary foundations (such as steel tubes or wooden railroad ties) and which can be moved with some dismantling, e. g. Smoky Valley Round Mountain ore conveyor, 36 inch wide by 2,600 ft long.

Shiftable Conveyor: Conveyor that is designed with sufficient flexibility to be shifted laterally intact with all components, e. g. Majdanpek waste conveyor, 60 inch wide by 4430 ft long.

Portable Conveyor: Conveyor that is designed as a rigid unit to be moved intact with drive and all components in any direction, e. g. Duval Sierrita ore reclaim conveyor, 120 inch wide by approximately 100 ft long.

In-Pit Conveyor: Conveyor which is totally or partially within the pit perimeter, e. g. Duval Sierrita ore conveyors, 60 inch wide by 3,700 ft long.

Around-Pit Conveyor: Conveyor that is routed around the perimeter of the pit and is contoured to the terrain with assistance of bridges and earthwork, e. g. Duval Sierrita ore conveyors, 60 inch wide by 11,200 ft long.

Overland Conveyor: Conveyor that is totally outside of the pit perimeter and is contoured to the undisturbed terrain between pit and concentrator or dumps, e. g. Anamax Twin Buttes' Eisenhower ore conveyor, 42 inch wide by 32,500 ft long; Marcona ore conveyor, 36 inch wide by 50,300 ft long; and New Caldonia's horizontally curved ore conveyor, 30 inch wide by 36,000 ft long.

Belt Conveyor: Conveyors which carry material on flat or troughed reinforced elastomer belts, e. g. the cable-driven systems at Newmont Similkameen and Anamax Twin Buttes, and steel-cable reinforced belting systems at Anamax Twin Buttes, Noranda Lakeshore, and Duval Sierrita at maximum inclines of 25%, 27% and 29% respectively. The maximum incline of these systems is a function of the angle of repose of material, i. e., the angle which the surface of a freely formed pile makes to the horizontal.

High-Angle Conveyor: Conveyors capable of carrying material at any angle between horizontal and vertical by mechanical means, e. g., sandwiching material between two belts, or belts with sidewalls and shovel cleats (vertical coal conveyor at Turris Coal Company).

Permanent Conveyor Transfers: Custom designed area where material is transferred from one belt to another belt.

Movable Conveyor Transfer: Transfer which is designed to be moved to new locations and operate within a range of conditions, e. g., conveyor transfers at Southwestern Illinois Coal Captain Mine.

Rotatable Conveyor Transfer: Transfer which pivots about center pin to accommodate shifting of attendant conveyor, e. g. Majdanpek fan-shaped waste disposal system.

2. Mine Planning Guidelines

2.1 Candidates for In-Pit Systems

In-pit systems are operational today with capacities varying from 550 t/h ore systems to 8,000 t/h waste systems. In general, unit cost savings per ton-mile increase with higher tonnages and with increased distances.

Properly designed conveying systems have a conservatively estimated life of twenty years. In general, the remaining mine life should be at least ten years to warrant a replacement conveying system. New mines or mines with obsolete rail system or truck fleet may justify a conveying system for shorter mine life.

Flat areas with short hauls are still best serviced by trucks. Early mine development and haulage between the working face and in-pit crusher will be predominantly by trucks for the next decade. Mature pits with high lifts favor conveying systems, and unit cost savings can increase exponentially with depth of pit due to escalating truck costs in deep pits. Long haulage systems have a significantly lower unit cost per ton-mile than short haulage systems. Mines faced with high diesel costs or lack of diesel because of government restrictions can justify conveyors under the least advantageous conditions if electrical costs per kilowatt hour are in the range of U. S. $ 0.05, which is the energy cost assumed for this paper.

2.2 Crusher Location

Because of their prototype nature, the first in-pit crushers were housed in conventional reinforced concrete structures. Such installations are too inflexible for most mines, and often result in locations that become outdated within a few years. Within a given pit, more locations become feasible if the same crushers can handle both ore and waste.

The in-pit crusher should be located as close to the working faces as possible. Required safe distance from blasting for a mobile, portable or movable unit is approximately the same as for a shovel. In general, truck haulage runs should be near horizontal (preferably down one or two benches at the most) or upgrade. Ore crushers should normally be located near the bottom of the pit, and waste crushers should be located near centroids of major overburden removal.

The best locations for crushers should be identified by quantifying the amounts of ore and waste to be removed from each of the bench levels. In general, a greater number of smaller mobile or movable in-pit crushing units are advisable when compared to near-pit or in-pit conventional crusher systems. The reasons for this are twofold:

— First, the greater number of units allows the units to be kept closer to more working faces.

— Second, the larger crushers impact disproportionately on mine planning when installed in mobile or movable systems because of weight and height parameters.

In a conventional system, the crusher can be placed deeper into the ground to handle additional height and the concrete can be increased slightly to accomodate additional loads. Intrinsically, the mobile or movable systems are more sensitive to height and weight because of mine feed requirements and potential structural vibration problems. For example, two movable 60 inch gyratory crusher systems can cost approximately as much as three movable 54 inch gyratory crusher systems, yet the three 54 inch crushers can handle greater tonnage.

Locating the crusher is ideally accomplished without disturbing the mine plan. Crusher location impacts on mine planning differently for the mobile, portable, movable and conventional systems. An improper choice could lead to the additional removal of several hundred thousand yards of waste or the blockage of ready access to a portion of the ore body.

2.3 Conveyor Routing

Few pits are fortunate enough to have a stable, permanent face established early in their development on which a conveyor might be routed out of the pit. Most pits are plagued with combinations of problems including localized instabilities, water seepage, restrictive haul roads, dispersed ore zones and multi-mineral ore bodies which can change configuration with changing market conditions. For these reasons, relocatable conveyors should always be used for in-pit installations.

The following parameters are normally used for routing a conveyor:

1. The conveyor should leave the pit at a 25% to 30% slope to minimize length of ascending conveyor, thereby reducing interferences.
2. Routing should minimize the number of transfers (sometimes at the expense of additional earthwork) to minimize belt wear, reduce energy losses associated with vertical drops through chutework, decrease capital and operating costs and increase reliability.
3. Future mining and crusher relocations should be taken into account. Sometimes a slightly longer conveyor will avoid unnecessary future moves.
4. Uphill and downhill portions of conveyor should be balanced within the same flight when possible to minimize energy usage.
5. Conveyor flights should be designed to ensure standardization of transfer drives, belting and pulley assemblies.
6. In general, a combination of earthwork and vertical curves is more economical than trusses.
7. Conveyor embankments that interrupt drainage areas must have properly sized culverts.

8. Roads should be established alongside all conveyors for maintenance. At conveyor transfers, the turning radii of roads should be checked to ensure crane access. Steep roads will have only downhill traffic.
9. Conveyors are better tunneled under than trussed over mine truck roads for safety reasons, although trussing is more common.

3. Major Cost Items

3.1 Transfer Areas

Conveyor transfers are required to accommodate a change in direction of material flow.

A transfer for 60 inch and 72 inch wide belts requiring a high tension drive can be in the range of $ 1 to $ 2 million for civil, concrete, steel, electrical, mechanical, chutework and indirect costs. The cost of an intermediate drive without transfer or of a transfer without a drive is much less.

For example, in the case of cable-driven conveyors, a drive is not required at a transfer if the drive cable tensions for two successive flights are low enough to be within the range of gearbox and other drive technology. In the case of steel cable reinforced conveyors, long, straight high-tension conveyors do not need in-line transfers if intermediate belt drives are used. The drives relieve high belt tensions through friction of a driving belt against the carrying belt.

3.2 Crusher Systems

A crusher system includes a feed arrangement, a method of control, a crusher and a discharge system. For a 54 inch gyratory crusher, costs can vary from $ 6 to $ 12 million, depending upon whether the system is conventional or completely mobile. In general, the more flexible the system the greater the cost.

3.3 Electrical Distribution System

For a crushing/conveying system requiring 15,000 to 20,000 HP, main substation costs can run in excess of $ 500,000. Any new transmission line costs would be in addition to this. The costs for transfer and crusher area substations are additional and are included in the transfer costs.

3.4 Earthwork Costs

In hilly country, earthwork quantities for conveyors and services roads can easily reach 500,000 yd^3/mile. This figure can include ripped cut, blasted cut, non-structural fill and structural fill. In general, transfer areas should be located on cut or structural fill, whereas conveyors and service road beds are often constructed of select run-of-mine waste. Normally, careful mine planning and conveyor routing can avoid much of the non-structural fill costs.

3.5 Belting, Idlers and Conveyor Frames

The actual conveyor runs can account for less than 25% of total system costs. For example, 60 inch wide conveyor belting and idler costs are in the range of $ 200/ft, and steel support frames with foundations are in the range of $ 100/ft.

4. Economic Trade-Offs

4.1 Impact on Mine Planning

Conveying systems are meant to assist mining and should not become an additional problem for the miners to overcome. In general, the most economical system from a strictly conveyor viewpoint is usually not the best overall system because of adverse affects on mining. For example, small savings in capital costs for a conveying system may be more than offset by unneeded mine operating costs.

In general, any excavation done for the conveyor should be excavation already required by the mine plan. Fill material should not be re-handle material where possible.

To avoid unneeded earthwork, conveyors may be lengthened and crusher systems should be relocatable.

4.2 Crusher Systems

Four crusher system types have been identified: Conventional, movable, portable and mobile (Fig. 1).

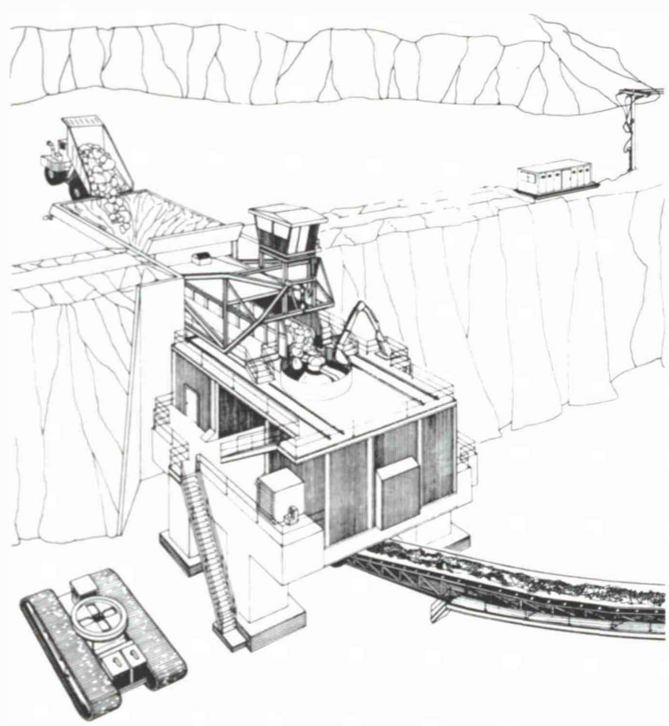

Fig. 1: M.S.M.E. movable crusher system

The conventional and movable systems are essentially of the same capital cost, but the movable systems require the additional cost of a transporter which can be handled as a capital cost (buy-out) or operating cost (rental). The portable and mobile systems can cost up to twice as much as a conventional system.

The conventional system is suited for the situation where the crusher location will be valid for a least 10 years and has the usual advantage of an enclosed environment. The movable systems address the market where the crusher needs to be relocated every one and one-half to five years. For relocation costs equivalent to 10% of capital costs, moves can be justified as often as every 18 months. For relocation costs of 15%, relocation can be justified as often as every two years.

The portable system has higher capital costs because of its flexibility and should be moved every three months to two years to justify this flexibility. In general, several systems should be serviced by the same transporter. Relocation costs are minimal. The mobile system should be moved weekly or monthly to justify the capital costs associated with its integral propelling mechanism. Relocation costs are minimal. In summary, flexibility, if purchased, must be used to justify its added cost.

4.3 Method of Accessing Crushers

Conventional crushers that are built into a side slope and movable crushers with retaining walls are accessed from one side from the bench above the crusher level. This requires selective location in a locally wide bench for convenient truck access. With proper design, their location physically impacts on two bench levels. Conventional crushers built into a flat area and movable crushers with bridges are often accessed from two sides above the crusher level. This requires selective location in a locally very wide bench for truck access. Their location physically impacts on at least two bench levels.

Portable and mobile crushers can be fed from below the crusher level with the use of an inclined apron feeder. This system requires a long flat area for equipment placement. Their location physically impacts on only one bench level.

4.4 Transfer Areas

Transfer areas should be eliminated where possible. This can often be accomplished by lengthening conveyor flights slightly and assuming a less contoured shape in reaching the final destination. Increased energy costs due to this longer total run should be compensated for by the lesser number of transfer/lift areas. Decreased capital costs should easily offset any increased earthwork requirements. Maintenance of the resulting system should decrease and availability should be greater.

For narrower belts, horizontally curved conveyors have been used to successfully eliminate transfers.

Transfer areas should be portable where possible because of the likelihood of future relocation, planned or unplanned. Structural/civil costs account for less than 25% of the total costs of a drive area. By modifying the structural steel slightly, transfer areas can be made skid-mounted. For low tension drives, the skids can be placed directly on earth. For high tension drives, the skids must be anchored for overturn; a thick slab on grade being a viable option for achieving this.

5. Representative Operating Costs

Operating costs for in-pit and around-pit conveyors are dependent on the length of the system and will range from $ 0.05 per ton-mile for long systems to $ 0.09 ton-mile for short, high-lift systems, including crushing costs.

When comparing these costs with truck costs, it should be noted that the route transversed by such a conveying system will be shorter than truck hauls because the conveyor can climb approximately three times as steeply as a truck.

Overland conveyor costs can be as low as $ 0.02 per ton-mile for downhill systems to $ 0.05 per ton-mile for relatively flat systems. These costs would be for cable driven systems or steel-cable reinforced belting systems.

Energy costs and labor costs vary widely worldwide. The following breakdown represents average values for operating costs of a "typical" mine.

Energy	40%
Replacement Parts	30%
Labor	30%

6. Concluding Remarks

Mature mining properties with average ore bodies and operating conditions with truck haulage may be forced to switch to in-pit crushing/conveying systems to survive the competition of the 1980s and 1990s. The potential cost savings will force rethinking of mine planning to accommodate a combined truck/conveyor mining system.

By the end of the century, continuous systems (i. e. no trucks) will be operational in the hard rock industry.

Bibliography

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Acknowledgements

The author gratefully acknowledges the cooperation of his staff members at Mountain States Mineral Enterprises.