A Holistic Viewpoint for Selecting the Vertical Haulage System – Shafts and Conveyors

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ABSTRACT

The haulage system used to convey ore from an underground mine to a surface stockpile at the mine process plant is a vital component of the mine’s overall infrastructure and economic viability. The system selected has a significant impact on the set-up of the mine and the access to the underground mine. In turn, the set-up of the mine and the access to the underground mine have a significant impact on the system.

A number of haulage technologies are available to transfer the ore from the underground workings to the surface stockpile, including hoists, conveyors, rail and trucks.

This paper focuses on the shaft hoisting and inclined conveyor haulage technologies. These technologies have been used consistently to deliver ore from at depth and/or at high tonnage. Previous reviews of the appropriate vertical haulage systems have nominally been restricted to the respective systems only, with no consideration for any other scope or issues that may affect the selection. The selection of the appropriate vertical haulage system, whether shaft hoisting or inclined conveying, needs to consider numerous key factors.

INTRODUCTION

A number of underground mining projects, both in Australia and internationally, are implementing or proposing to implement mass mining methods. These methods include sublevel caving (SLC), block caving (BC) and panel caving (PC). The underlying philosophy is to create an underground ‘rock factory’. To be successful, the mining approach needs flexible, reliable and have capital-effective infrastructure systems. Implicit in this approach is a focus on the application of process control systems and the pursuit of opportunities for automation systems to maximise the effective working time available for ore production.

Implicit with any mass mining system is the difficulty in controlling the ore fragmentation. For the purposes of this paper, it has been assumed that a primary crusher system is installed. The vertical haulage system conveying ore from the underground crushing system to a surface stockpile at the mine process plant is a vital component of the overall mine infrastructure. The system selected has a significant impact on the setup of the mine and the access to the underground mine and economic viability.

A number of haulage technologies are available to transfer the ore from the underground workings to the surface stockpile. These include:

- vertical conveyors
- hydraulic hoisting
- shaft hoisting
- inclined conveyor haulage
- truck haulage
- rail haulage

This paper focuses on the shaft hoisting and inclined conveyor haulage technologies. For a brief description of the other haulage technologies see Pratt (2008).

The shaft hoisting and inclined conveyor haulage technologies have been used consistently to deliver ore from at depth and/or at high tonnage. Figure 1 displays benchmarking of shaft and conveyor systems for various mines (including mines that have operated in the past, are operating now or are in the planning stage).

Many reviews of the haulage systems have concentrated on comparing the respective systems only. However, the selection of the appropriate system, whether shaft hoisting or inclined conveying, needs to consider a holistic mine viewpoint. The vertical haulage system (shaft hoisting and inclined conveying) impacts on the planning, development and operation of the mine. Items to be considered include:

- mine access requirements
- greenfield development or brownfield expansion
- costs, both capital expenses (CAPEX) and operating expenses (OPEX), with the resulting net present cost
- personnel capability and availability
- schedule to develop and construct
- maintenance of the systems in terms of number and skill level of personnel

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• the expandability, flexibility and continuity of production of the system
• power supply requirements
• surface impact and asset security
• geotechnical and geological risks
• ventilation requirements of the mine.

SYSTEM DESCRIPTIONS
A comparison of the two vertical haulage systems requires a holistic viewpoint of mine development and infrastructure and an analysis that includes, but is not limited to:
• ore extraction systems from within the orebody footprint
• primary crushing, tramp metal detection/collection and lateral conveying
• vertical haulage including decline development and/or shaft sinking
• surface conveying to the process plant stockpile
• underground mine services/infrastructure including dewatering, raw/fire water, high voltage power reticulation, communications, controls and workshops
• surface mine services/infrastructure including dewatering, raw/fire water, high voltage power reticulation, communications, controls, workshops
• mine ventilation requirements including bulk air cooling ducts accessing the shaft subbrace area, primary exhaust fans
• ability of the selected method (hoist/conveyor) to meet the tonnages and lifts required.

Items that have similar scope and economics for both vertical haulage systems may be excluded from the comparison. Those items that are sufficiently different need to be considered.

INCLINE CONVEYING
General
The inclined conveyor system components are as for any conveyor system, including transfer chutes, belt, drives, pulleys, idlers, support structure and maintenance facilities. Figure 2 shows a typical underground transfer station.

Large conveyor haulage systems for underground mines generally consist of more than one transfer point. The incline of the conveyor is nominally limited by the ability to mine that grade and to provide maintenance access, which generally is limited to a maximum 1:5.3 (~10.7°). The capability of underground conveyors is underpinned by the development and application of conveyor technologies including:
• Increased belt strengths and splice efficiencies. Belt strengths up to ST10000 are now available, which will allow conveying of longer lengths, higher lifts and or higher tonnages (refer Figure 3). Belting also includes the appropriate load support, covers for wear and fire resistance, belt rip detection system and ongoing online monitoring systems.
• Conveyor drive technologies including the use of variable speed drives for starting/ Stopping and drive pulley speed matching. Low-speed ‘gearless’ drives are being considered and installed for higher powered conveyors (>7–8 MW installed).
• Analysis, design and implementation of transfer chutes to ensure uniform and central loading onto the receiving belt, which improves belt life. The analysis includes discrete element modelling and scale modelling of the chute flow to ensure appropriate design of the chutes.
• Increased belt speeds with underground belts travelling at 6 m/s. Note that some surface conveyor installations are approaching 9 m/s.

The arrangement of the incline conveying system commonly has the conveyor modules hung from the back (roof), as shown in Figure 4. The underground conveyors require large excavated chambers at each primary drive station/transfer between conveyors and at each secondary drive station, as shown in Figure 2. The extent of the excavation is driven by the size of the conveyor drives and the need for safe construction, operation and maintenance, especially in relation to removing a drive, chute, or pulley and lowering it to the ground beside the conveyor and undertaking belt splicing and installation.

Person and materials access is usually via another decline, which is commonly used as the mine’s fresh air intake. The conveyor decline may be used for access; however, vehicle/equipment size and potential damage by mobile equipment need to be taken into account, as well as the potential for primary crushed ore to fall off the belt. Another consideration is that during construction of the conveyor access declines can
become congested as a result of construction activities, with vehicles moving through the construction area to other parts of the mine and interacting with the mine production and development fleet.

Conveyor belt limitations
The goal in the layout of an underground conveying system is to maximise the length and lift of the flight of any one conveyor, in order to minimise the number of transfer stations. This in turn improves the operational and maintenance requirements of the system and reduces the development costs.

To date, the strongest belt installed is at Los Pelambres, Chile, which is an 1829 mm ST8500, but de-rated to ST7800 due to splice fatigue life. Currently one of the major belt suppliers has an order to supply a 2200 mm wide ST8000 belt and the same supplier has recently completed splice fatigue testing for an ST10000 belt and has achieved 50 per cent dynamic fatigue strength to DIN22110 Part 3.

Another limitation is the safety factor of the belt. Following the German standard for conveyors, DIN22101, the potential belt safety factor may be as low as 4.2; however, belt manufacturers are unwilling to warrant a conveyor belt with this low safety factor. The belt manufacturers suggest a minimum safety factor of 5.5 to 6 with ongoing monitoring and maintenance. The safety factors need to be confirmed with the respective belt manufacturers as the conveying system is being developed.
SHAFT HOISTING

General
Shaft hoisting has been widely used to service both shallow and deep mines, with tonnages up to 10 Mt/a from individual hoisting systems. High-capacity operations include the Oyu Tolgoi in Mongolia; Clarke shaft at Olympic Dam in South Australia; U62 at Mount Isa in Queensland, Australia; Esterhazy K2, and Palabora. Shafts at these mines have diameters in the range of 6 m to 11 m and operating capacities of 5 Mt/a to 10 Mt/a. Large-capacity systems have multi-winder setups within the one shaft, such as U62 and Palabora. Oyu Tolgoi, which is currently being investigated, is expected to have an 11 m diameter shaft, with two winder systems contained within the shaft, each capable of delivering approximately 10 Mt/a.

The current winder technologies available include single and double drum, friction (Koepe) and Blair multi-rope drum winder (BMR). The above-mentioned high-capacity winders are all friction (Koepe) winders.

The winder configuration is driven by the operational flexibility required, duty tonnage, depth of wind and site constraints.

Hoisting limitations
Drum winders are either single or double drum machines. In the case of a double drum machine, the common layout has two drums mounted on the same shaft. Each or one of the drums is fitted with a dog clutch. The clutching of the drums provides operational flexibility, improving the efficiency to service different levels in a mine shaft. There are electrically coupled machines, but these are rare.

Drum winders can operate in short lift shafts and in the other extreme at 3000 m. The payloads hoisted are a function of the layout and number of the ropes. The greater the depth of hoisting results in a smaller payload. The Blair multi-rope winder greatly improves the operating range of the single rope drum winder by having two ropes per conveyance. For example, at the South Deep Mine in South Africa, a Blair multi-rope winder is operating at 3000 m hoisting a 31 t payload.

Rope layout for a Koepe winder allows for multiple head ropes to be attached to a conveyance, which greatly increases the machines’ capability to hoist high payloads. Theoretically there is little limitation to the number of head ropes that can be used; however, in practice the number has been limited to six. The current extreme for Koepe winders is Oyu Tolgoi’s No 3 Shaft, which is planned to hoist 64 t payload from 1200 m.

Koepe winders are limited in the depth from which they can hoist. The depth limitation is as a result of a number of functions related to the rope diameter, rope slip on the drive sheave, drum diameter, rope tread pressure on the drum and rope load range. Present thinking is that the efficient practical operational depth of Koepe winders is limited to approximately 1400 m. Greater tonnages can be hoisted by increasing the number of winders servicing the shaft. An assessment of hoisting limitations is presented in Figure 5.

Headframe
With double drum and BMR winders, the winder systems are ground-mounted.

These winders can be used for shaft sinking. However, these winders are usually a long-lead purchase and not available for the sinking operation. As a result, the purchase, fabrication and installation is usually done off the project critical path. Most shaft sinking contractors have winders available for their projects.

Koepe winders can be either ground- or tower-mounted. They have been known to be used as single drum kibble hoists in sinking operations. Ground-mounted Koepe winders require extensive foundations, which can be costly if the ground is not competent.

Tower-mounted Koepe winders are quite common. However, their construction can impact on the sinking operation as they are installed above the shaft sinking operations. Their construction therefore requires careful planning and rigorous safety management.

Skip loading system
Two types of skip loading systems are commonly used in high-tonnage hoisting systems, namely flask or conveyor loading (Northcote, 2011).

Figure 3 shows the capacity (belt width) limit for various conveyor flight lifts for various belt strengths.
The flask system uses a tub that is loaded during the travel time of the skip between the loading point and the tip. When the skip arrives to tip, the lower skip is loaded by the preloaded flask. This system allows for quick skip loading. A disadvantage is the spillage that occurs as the load discharges into the skip and the rope stretches. Rope stretch is a function of the speed of loading, the payload and the length of rope.

Conveyor loading systems provide a better controlled load rate to the skip, thereby addressing the rope stretch issue and the spillage. The penalty is the considerable increase in loading time, resulting in a significant portion of the winder’s cycle time being allocated to loading. This in turn reduces the hoisting rate of the winder.

Each loading system needs to be assessed for its impact on the hoist’s performance. Koepe winders usually have more head ropes than drum winders and rope stretch during loading is less for the same rate of loading and payload. Generally, for shallow winds, say less than 1200 m and payloads less than 25 t, the flask system is preferred, which is driven mainly by the impact on the loading cycle. For deeper winds and greater tonnages, the conveyor system should be considered.

### Shaft layout

The diameter of most mine shafts is a function of the ventilation to the underground mine. A single ventilation shaft can be designed to cater for fresh air downcast and return air upcast by separating the two with a brattice wall. Hoisting usually takes place in the fresh air side of the shaft.

When the shaft cross-section is constrained (see Figure 6), buntons and guides are used to locate the conveyances. Where there is a single hoist in the shaft, rope guides are often used.

### Shaft sinking options

There are three common options for sinking a shaft: blind sink; raise bore, strip and line; and vertical tunnel boring. Each method has its merits and constraints (Northcote, 2010). A single shaft may employ two of the methods; for example, blind sink to a certain depth and then a raise bore strip and line thereafter.

The raise bore, strip and line technique is commonly used when access to the shaft bottom is available. This occurs in mature mines with a decline that can provide access to the shaft bottom from where the raise bore chips and the mullock are removed. This method requires the mullock to be transported to a dump site. Should the dump site be on the surface, the traffic in the access decline increases, which then competes with the production traffic. Should the dump site be in worked-out voids, this problem can be reduced.

Blind shaft sinks and vertical down tunnel boring machines are usually independent of the mining operations and therefore do not impact on existing underground production activities.

Where ground conditions and intersection of large volumes of water are anticipated, the blind shaft sink method is the preferred option. There are known and proven techniques to control the ground and seal the aquifers.

Vertical tunnel boring machines are commonly used in short-lift shafts located in competent, but soft ground. These shafts are always round in cross-section.

All shaft sinking methods can achieve 10 m shaft diameters. The blind sink and raise bore, strip and line methods are not limited in diameter or in cross-sectional shape. Ventilation shafts fitted with brattice walls are sometimes two half-circles joined by straight section. Yesteryear’s miners often sank rectangular shafts.
PARAMETERS TO CONSIDER

Mine access requirements

Studies completed to date regarding access to mines have shown that the geology, topography, location and maturity (greenfield or brownfield) of the mine are key factors.

Mine access on a greenfield site needs to address the constraints presented by the topography of the region and the geology in which the access and deposit is placed.

The geology and topography dictates not only the haulage system, but also the mine logistics in terms of person and materials flow into and out of the mine and the development of waste removal.

An additional constraint may be the surface road access to either a decline portal or shaft collar, particularly if the road needs to pass through difficult terrain; eg mountains or swamp.

Greenfield development or brownfield expansion

For a greenfield development, all parameters are open for debate and investigation into the most appropriate system. The parameters should be considered systematically and in detail to ensure the validity of the process.

For a brownfield expansion, a number of parameters are already established; eg mine site access, power supply, maintenance and operating regime. This helps to focus the investigation, as at least some of these parameters may not need to be considered. Normally any expansion has to be integrated with existing systems, which limits the possible options. Hybrids of hoisting and conveying options that tie into existing systems may present themselves as more viable options. Other considerations, such as interacting with existing operations, need to be taken into account, particularly during the development and construction phases when there are large numbers of personnel, materials and waste movements. Carrying out these activities to meet schedule and quality requirements while maintaining good safety practices demands experienced management. The logistics of constructing the expansion concurrently with existing operations need to be carefully considered and scheduled.

Costs

When considering the life of mine cost for either vertical haulage system, the total infrastructure and development impacted by each of the systems need to be considered; that is, a holistic approach should be taken, incorporating items such as the primary ventilation system including extra shafts and lateral vent drives; ore/waste collection, crushing and transfer; services, raw water, power, communications and dewatering.

The implementation and construction of these systems take a number of years to implement and expand. Therefore a cash flow model needs to be completed and together with the operating cost of the system, a net present cost of each system developed.

The accuracy of the estimate and the level of engineering are commensurate with the stage the project has reached in the project life cycle.

Personnel capability and availability

A number of mines have been developed and operated according to personal and/or company experience. The Australian mining scene is dominated by decline access with high-capacity conveyors, while the mining communities in Canada and South Africa have a predisposition towards shaft systems (Thomas 2013).

It is acknowledged that the pool of people that will be capable and available to develop and operate the mine will have an influence on the selected option. However, caution should be applied to ensure that the process of assessing the optimal case is not compromised by biasing the decision according to personal and company history and preferences.

Schedule

The schedules to implement the options need to consider the following:

- Access to the site. Depending on the location of the respective portal or shaft collar, time is required to access these locations, as well as develop pads for shaft sinking or portal construction.
- Availability of power, water, communications and accommodation. These may need to be constructed before development can start.
- Time to develop another underground access decline to assist with construction of either system; eg access to shaft sink/mid-shaft or access to provide multiple fronts for conveyor decline development.
- The shaft and decline construction method, which impact mobilisation and development rates; eg whether the shaft is a blind sink or raised bore, strip and line; whether the decline is developed by road headers or drill and blast techniques; and the number of headings that are being developed in parallel.
- The lead time in engineering, procuring and constructing the system.
- Other infrastructure aspects; eg primary ventilation, which impact the development and operation of the system selected.

Maintenance

High-capacity materials handling systems require skilled labour for adequate inspection, monitoring and maintenance.

If conveyors in the decline are chosen as the vertical materials handling system, only one type of fixed materials handling system requires maintenance. If shaft hoisting is selected, as well as shaft and winder maintenance being required, there is also maintenance required for conveyors that transfer ore from the footprint to the shaft(s) and from the shaft(s) to the process plant stockpile.

With both systems, teams of maintenance personnel are required and it is likely that external resources need to be mobilised to site for major shutdowns. The skill set required for maintenance of the hoisting option is more diverse than that for the conveyor option. Hoists are equipped with sophisticated control and safety systems which are further enhanced by statutory requirements, making the maintenance skills more costly than those needed for a small to medium-sized conveyor system. However, with the larger conveyor systems, the control and monitoring systems can be just as sophisticated.

Expandability and production rate

Figure 1 displays benchmarking of shaft and conveyor systems. The current limit of an individual hoisting system is ~10 Mt/a from approximately 1400 m. Conveyors are presently operating at 12 000 t/h, equivalent to 70 Mt/a;
however, a number of flights may be required to attain a certain depth.

In shaft systems, there is limited scope to extend the winders to achieve any significant increase in hoist rate and therefore mine production, should there be a production opportunity to do so in the future. An opportunity for a moderate increase in production capacity could be achieved by incorporating into the initial design some upgrade allowance; eg allowing space for extra head ropes on the drive sheave and a possible extra motor. A significant increase in hoist rate would require the installation of an additional hoist. It may be possible to achieve this by fitting an existing shaft with buntons and guides, or equipping an existing ventilation shaft. If no ventilation shaft is available, a new shaft needs to be sunk.

Existing conveying operations have shown that quite significant capacity increases are possible. Production can be increased by speeding up the conveyor system; for example, one conveying system originally designed for 4 Mt/a is now achieving 7–8 Mt/a. Before speeding up a system, the necessary checks need to be done on the conveying system’s mechanical and structural components and the mine services (power). As with shaft systems, an opportunity exists to design an upgrade allowance into the system at the onset without stepping beyond current technical boundaries.

Production system

The conveying system is a continuous system, where material that has passed through the crushers from any of the orebodies is then continually ‘in motion’ until it arrives at the stockpile at the process plant.

The hoisting system, by its nature, is a batching process and therefore ore storage bins are required to take up the surges presented by an individual process. The batching and starting/stopping of the material flow adds to the complexity and throughput of the system and therefore the associated control system. It also adds to the cost of the infrastructure required.

Power

The power supply upstream of the mine must be capable of handling not only the overall load expected, but also potentially a significantly varying load.

Conveyor drives, once started, essentially operate under continuous load and are better able to maintain a steady state draw on the power system.

Hoisting systems due to the batching nature of operation involve swing loading on the power system, which may have an impact on the power supply.

Therefore, the power supply needs to be sufficiently ‘stiff’ to handle the swings and peaks due to the constant accelerating and decelerating cycles.

Geotechnical

Before shaft sinking commences, a pilot hole is drilled to cover the entire depth of the shaft. Detailed logging and analysis provide information to the shaft sinking contractors for the calculation of detailed cost and schedule estimates. This essentially guarantees close to 100 per cent coverage of ground conditions to be encountered during the shaft sink. If poor ground conditions or aquifers are encountered in the pilot hole, there are two options to be considered. Can the ground conditions and water from the aquifers be controlled with known techniques? If not, relocate the shaft to another site and redrill the pilot hole.

Conversely, only sparse coverage of the conveyor decline path can be achieved due to the cost of drilling in detail over the length and spread of the area. An understanding of regional geology and existing structural models will give a reasonable estimate of anticipated ground conditions, but it will not achieve the same degree of confidence as a shaft pilot hole.

With the conveyor option, if difficult ground is encountered in advance of the decline face, there is the flexibility to adjust the decline alignment to avoid this ground. This decision would, however, impact on material transfer design and could potentially add transfer points and additional conveyor flights. The location of transfer chambers needs to be considered in the context of the geotechnical environment. Increasing conveyor capacity and lengths/lifts leads to larger chambers to house the transfer and drive systems. The size and location of these also dictate the alignment of the conveyor declines.

In shaft sinking, unlike the conveyor option, there is no flexibility to avoid difficult ground once the sink has commenced. Any difficult ground conditions that are encountered must be tackled and surmounted.

Another consideration is the effect of ground movement on the shaft or decline. For a caving operation, the extent of the cave influence zone affects the location of shafts, the alignment of declines and their respective infrastructure chambers. The size of the chambers where various elements of mine infrastructure are to be installed and their ground support requirements are influenced by the potential for ground movement during development and production.

Sterilisation

For ground stability in a shaft, a pillar needs to be provided. As a rule of thumb, the pillar starts at approximately 400 m radius and increases in size with increase in shaft depth and geology (Budavari, 1986). Should the mine pillar be removed prior to the shaft being sunk, it can be backfilled to provide some stability. However, if the shaft pillar is removed after the shaft is in operation, techniques are available that allow shaft steelwork to accommodate any movement that may occur.

Should a decline intersect a previously unidentified deposit, the decline direction can be changed. This would result in an additional transfer point and realignment of the remaining conveyor system. The additional transfer point and associated excavation may also result in additional costs.

The inclined conveying option for vertical materials handling also requires ventilation shafts that take time to excavate and whose design cannot be varied once excavation has commenced. These ventilation shafts also have the potential to sterilise an orebody, but it is easier to re-sink a ventilation shaft than to relocate an entire shaft hoisting system and overland conveying system.

Surface impact and asset security

Depending on the location of the shaft or portal relative to the process plant, a significant length of overland conveying may be needed. Ideally the conveyor decline portal and the shaft location are located as close as possible to the process plant. However, the decline portal or shaft may need to be located some distance from the plant due to various geotechnical, geological and topographical constraints.

For a mine in a remote, risky environment, the security of infrastructure spread across a wide area needs to be evaluated.
Ventilation
The life-of-mine primary ventilation requirements are principally governed by the virgin rock temperature, emissions from mining equipment, gas emanations, aquifers and the footprint of the underground mine working. The construction schedule also plays a key part in determining the primary ventilation requirements.

The hoisting shafts can also double as ventilation shafts and thereby reduce the number of shafts required. Normally the hoisting shafts are used as intake shafts and separate shafts are used for upcast air. Upcast ventilation air tends to be saturated and becomes super-saturated as it rises up the shaft. The increased moisture tends to accelerate corrosion of the shaft steelwork, ropes and conveyances. In addition, personnel travelling in upcast ventilation air need to wear suitable protective equipment.

The hoisting system has all the main heat sources on the surface (winder motor) and does not affect the mine ventilation system.

The conveyor option requires both intake and upcast shafts, as the conveyor decline can only deliver/extract a limited amount of air. The velocity of the air travelling along the conveyor decline is nominally limited to 6 m/s to minimise dust pick up on the conveyor and for discomfort felt by workers inspecting and maintaining the conveyors.

The inclined conveying option provides additional heat sources underground; eg from idler friction, drive assemblies and variable voltage variable frequency (VVVF) drives. As well, the ore transported on the conveyors spends a longer time in the ventilated air and dissipates more of the contained energy within the ore. This extra heat needs to be removed by the ventilation system.

Reliability/Utilisation
The conveyor system is a continuous, linear system where the failure or scheduled maintenance of any component within the system impacts on the whole production rate. A single-flight conveyor has an availability of approximately 99 per cent. An inclined conveying system with \( n \) conveyor flights has a theoretical availability of 0.99\(^n\).

Depending on the hoisting capacity, more than one winder system may be required, which means that some level of production can continue if one hoist is taken offline for maintenance. If the hoisting systems are contained within the one shaft, this may not be the case. Similar to the conveying system, however, failure of one of the lateral feed conveyors in the hoist system or the failure of the overland conveyor would also impact on the whole production rate. Winding plant availability is of the order of 98 per cent.

The overall availability/utilisation of the mine materials handling system also depends on the crushing and tram detection/collection systems, together with the run-of-mine (ROM) ore delivery to the materials handling system. Taking these into account with the vertical haulage system, the materials handling system utilisation is typically in the order of 70 per cent. The utilisation takes into account the statutory requirements for winding systems. Analysis of the utilisation usually reveals the supply of ore to be the restricting factor. Detailed simulation from mine to plant is recommended to establish the expected utilisation and surge buffers required (such as bins and stockpiles).

CONCLUSIONS
Inclined conveyor, shaft hoisting or a hybrid system are viable alternatives for the vertical haulage of primary crushed ore and waste to the surface from large, underground mines. Benchmarking shows that both options are prevalent around the world.

The aim of this paper is to show that the individual vertical haulage systems should not be considered in isolation, but from a holistic viewpoint. The selection of the preferred solution will be affected by and will affect, many other parameters that would be normally considered outside the battery limits of the vertical haulage system.

The process for selection of the preferred vertical haulage system needs to be rigorous to arrive at the most appropriate solution. To ensure an unbiased solution, personal preferences and experiences, albeit valuable input, should not dictate the selection process.

It is also recommended that an independent peer review of the process be undertaken to ensure that the final selection has been based on a holistic approach and has resulted in an unbiased outcome.

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