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A comparison of strategic mine planning approaches for in-pit crushing and conveying, and truck/shovel systems

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ABSTRACT

In a global environment where energy and labor are becoming increasingly expensive, continuous mining systems such as In-Pit Crushing and Conveying (IPCC) systems have been advanced as offering a real alternative to conventional truck haulage systems. The implementation of IPCC systems in hard rock operations in open pit mines however requires different and more comprehensive planning approaches in order to adequately reflect the practical aspects associated with these. This paper investigates the impact that these approaches may have on the implementation of IPCC systems on a basic metalliferous deposit amenable to open pit exploitation. A strategic life of mine plan to provide numerous economic indicators for each approach is analyzed and compared to traditional truck haulage systems. The mine planning and evaluation process highlights the increased overall resource recovery that may accompany the use of IPCC systems. This investigation also provides insights into the issues associated with IPCC and the scale and type of operation and orebody that is likely to provide a feasible alternative to truck haulage.

1. Introduction

The prolonged downturn in international commodity prices has forced major changes in the resources sector. Cost reductions for the purpose of improving productivity have become a central focus for most resource producers in order to remain competitive. In looking beyond current cost cutting initiatives, the next phase in the push to improve productivity will come from new innovations that transform the way traditional processes are carried out. Surface mining operations have historically been able to rely on increasing economies of scale using traditional discontinuous truck and shovel techniques. However, the scope to continue introducing larger and higher capacity trucks and equipment into mining operations in order to improve productivity is limited. Truck haulage is a highly energy, labor and water intensive operation. It is also associated with significant occupational health and safety risks, as well as impacting the environment through the production of dust and noise.

Mining operations are thus increasingly looking to more efficient, less energy and labor intensive, and safer methods to carry out the daily operations of a mine. Adopting continuous mining systems into the mining industry has been heralded as a means of providing the large scale productivity improvements that are so desperately needed. Continuous In-Pit Crushing and Conveying (IPCC) systems are gaining increasing attention in the recognition that these have the ability to offer numerous advantages over traditional truck haulage systems.

As the remaining 'easy' to reach near surface mineral deposits are exhausted and the approvals and financing process for new operations become increasingly difficult, mines of the future will become deeper, more remote, and more hostile. This will result in an increasing trend toward larger, higher capacity, bulk movement operations that will have to include material well outside previous breakeven economic cut-off grade boundaries. As such, overall resource recovery will need to significantly improve. Some countries, such as Russia, have legislative incentives that oblige companies to demonstrate maximum resource utilization. Future mining operations will have to deal with less favorable ground conditions with a drive toward consuming less energy while generating fewer greenhouse gas emissions. While these conditions present huge challenges in themselves, all this will be against a backdrop of more intensive public scrutiny over environmental awareness and community relations.

The aim of this paper is to highlight the fundamental mine planning aspects for the implementation of two main types of IPCC systems and how these differ from traditional truck and shovel operations. In doing so, a conceptual two dimensional metallifer-

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ous case study will illustrate the economic differences resulting from the unique strategic mine planning and sequencing requirements of each system in comparison to truck and shovel. This paper highlights the resource recovery associated with each scenario.

2. IPCC opportunity

Future resource extraction will inevitably be deeper and at lower grades compared to standard practice today. In order for this to occur under present circumstances, truck fleet numbers will need to significantly increase due to the longer haulage distances and consequently higher cycle times associated with deeper pits. With this increase in truck numbers, there is an associated increase in the workforce required to operate, and an increase in fuel consumption. These factors contribute to higher Operating Expenditure (OPEX) for mines utilizing truck haulage. These negative effects are further exaggerated by increased noise, dust and CO_2 emission levels generated by additional trucks, leading to a larger environmental footprint. IPCC systems offer several opportunities to substantially reduce the impacts of expanded truck fleets.

According to McCarthy and Turnbull, in order for IPCC systems to be an appropriate alternative haulage system, some key design parameters must be considered [1,2]. These parameters range from fundamental requirements, to practicalities, and preferences, including:

(1) Material movement of over 4 Mtpa is desirable in order to justify the initial CAPEX, though upwards of 10 Mtpa is better.
(2) A mine life greater than 10 years in order for the lower OPEX to pay back the higher initial CAPEX.
(3) Electricity costs ($/kWh) less than 25% of diesel cost ($/L).

Depending on the type of IPCC system used, labor requirements can be as low as 80 people, including operators and maintenance personnel [3]. Exact numbers will vary depending on the selected system, and the number and length of installed conveyors. It is estimated that one truck requires staffing of approximately seven people to operate. In a two 12-h-shift-day roster, this consists of 4.4 operators (0.4 to account for covering vacations and absences), and 2.7 maintenance workers [4]. From a labor and safety perspective, if an IPCC system is able to replace enough trucks to reduce the total number of workers, they become a more attractive option.

IPCC systems are typically run on electrical power, which reduces a mine's dependency on diesel fuel. Diesel fuel is a major contributor to the cost of truck haulage. If the volume of fuel consumption can thus be reduced, operating expenses of a mine will also be reduced. An example of this in practice is an iron ore mine in Brazil with two installed Fully Mobile IPCC systems with a combined capacity of 7800 t/h, resulting in an estimated reduction in diesel consumption of 60 Million litres per annum (MLpa) [5].

With savings opportunities arising from reduced labor requirements and reduced diesel consumption, IPCC OPEX can be significantly reduced when compared to truck haulage OPEX [6]. In addition, conveyor haulage is inherently more weight effective than trucks, requiring less energy per unit weight of material transported. Another important aspect is that, conveyors use more (81%) of the consumed energy for transportation of the payload in comparison to trucks (39%) [7]. It is estimated that OPEX of conveyor haulage can be as low as one-third of a comparable truck haulage system [4].

Though the OPEX of IPCC systems can be reduced significantly below that of a truck haulage method, the Capital Expenditure (CAPEX) required in order to use an IPCC system is often higher. Fig. 1 shows that although the IPCC system has a larger initial CAPEX, due to the reduced OPEX, after six years the mine breaks even, and the NPV of the IPCC case becomes significantly higher than the trucking case.

An additional benefit of lower diesel consumption is a reduction in CO_2 emissions. The 60 MLpa reduction in diesel consumption previously mentioned equates to a reduction of approximately 130,000 tonnes per annum (tpa) of CO_2 emissions [5]. This is approximately equivalent to the removal of 36,000 average passenger vehicles off the road each year [9]. In addition to the reduction of emissions, the reduced reliance on diesel fuel also means that less fuel trucks will be on the roads, reducing logistical demand on local road networks.

IPCC operations can also reduce the amount of dust that is released as an airborne contaminant. As there is less traffic on haul roads, due to the reduced truck fleet, less dust will be generated by the operations and less need for spraying haul roads, which will result in a saving of water consumption. Some water will still be required in conveyer systems for suppressing dust at transfer locations. Conveyors not only reduce the number of trucks required, but have also been stated as reducing overall auxiliary equipment requirements by 25–30% [10].

IPCC systems can also reduce noise pollution as a result of conveyors operating at a lower decibel level than haul trucks. Typically, haul trucks emit at a volume of 90 dB at a distance of 10 m, whereas conveyors emit at a volume of 70 dB at a distance of 5 m. For comparison, a conversation between two people 2 m apart requires a volume of approximately 60 dB [11]. This noise reduction can make them a useful system in areas where mines are located close to townships, or in areas where neighbouring properties are noise sensitive.

The combination of each of these financial, environmental and social advantages provides a clear justification for the more extensive use of IPCC systems now.

Though there are many manufacturers of the equipment associated with IPCC systems, there are no off the shelf solutions as each site will require a system that is uniquely tailored for its specific requirements. As such there is a range of available options regarding IPCC systems. Broadly speaking, there are three types of IPCC systems, with each setup having its own set of advantages and disadvantages for specific operating conditions and deposit type. The three broad categories are: Fixed, Semi-mobile, and Fully-mobile systems.

Fixed In-Pit Crushing and Conveying (FIPCC) systems are characterized by the crushing unit being situated in one location for an extended period of time. This location is usually located at some point near the crest of the pit, near the haul road exit point. Conventional truck haulage is used within the pit to move material from the working face to the crushing unit. Once the material has been crushed, it is fed onto a conveying network which transports it to either a spreader (waste) or stacker (mineralized mate-

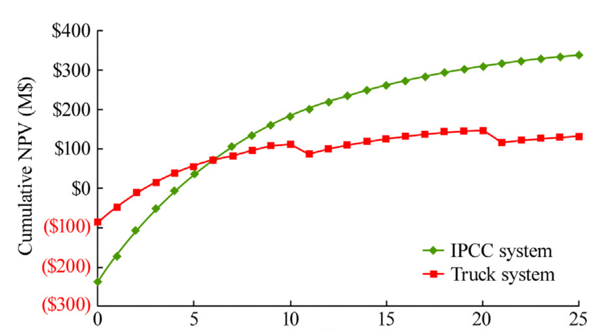

Fig. 1. Cumulative NPV comparing IPCC and truck haulage [8].