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Integrated optimisation solution: an innovative approach to mining operational success

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Mining companies have historically applied a combination of point solutions and local optimisation models within functions such as exploration, planning, operations and maintenance. Normally, multifaceted reports are created to guide downstream processes (often the next step in the mine value chain), or to inform upstream processes of opportunities to make corrections or for future process improvements. This traditional approach has limitations often associated with miscommunication of essential data and information, timeliness of the communications, impediments to effective collaboration that lead to wasted resources and time, increased energy consumption, increased risks to process quality, and increased risks to production.

New technological advances have created solutions that can help to address these problems. Development of an integrated optimisation model based on advanced data analysis methods can potentially create a solution that can enable improvements across the whole pit-to-port value chain. Specially designed to eliminate the costly inefficiencies arising from local legacy solutions, advanced data analytics solutions maximise the value of data generated throughout the mining value chain and facilitate more effective collaboration across the enterprise. As an example, this approach can provide operations and maintenance teams with visibility of overall performance and highlight critical performance drivers throughout the entire mining value chain. The opportunity this presents is to identify and correct in-flight processes and optimise business performance.

Let's explore this approach in some more detail. Activities like planning, operating and maintaining equipment along even a small subset of the end-to-end value chain like the 'mine, load, haul and dump' process is, in fact, very challenging. These are activities that are highly coupled and are threrefore guided by complex, nonlinear relationships. In our experience working with real datasets collected from operating mines, the simple, linear functional models that are often based on equipment manufacturers' data cannot be used to drive optimisation of mining processes. A standard 'plan, do, check, act' feedback correction approach can be used with insufficient success.

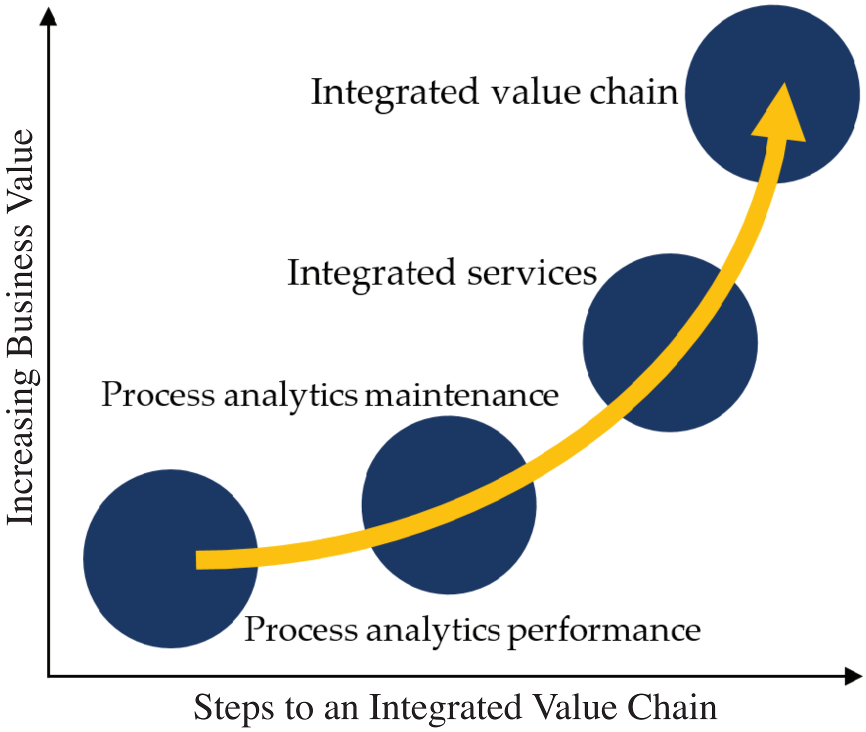

Figure 1. Creating business value from integrated value chain operations

Standalone mining applications that independently control activities like planning, drilling, blasting, loading and hauling processes, and only receive feedback from other value-stream process modules periodically, are unable to optimise the performance of the whole value stream, which is a highly coupled system.

This is where the new generation of advanced data analytics techniques can add value by creating an integrated optimisation solution (IOS). Tightly coupling equipment maintenance with planning and operations (for a bounded set of processes, like drill and blast through to milling) can be achieved by using an advanced data analytics approach. These advanced data analytics techniques can create an integrated value chain that can then be modelled and optimised using, for example, artificial neural networks (ANN) and genetic algorithm (GA) techniques.

Moving from optimising individual functional performance to optimising an integrated value chain, which incorporates the technical operations, is the step that will release new, extra value for the business (Figure 1).

We give an example of how to build the framework and building blocks for an IOS for the 'mine, load, haul, dump and mill' sub-process, but first, we've listed some of the important reasons IOS brings extra business value, along with some pointers about how this can be achieved.

An IOS eliminates expensive inefficiencies arising from local (functional) legacy solutions. Costly inefficiencies resulting from outdated enterprise resource planning (ERP) programs, often slow down feedback mechanisms that produce in lost improvement opportunities, or, in some cases, even unexpected penalties. IOS's ability to accurately model process and functional interactions decreases the risk of these occurrences.

An IOS will minimise the time wasted generating independent mine operation and maintenance plans. New

IOS-based planning and maintenance optimisation solutions will enable faster, combined planning, scheduling and operational management across increasingly extended parts of the value chain, enabling faster, more accurate decision-making.

To develop an IOS requires deep levels of collaboration between all the enterprise functions engaged in the IOS, whereas existing mining solutions need operations and maintenance to be managed at local levels. The collaboration required by the teams involved in creating an IOS delivers business value in itself – a greater understanding of how business processes interact and skills like root-cause analysis.

Applying an IOS approach can improve the performance of specific disciplines; published results report that IOS for mine planning increased overall performance and mining productivity by around 15 per cent.

An IOS can enable stakeholders to gain an understanding of the highly complex coupled systems they are dealing with, and helps them to gain a deeper insight into the way their mining processes operate in practice.

IOSs increase visibility into, and an understanding of, the mining value chain. In a rapidly changing industry, being able to adapt to change is of utmost importance. Better understanding and insights into how the entire value chain operates are critical for changes to be undertaken efficiently and at low risk. IOS models help with these.

IOSs minimise misalignment between modelled processes, eliminating any risks due to failures of communication – people- or technology-related.

Time efficiency is critical to mining operational success. An IOS minimises the overall time it takes to configure and install specific instances of an IOS. Using an IOS is a valuable way of reducing the time to set and deploy instances.

An example

The following is a simple breakdown of how we go about building the framework and the building blocks for an IOS – in this case, to integrate mining operations from the drill and blast function down to the mill.

A simple IOS starts with a comprehensive breakdown of the functions that are going to be included in the model. In this case, the process begins with the drilling operation, which is guided by mine planning data defining business requirements and drilling parameters. Ore deposit data provides geological and geotechnical parameters, along with technical and operational ones. Data is determining drilling parameters and economic data about the costs associated with the drilling and blasting operation.

The outputs from the drill and blast activities include parameters, some measured in process, that are critical to the efficient and productive operation of downstream processes. The 'next in line' processes are associated with managing the muck piles created by blasting and making preparation for loading the blasted products onto haul trucks for transportation.

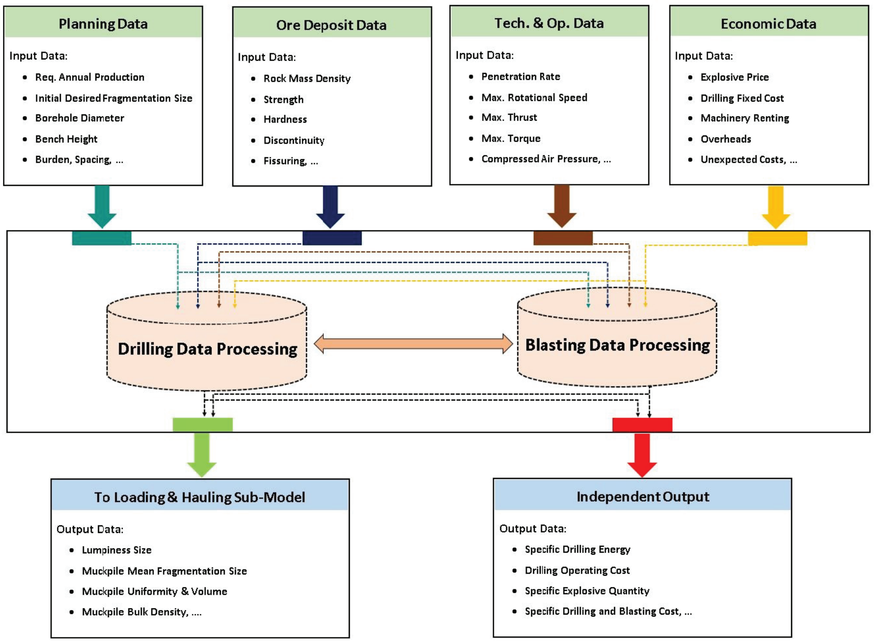

Figure 2. The drilling and blasting data model

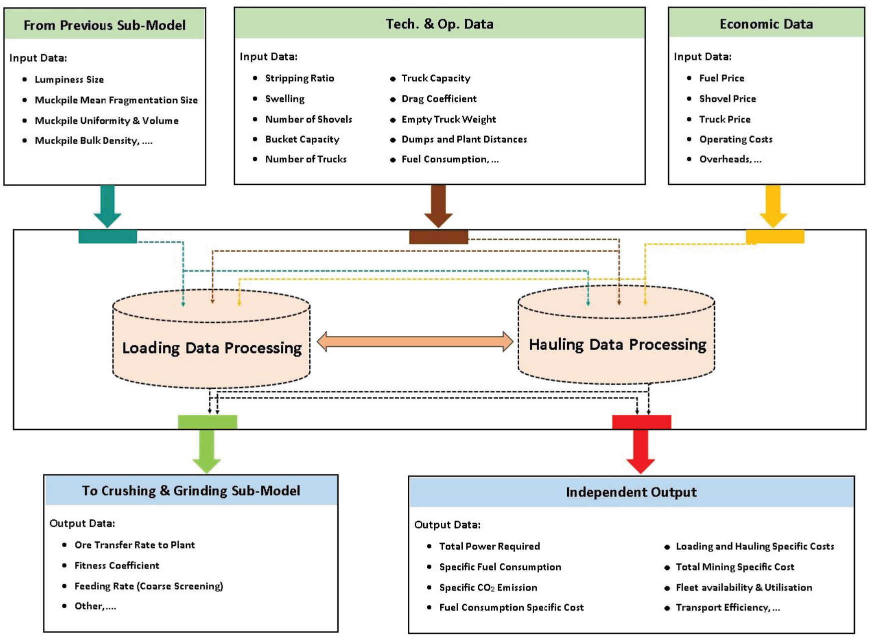

Figure 3. The loading, hauling and dumping data model

There is, of course, data that is not needed by the loading and hauling operations – but may be critical control parameters for subsequent downstream processes. For example, rock mass density, strength, and hardness were data inputs to the drilling and blasting process. This data was created by earlier survey studies. When drilling for blasting preparation, there is an opportunity to measure these (and other) geological and geotechnical parameters at each new hole.

This new 'actual' parameter data from the material that will be loaded and hauled and will end up in downstream processing is extremely valuable – provided it can be captured and communicated in an appropriate form and a timely manner to the downstream processing stage. There is also the opportunity to feed the data upstream to potentially adjust old data with new updated values that can then better inform the next round of drilling and blasting.

The next downstream process is loading and hauling – both waste (overburden) material and product. Hauling is followed by dumping at waste sites or processing locations – for simplicity, we have not included details of the dumping activity.

Critical measured parameters from the previous blasting activity are used to inform the loading and hauling, and dumping activities – provided they have been delivered in a timely manner and in a format that can be understood and used by the loading, hauling and dumping process. Sometimes data is not in the right format, doesn't have the same taxonomy or can't be delivered in time.

In this case, the previous sub-model delivers some data that can enable the loading activity to proceed more efficiently – for example, information about the muck pile's mean fragmentation size and mean

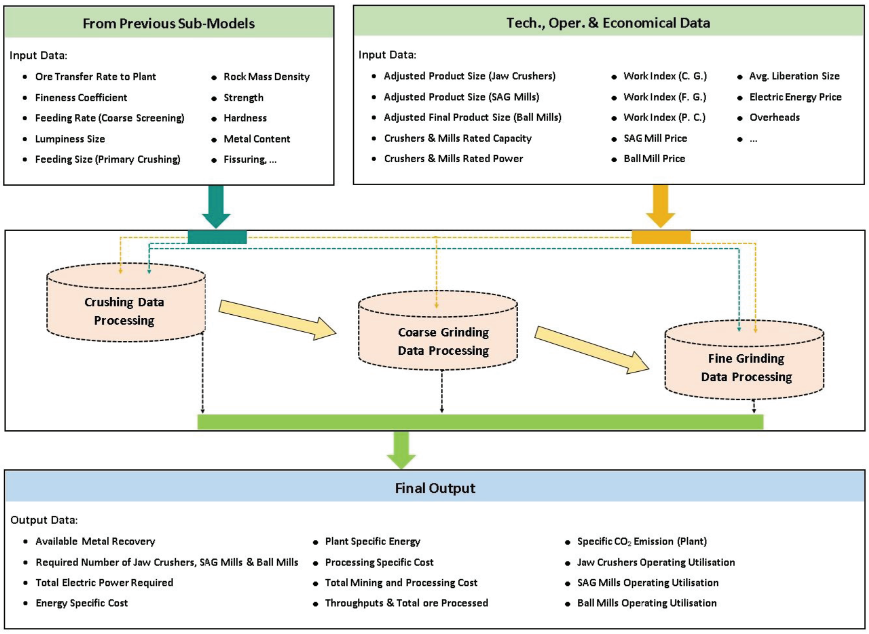

Figure 4. The crushing, coarse and fine model

bulk density may influence the choice of bucket size for a loading shovel – to minimise the number of passes to load a haul truck.

Technical and operational data is provided for this sub-process of loading and hauling – along with economic data about shovel, truck and other expected operating costs. There is an opportunity to measure real operating parameters, and use these to feed back in the actual operating costs and different operating settings so that the next estimates are more accurate as the loading and hauling operation executes.

The modelling continues with the next downstream process – in this case, the delivered product is crushed, and then coarsely and finely ground. Each of these individual activities can be modelled in a similar fashion until the critical parameters that control performance, cost, waste, et cetera, are evident.

Creating the IOS model

To identify the level of granularity needed to create an IOS for the end-to-end process requires deep expertise from the subject matter experts associated with each of the activities described.

These need to be identified, their importance to the overall efficiency of the value chain process estimated – or better still, measured in a series of analytical experiments to determine their contribution to driving improved operational efficiency (or other optimisation targets).

The critical aspect of the IOS approach is to identify the cross-process control parameters from each sub-process – the ones that influence the interactions between sub-processes as well as affecting individual sub-process performance. The ADA uses operational data, gathered from the end-to-end process activities, to analyse and then optimise overall performance – even if this global optimisation requires some sub-processes to run at less than their optimum performance.

An elementary and well-understood example of this could be the need to expend more effort or money on the drilling and blasting sub-process to improve fragmentation and thereby improve loading, hauling, and subsequent milling and processing.

A smart approach to this is to cycle downstream savings made in loading, hauling, et cetera, back upstream to self-fund the increased costs of drill and blast.

Extra challenges may arise, of course, when commercial constraints are overlaying the end-to-end value chain. If the drill and blasting are subcontracted, then there may be a reluctance on the part of the subcontractor to 'spend more' to provide value to another party who runs the downstream process that benefits.

Recycling the benefits in these circumstances requires some smart contracting, and one of the advantages of an IOS is its ability to incorporate complexities as part of the overall optimisation schema.

Closing thoughts

Mining processes are incredibly complex – in ways that make them significantly different from other highly complex industries like oil and gas, automotive, or aerospace and defence. They do share some aspects of operating and maintaining a costly plant that has to operate at very high levels of utilisation to deliver its return on investment. They have to operate in highly regulated environments, often in potentially dangerous conditions. They have highly repeatable processes that can be tuned and optimised to minimise variability and increase performance – productivity, efficiency, timeliness, and so on.

Like these other industrial sectors, mining can now measure and capture the operational performance of its equipment and mining processes, enabled by the recent developments in Industrial Internet of Things (IIoT), sensor, communication systems and cloud systems. The sector can use big data; can acquire new and emerging AI technologies; and can have an unprecedented opportunity to learn from adjacent sectors that have travelled the 'digital business' route already to create the digital mine.

The approaches we have discussed in this article describe how mining companies can start this journey, to build highly integrated, end-to-end models of their operations and then use new AI technologies to create the next generation of optimised mines, guided by IOS.

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