

# BOOSTING PROCESS STABILITY AND OUTPUT

**Nathan Flesher (USA) and Eben van Niekerk (Australia), McKinsey & Company,** describe a data analytics-based approach to improve the stability of coal mining processes and raise productivity.

**C**oal is by far the highest volume mined commodity, but to date, the coal industry has not taken a lead in embracing the new approaches being made possible by digital advances. Coal companies now have large amounts of data generated on the mine site. There is an important opportunity for the coal industry to benefit from the ways that other parts of the mining industry are already using this kind of data to make mining processes run more consistently with improved process stability and to boost output.

The gains from these approaches can be substantial. One large opencast mine was able to raise its overall productivity by 25% over a two year period, and now far exceeds top

quartile mining industry performance worldwide on truck and shovel output (as measured by McKinsey's MineLens Productivity Index, which benchmarks mine performance across 250 mines worldwide). The investment required to cover data capture, analytics and workforce training is in the range of US\$1 - 3 million, which is low relative to the impact typically achieved; initial benefits can be captured within three months.

## **Coal mining's productivity pain point: lack of process stability**

It is well recognised in coal mining, as in mining overall, that achieving stable operations is one of the industry's greatest challenges. This lack of stability is a major contributor to the way that mining lags behind many other industries on measures of productivity performance. Mines can have very good days when all the systems are working together and there are no equipment breakdowns, but they typically struggle to consistently perform at this level (Figure 1).

The consequences of this lack of stability are familiar to coal mine management. It causes inaccurate planning and suboptimal scheduling, which – at the mine face – can lead to excessive drilled inventory that is liable to collapse,

spontaneous combustion of coal stockpiles and excess fleet capacity. Further down the product delivery chain, unstable operations make it necessary to hold higher volumes of coal in stockpiles to ensure supply is always on hand, and to carry excess buffer supply at wash plants.

What can the coal mining industry do to increase process stability? The first step is to understand the nature of the instability. McKinsey has undertaken a series of analyses using a methodology, which is well established in the reliability engineering field, called Weibull analysis (see sidebar).

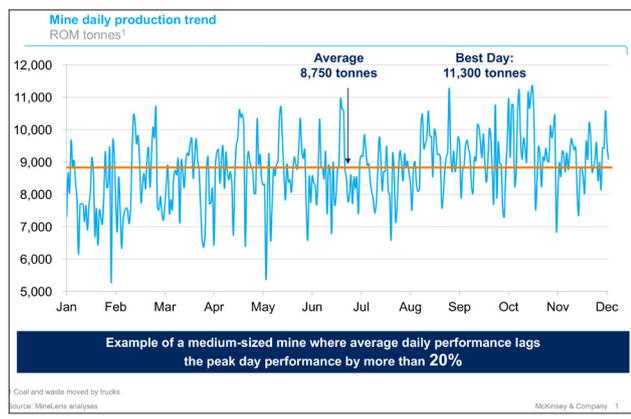


Figure 1. Typical daily mine production is unstable.

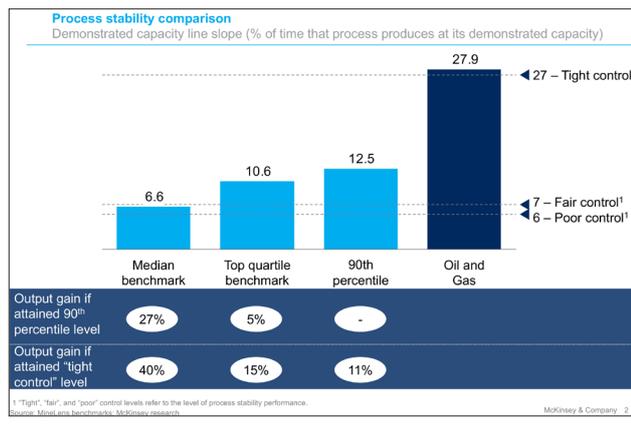


Figure 2. Process stability comparison.

**Example of how to manage load and haul cycles**

By using granular fleet management data, each round-trip is broken into the individual cycle component and measured against historical data points

Cycle component	Unique identifiers	Example of historical data points to use for a benchmark
Loading rate (tons/hour)	<ul style="list-style-type: none"> <li>Loader type</li> <li>Truck size</li> <li>Optional: loading location</li> </ul>	44 yd <sup>3</sup> rope shovel loading 350t trucks (optional: at loading face A)
Full haul (seconds)	<ul style="list-style-type: none"> <li>Truck model and series</li> <li>Route</li> <li>Optional: shift</li> </ul>	350t A-series trucks, hauling from loading face A to dump Z (optional: on nightshift)
Queue at dump (seconds)	<ul style="list-style-type: none"> <li>Dump location</li> </ul>	Dump Z
Dump (tons/hour)	<ul style="list-style-type: none"> <li>Truck model and series</li> <li>Optional: dump location</li> </ul>	350t A-series trucks (optional: at dump Z)
Empty haul (seconds)	<ul style="list-style-type: none"> <li>Truck model and series</li> <li>Route</li> <li>Optional: shift</li> </ul>	350t A-series trucks, hauling from dump Z to loading face A (optional: on nightshift)
Queue at loading unit (seconds)	<ul style="list-style-type: none"> <li>Loading location</li> </ul>	Loading face A
Spotting <sup>1</sup> (seconds)	<ul style="list-style-type: none"> <li>Truck model and series</li> <li>Optional: loading face location</li> </ul>	350t A-series trucks (optional: at loading face A)

1 "Spotting" is parking the truck in the correct position – or spot – to be loaded by the shovel.  
SOURCE: McKinsey's productivity model

Figure 3. Detailed fleet management opens the way to continuous improvement (haul cycle example).

Applying Weibull analysis to individual mines shows the range of performances seen in the mining industry, as well as how far mining lags behind other industries (Figure 2).

The performance comparisons between median, top quartile and 90<sup>th</sup> percentile mines point to how substantial the output improvements could be. For example, raising a median mine's process stability performance to the performance level of a mine at the 90<sup>th</sup> percentile would translate to a 27% output increase.

It is important to underline here that this kind of performance improvement is very much within these mines' grasp. Median mines have shown themselves to be capable of frequently having days of operation where daily output is in the top quartile, but they fall behind because they have not achieved it on a consistent basis.

How could the process be made more stable? The basic principle is to eliminate the excursions from the regular process steps. Most mining companies are making good progress on resolving major outages, such as longwall equipment failure. The bigger challenge is capturing gains in the more routine steps of the mine's operation. Here, McKinsey's experience working at a large number of mines worldwide suggests that mines have made major progress on availability and utilisation performance of their equipment, but there are still substantial challenges around operating rates. Achieving optimal rates under a mine's particular conditions and avoiding upsets to the process stability of all the interlocking steps of the mine's operations are high priorities.

## The way to increase process stability in coal mining

How can coal mines identify and correct the places where the process cycle is not functioning correctly and improve stability? Proven approaches from manufacturing industries, called short interval control analysis, can identify the excursions from the regular process. This can then be followed up by action steps to correct the problems.

The short interval control approach is based on breaking the mine's processes down into pieces of 'standard work', which make up the mine's overall operation. The mine's real life performance on these pieces of work is then compared to the standard work model. This must be done in a detailed way which takes full account of particular conditions across the mine, and expectations for rates should be tailored accordingly. Where there are shortfalls from the model, the causes can be investigated and steps taken to correct them. This kind of approach is used widely in manufacturing industries and is proven to generate performance improvements. Mines typically start by analysing historic data, then move to daily data, to shift data and, for mines at the leading edge of performance improvement, analysing cycle by cycle.

How has this been successfully deployed? Here are the steps that mines have followed:

### First

A fleet management system (FMS) – common at most mines – provides the foundation mechanism to generate

data on location, payload, speed and often additional information such as engine temperature, tyre pressure, suspension load and throttle position. Even in mines without a formal FMS, options are available to provide basic information to a central location. This data is gathered over cellular or other radio connections in real time to the dispatch system.

### Second

At a central dispatch location, this data is then processed and structured to allow its use in managing operations. Many mines use this data in real time for dispatch and historically for analysis, but mines can capture bigger gains by fully exploiting the system's capability, which allows more real time analytics and automation than is usually taken advantage of.

### Third

In parallel, a detailed theoretical model of the mine's existing operations must be built and broken down into a series of process tasks so as to make short interval control possible. Figure 3 shows an example of the detailed way in which load and haul cycles can be analysed and managed.

### Fourth

The operations of the mine are then monitored on a real time basis to find out how the mine performs vs the standard work model, using short interval control tracking analysis to identify the excursions from the standard process. The key to achieving substantial performance improvements is that when the mine supervisor identifies the excursions, he or she can address them right away. If the data shows that Truck A has taken the wrong road, then steps are immediately taken to get it back on the correct route. Analysis of performance across different time periods can also be undertaken: if the analysis shows Truck B is running slower than Truck C, regardless of which worker is driving over several days, it can be followed up with a checkup on the maintenance state of Truck B. Alternatively, if the data shows that Truck B only runs slower when driven by Driver X, Driver X can be assigned to additional training so that he learns to safely drive faster.

### Fifth

Using this approach, it is possible for a mine to continuously work on improving its performance, so that cycle times converge to the planned, ideal time. Continuous improvement can also include reallocating equipment and workers to tasks where they are best able to function. For example, one mine temporarily reassigned an underperforming truck to less

## Bringing insights from reliability engineering to improve coal mining process stability

The coal mining industry is not alone in needing to turn data into insights: many other industries have faced the same need to better understand their production processes and improve stability. One approach that has been successfully applied is Weibull analysis (also known as life data analysis). Originally used for failure analysis in reliability engineering, it is now being employed more widely. It is well-suited to mining because daily throughput can be used as the input parameter to assess process stability.

The methodology consists of plotting daily production (on the X axis) on a logarithmic scale against the cumulative probability of the mine achieving less than planned daily production (termed 'unreliability') on the Y axis (Figure 4). Once this is done, a best fit line (called the 'demonstrated capacity line') is drawn through the linear portion of daily data points. The slope of this demonstrated capacity line – referred to as 'beta' – indicates the mine's process stability, and this metric can be used to identify improvement potential. The steeper the line, the more consistent and, therefore, stable the process is.

The analysis identifies two potential improvement areas. The first is reliability losses ('R'), indicating an increase in potential daily throughput levels if major system failures are reduced. Examples of such failures include breakdown of primary equipment or key pieces of equipment such as a longwall miner or dragline, or flooding of the mine. The second is efficiency losses ('E'), indicating the potential to improve output by consistently producing at a higher level – in other words, with better process stability – which moves the demonstrated capacity line towards the nameplate capacity line. Improvements include raising cutting rates in underground coal mines, accelerating loading and hauling rates for trucks and shovels, and getting better equipment utilisation and higher quality maintenance.

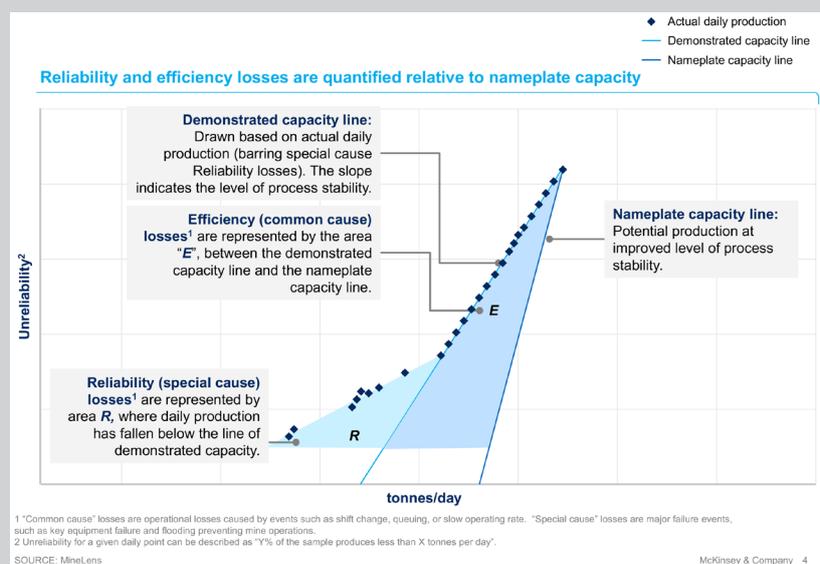


Figure 4. Using Weibull analysis identifies losses and points to ways to improve performance.

demanding tasks, such as flat hauls, so that it does not slow down the overall production process until the truck could be repaired. Targeting and maintaining rates that can be sustained on a consistent basis is of paramount importance: interruptions from outages caused by going too fast will upset the process stability of all the interlocking steps of the mine's operation as badly as going too slowly.

## Sixth

Successful mines typically back up these initiatives by building a mentality of continuous performance improvement across the workforce. They do this by training programmes and design of remuneration plans to create incentives for the workforce collectively and individually to constantly pursue continuous improvement. Here, there are many parallels with how workforces in manufacturing plants can be managed and incentivised, and the same kinds of approaches employed.

## Lessons learned and ways to maximise gains

It is important to stress that the primary objective of the FMS is to actively manage the mine's operations, and that successful mines invest a significant amount of time in carefully defining the tasks that constitute the mine's overall process. At many mines, the FMS is not used to its full power – for example, if its automatic dispatch capability has been switched off – or if auxiliary sources of information are not integrated – for example, from equipment health monitoring or eye gaze tracking. The full power of the site data is only realised by closely integrating all of these systems and

feeding the insights back to operators and frontline supervisors to adjust operations in real time.

There are three major pitfalls that coal mine operators must avoid if they want to capture the greatest potential benefits. The first is to accept from the outset that the insights generated by the data collection and analysis must be put to work: buying the equipment is just the first step and is not going to solve a mine's productivity problems.

Secondly, mine supervisors who are going to use the data and analysis outputs must truly have access to them, and have the capacity to be able to use them. Supervisors must not already be overwhelmed in their tasks, and must have the skills to discuss and improve performance with frontline operators. The key to success here is well organised training and supervision, and planning a programme of incremental and continuous performance improvements so the supervisors can properly learn the new approaches.

Thirdly, successful mines create a mindset from the beginning that the purpose of the analysis is to help capture performance improvements on a regular basis, and they do not let the analysis simply get used to justify reasons for poor performance. Again, the successful approach is best underpinned by well-organised training and supervision.

Where mines have implemented this approach, they have seen significant performance improvement. As noted, one large opencast mine was able to raise its overall productivity by 25% over a two year period. Its truck and shovel outputs are now 18% and 15% respectively, above top quartile mining industry performance worldwide, and the comparison to median level performance is even more impressive, surpassing median level performance by 43% and 54% respectively.

These types of programmes typically follow a S-curve pattern of gains: an initial round of performance gains is captured within 2 - 3 months, with a much more substantial set of gains captured over a period of 6 - 18 months as the mine supervisors and management learn how to deploy the analysis and start to build a mentality of continuous improvement across the mine workforce. The rate of gains then slows, which makes necessary a new round of performance improvement idea generation, prioritisation and implementation.

Coal prices may currently be on an upward trajectory, but as coal CEOs know only too well, coal markets are inherently volatile as coal suffers the whiplash effects of oil and gas prices and emerging market demand growth for steel. That is when the kinds of gains provided by the approaches described in this article could be all the more valuable. 



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