Employing operational excellence to optimize underground haulage systems

Jim Haughey, Product Director - Room & Pillar
Yiwen Sun and Joe Sidhom, Mining Engineers
Willem Fourie, Product Manager-Smart Services
Joy Global

These days it’s not enough to work harder, mines have to work smarter. Improving efficiency, reducing costs, increasing safety: these are no longer “nice to haves,” they are “must haves.”

Starting with the best products and the right people is a first step, but then what? How do mines take their operations from just OK to being a top-performer? By using operational excellence principles aimed at eliminating waste, simplifying processes, automating where possible and removing people from harm’s way.

The fundamentals of operational excellence (OpEx) are based upon the DMAIC Process, which stands for Define, Measure, Analyze, Improve and Control. DMAIC is an improvement cycle that helps with, for example, haulage optimization by: defining the issues and problems in the process as well as the areas of improvement; measuring and collecting mining operational data by time study and equipment monitoring system; analyzing through sensitivities and production modeling to determine root causes; then improving the performance and controlling the operation.

At Joy Global, we use Joy OpEx or “lean” principles inside our organization to drive efficiency, but we also help customers employ them to achieve new levels of productivity and safety. These same principles can be applied in most any situation, to streamline processes, improve operations and deliver value.

As applied to mining, operational excellence is seen as moving the needle on value creation by first identifying the value stream, then analyzing the areas that are not optimized. Once defined, these areas are “designed out” of operational processes to create an automated operational flow.

At a U.S. coal mine, Joy Global was brought in to apply Joy OpEx principles to optimize mining and haulage to improve productivity and reduce costs. This multi-phase process started by defining the existing systems challenges to start finding areas for improvement.

Define

Traditional room-and-pillar mining (R&P) is constrained by its reliance upon multiple pieces of mobile equipment. The standard R&P operation includes one continuous miner for extraction
and two shuttle cars or battery haulers to haul product. Defining the value stream map pictorially (Figure 1) helped define this customer’s challenges within the mining process. In this example, every cutting cycle took approximately 4 minutes to complete, and each shuttle car was only used for 3 minutes of the cycle.

Figure 1: Value Stream Map for Batch Haulage System: Value Stream Map is an OpEx tool to identify and understand the flow of materials or information required to produce a product or service for customers.

Measure

The next step was to measure and collect operational data from the mine site. Joy Global teams collect data in several ways: through site visits and by analyzing near-real time information as it comes off the machines.

Smart, connected machines are equipped with at least one of many communication technologies, the most robust of which is a broadband powerline modem with a physical data rate of up to 115 megabits per second. Data can be transferred from underground to surface, where a transcender enables the collection of data from more than 165 systems of underground equipment. Through a customized service package such as JoySmart Solutions, for example, technical specialists then provide 24/7 monitoring and support to mine site personnel. They also have communication with the machines underground and can assist with remote fault-finding and diagnostics.

Typical cycle information provided by a Joy Global analytics system is detailed below in Figures 2 and 3. Through the monitor and analysis of the real-time data, JoySmart teams can easily assess and visualize the operational data for each machine and conduct statistical analytics.
through complex algorithms to provide real-time feedback to the operator as well as shift summarized analytics.

Figure 2: Operational Data Monitoring System Using JoySmart Solution

In Figure 2, the color bars depict the motors’ running time. Joy Global analytics were used to extract the continuous miner tram time, each shuttle car load/tram time and feeder-breaker running time to determine an accurate picture of machine operating time and use, to look for opportunities for improvement in each cycle. This was a critical step to gain an understanding of the mine operation.

That data was also provided to the mine management information system (MIS) and our analytics system enables automatic exchange of data with the mine MIS. Reporting solutions are designed to emphasize the key performance indicators (KPIs) that are important to management. This reporting then supports the coaching and performance improvements of section personnel.
From Figure 3, one can see that in this example the miner loaded 83 shuttle cars during the shift, with an average loading time of 66 seconds per shuttle car. An average away time delay of 87 seconds is shown, and information on the operation and utilization of each shuttle car. This information is used to provide direction, allowing JoySmart personnel and the mine site to optimize productivity to drive results and move the needle in mine performance.

**Analyze**

Using value stream mapping and a monitoring system, constraints are identified and measured against the mine’s KPIs. In this scenario, the mine is looking to increase productivity by optimizing performance and equipment use, to ultimately lower operating costs.

A sensitivity analysis helps reveal several potential factors impacting the mine’s ability to achieve its desired results: number of shuttle cars, dump position and shuttle car tram distance, shuttle car capacity, and machine availability.
The number of shuttle cars and shuttle car haulage distance (Figure 4), for example, impacts the average utilization, which eventually impacts productivity. A key measure of tons per employee hour then is used annually to determine the net effect changes to the business. In Figure 4, continuous miner (CM) utilization is used to show productivity levels. In this example, maximum utilization was topping out at 38%, so for 62% of time the machine was not utilized. The optimized solution was determined to be three shuttle cars with tramming distance of less than 200 meters, to enable the section to achieve optimum performance.

Machine availability also has a significant impact on the productivity in the system (Figure 5). Machine availability percentage is calculated as follows: available time minus non-available
time. The sensitivity of one machine’s availability percentage impacts the whole system’s productivity.

Improve

There are many ways to help mines limit bottleneck and improve system performance. Some mines use super sections (example: one feeder-breaker serving two continuous miners) to maintain high productivity. In one super section, there are normally two continuous miner with four to six haulers. At this customer’s mine, one super section with two Joy continuous miners was able to achieve 9,600 tons a day. The advantage of a super section is to limit the downtime caused by feeder-breaker move up. The disadvantage is more labor is required. At this particular mine site, there are 17 people in this one system.

An alternative option is to employ a Flexible Conveyor Train (FCT), which provides continuous material clearance from the continuous miner, making it a continuous haulage system that significantly enhances safety while maximizing high-production tonnage output and lowering overall operating costs. The machine’s flexible conveyor and traction system allows it to operate as one single unit conveying material along its length while simultaneously tramming and following the continuous miner around corners and cut-through. This option offers safety benefits, as the FCT combines hauling into a single, relatively slow-moving machine that follows a known path of travel and requires only one operator using a remote control. Most importantly, the FCT eliminates the need for multiple mobile haulage units and eliminates delays associated with batch haulage.

This customer also tried a Joy FCT to improve system performance. With only 9 people in an FCT section, the system was able to achieve an average of 850 tons/person/per day, compared to the super section which only achieved 570 tons/person/day.

Adding an FCT to the haulage sensitivity table (Figure 6) provides a more than 15% increase in cutting time compared to the regular batch haulage system (utilization of 35% jumps to utilization over 50%), with an average of 20% improvement in production. Due to the higher efficiency and productivity a continuous haulage systems provides, along with the reduction of operators required, the average operating cost can be reduced with as much as 20% compared to a batch haulage system.
Employing the FCT improves safety, as well, by moving people from harm’s way. The system with FCT required only four workers/shift/section (with future reductions down to two workers/shift/section), compared to 10 workers/shift/section.

Control

Working through the OpEx process to determine areas for improvement is helping this U.S. mine convert to true continuous mining and haulage, a system that is designed to meet the strategic imperatives initially defined by the mining operation.
To monitor the process and improvements, data is collected and used to measure KPIs, to help the mine maintain control for optimized performance. Each machine and system has its own KPIs.

Mines will find the most success when they provide employees visibility to the process and the improvements. In this example, management at the U.S. mine is committed to “empowering employees within a simplified structure” that will support ongoing safety and efficiency goals. The latter is integral to success, as the OpEx process involves every person and every level of the organization. Visibility in a simplified structure makes the process clear, actionable and teachable.

There must be a “visible flow” of information, both qualitative and quantitative. Actions are visible via the ongoing availability of key data, which is shared throughout the organization. If the visuals are easily understood, every employee will be able to distinguish between what is a normal and a deviation, and be able to apply corrections.

To remain competitive in this market requires a complete, single-source approach to operational improvement – one that takes all processes and every worker into account. Done correctly, mines can achieve similar gains in productivity and cost reductions.

To learn more about Joy OpEx and JoySmart Solutions, visit www.joyglobal.com