Building a Better Maintenance Plan

Finding and putting the right pieces in place is getting easier as vendors offer innovative solutions for emerging challenges

By Russell A. Carter, Contributing Editor

Effective machine maintenance is an important factor in achieving operational goals such as improved productivity, safety and availability. A well-planned approach that combines sensible implementation with useful emerging technologies can bring benefits in maintenance-related cost, time and resource outlays.

When it comes to planning, the mining industry takes a back seat to no one. Scoping, prefeasibility and bankable feasibility studies and financing plans guide a company's path toward commercial development of a mineral deposit, while production, ESG, closure/reclamation and other plans outline strategies for operating a mine within the bounds of business and regulatory constraints.

In an industry where it may take 20 years to bring a major mine into production, nobody has to sell a CEO, CFO or even CIO on the value of project plans. They're simply part of the fabric that connects a promising concept to eventual operational reality. It might be a harder sell, however, when it comes to planning initiatives such as large-scale computerized asset management (AM) or equipment maintenance programs (CMMS), which are entirely optional and require top-to-bottom management commitment of time, resources and money to achieve goals that, to a skeptical observer, might seem more aspirational than empirical. Yet, it's generally recognized that mine design, equipment maintenance and production scheduling should be considered equally important elements in the overall planning process if the goal is to obtain optimum benefit from production equipment throughout the life of the mine.

Making the business case for enhanced maintenance planning is getting progressively easier, though, because it's an area in which mining companies now have the opportunity to obtain unprecedented value through the convergence of the industry's move toward digitalization with recent advances in technology that enable enhanced data collection and robust analysis. This makes it simpler to get a handle on machine-health trends, and along with the increasing unpredictability of external events that have the potential for affecting production, seems likely to push mining companies even more strongly toward adopting innovative methods for eliminating uncertainty in mine operations that are under their control. Maintenance falls into that category.

Looking industry-wide, mining-company maintenance programs are scattered along the spectrum of scope and sophistication, starting from those that depend on basic reactive maintenance strategies to others committed to predictive maintenance and PdM's more intelligent offspring, prescriptive maintenance (RxM). In fact, a 2021 GlobalData survey indicated that about 75% of the mining companies responding to the survey had made at least some level of investment in PdM for their fixed and mobile assets.

Without careful preplanning, however, organizations can run into problems right from the start of a maintenance-improvement initiative. Consultant firm McKinsey & Co., in an article aimed at explaining how companies can realize more value from their PdM efforts, highlighted several things that can stand in the way of a successful large-scale program, with most companies facing issues in one or more of these areas:

- Data is insufficient, inaccessible or of low quality;
- Technology is inadequate, with too few sensors or poor IT infrastructure;
- Prioritization is difficult, as companies lack a clear view of which assets to include in their PdM programs;
- Capabilities are missing, such as data engineers and data scientists required to build advanced analytical models;
- Change management is weak, often because of user-unfriendly design;
- Economic return is low, due the high cost of developing models to cover diverse assets and numerous potential failure modes.

Having an incomplete understanding of program elements and objectives was also identified as a basic issue by participants in a virtual workshop on asset management

conducted by the Global Mining Guidelines Group (GMG) in 2021. The factors listed as necessary to overcome common obstacles in the way of establishing a strong management framework — failure to include all departments, siloing, lack of integration between strategic planning and operational activities, etc. — included:

- Better articulation of the framework business value proposition;
- Pragmatic examples (of a simple asset) to demonstrate benefits to operational crews;
- Understanding the relationship between asset and maintenance management;
- Linking asset management and value drivers to financial incentives;
- Agreement on the ROI of a framework approach;
- Effective change management and communicating business value.

Data Dependence

With the exception of reactive maintenance, which requires no data at all to function as intended, all subsequent maintenance approaches from preventive maintenance (PM) and condition-based maintenance (CBM) on through to PdM and RxM require machine data, beginning with simple historical information on time and usage needed for PM and expanding to the massive volume of input demanded by RxM to learn root causes of machine failures and make suggestions for specific corrective action. This need for timely and comprehensive data might be a stumbling block in the industry's drive toward digitalization, according to some recent studies, because the likelihood of success depends on connectivity of IIoT systems. A 2021 report by satcom provider Inmarsat indicates that despite the accelerating speed of IoT deployment over the course of the COVID-19 pandemic, poor or unreliable connectivity is still a widespread problem in the mining sector.

According to the report *Industrial IoT in the Time of COVID-19*, 92% of all mining businesses experience connectivity challenges when trialing IoT projects and 72% don't find public terrestrial networks completely suitable for their IoT needs. Where terrestrial connectivity, such as cellular or fiber, is either limited or non-existent, mining respondents prioritize reliability (51%), latency (41%) and bandwidth/speed (40%). This focus on reliability of IoT connectivity is even more pronounced in certain countries such as Canada (60%) and Australia (57%), as both have vast remote territories with limited terrestrial connectivity. Additionally, only 10% of mining respondents in Canada said public terrestrial networks were completely suitable for their IoT needs.

Overall, the Inmarsat report said there is still a considerable amount of work to be done to improve IoT connectivity strategies, with only 39% of mining organizations using some form of backup connectivity to continue collecting IoT data in remote areas away from terrestrial communications. Again, there is a notable geographical variance here, with only 21% of mining businesses in Latin America electing to use some form of backup connectivity when they cannot access their chosen connectivity type.

An IDC 2021 Worldwide Mining Decision Maker Survey revealed that 86% of mining companies plan to invest in wireless infrastructure in the next 18 months, with most of them naming 5G as their priority because of its lower latency and higher bandwidth. Cellular and networking service vendors are aggressively refining and improving their 5G cellular platforms to handle industrial-grade demands in mining environments, often working closely with equipment suppliers to ensure integration throughout a mine's equipment fleet.

For example, Nokia and AngloGold Ashanti Colombia, in collaboration with Epiroc, Sandvik, Tigo and OSC Top solutions, recently conducted the first underground 5G mining trial in Jerico, Colombia, where AngloGold Ashanti owns and manages the Quebradona copper-gold project. According to Nokia, the successful trial proves it is possible to deploy multiple mining use cases over a private 5G industrial-grade network in a challenging underground environment.

Four mining use cases were tested as part of the trial including mission-critical communications, connectivity and remote teleoperation of vehicles, mining machinery and systems, and inspection and monitoring with drones and high-definition cameras. Nokia deployed an industrial-grade 5G private wireless network with speed in excess of 1 Gbps and ultra-low latency. The network is powered by the Nokia AirScale 5G portfolio in the 3.5 GHz spectrum band with the support of Tigo Colombia.

Nokia and Sandvik also are collaborating with Finnish technical research organization VTT to conduct 5G-powered research on advanced connectivity in underground mine applications. The Next Generation Mining (NGMining) project is funded by Business Finland and is aimed at bringing together industrial 5G private networks, edge computing and AI solutions to enable digital transformation in mining. The project's goal is to build Proof of Concept experimental systems to evaluate integrated connectivity solutions, which will then be tested in harsh underground mining environments. The objectives cover spectrum usage in the underground mining environment, 5G modems integrated in relevant machinery and user equipment, and edge computing.

For companies that already have a solid connectivity setup, another potential obstacle in the way of data-driven maintenance planning can be how to handle incoming data for maximum usefulness. As industrial optimization software developer AspenTech pointed out in a recent white paper*, there are a number of prescriptive maintenance solutions available on the market, and it can be difficult to know which one to choose. First, some questions need to be answered:

- Does the solution work using existing data and resources?
- How far in advance does the solution alert users prior to potential equipment breakdown?
- Does the solution provide precise failure pattern recognition so operators can act on predictions with confidence?
- How quickly can the solution adapt to new operating modes and processes?
- Can the solution be easily configured by a company's internal team?

With an eye toward providing a solution for companies that might have limited data-analysis resources, the most recent version of AspenTech's Mtell RxM software includes Aspen Maestro, a feature that automates the development of better models by guiding less-experienced users on how to build a particular model or agent. Maestro, according to the company, is an AI-based agent that can quickly and efficiently perform data analysis tasks that might take humans days

* Prescriptive Maintenance for the Metals and Mining Industry: From Assets to Enterprise; *Edward Bardo, director mining & metals, Aspen Technology.; Richard Diering, senior principal solution consultant, Aspen Technology: and Eduardo Gonzalez, senior account engagement consultant, Aspen Technology.*

As part of an overall maintenance plan, a tire management program like Kal Tire's TOMS can be implemented to establish and maintain benchmark tire care strategies including inspection frequency and guidelines, tire rotations, target cold pressures and rim non-destructive tests (NDTs).

or even months to perform. These include identifying multiple failure modes that share identical root causes, searching for different operating states that result in similar outcomes, distinguishing cascading failure modes where one event causes others, explaining failure modes using first principles, and identifying failure modes that may take months to evolve.

Potential savings from this level of analysis can be sizable. AspenTech highlights several examples of how Mtell can potentially pay off for users, involving repair and lost production costs for both mobile and plant equipment applications:

Continuous Miners – Monitoring cutter motors to schedule planned maintenance. Potential savings: $300K/yr.

Haul Truck – Using machine learning to optimize scheduled maintenance for ultra-class haul truck engines. Potential savings: 10% reduction in maintenance spend.

Conveyor Belt – Identifying gearbox oil imbalance on startup in advance of actual problem occurring. Potential savings: $1 million per failure.

Crusher Conveyor – Taking early, less-disruptive action to decrease the likelihood of a major asset breakdown. Potential savings: $500,000.

Pump – Using data to replicate the wear pattern of faulty pumps and apply it to additional pumps, demonstrating scalability. Potential savings: $2.5 million/yr.

Back to Basics

Two of the most essential maintenance activities at any mining operation are tire care and equipment lubrication. The task of administering these basic services to mine equipment fleets that face unique combinations of high payload demands, long shifts and wide exposure to extreme weather conditions is a formidable challenge to any maintenance organization or plan – but potential solutions are available from a variety of sources. Here are just a few examples.

Haul truck "hot tire" incidents can be highly detrimental to production, and their detection often depends on an operator smelling smoke or seeing some other indication of a problem. But what happens when a mine turns to autonomous haulage and operators are no longer needed?

Kal Tire's Mining Tire Group and Australia-based computer vision specialist Pitcrew AI have developed a tire monitoring system designed to offer mines autonomous detection of hot tires, tire separations and other tire and mechanical damage without the vehicle needing to stop. Inspection anomalies are automatically transmitted into TOMS, Kal Tire's proprietary Tire Operations Management System.

"Tire pressure monitoring systems (TPMS) can give a strong picture of what's happening inside the tire, but so much that can indicate the potential for tire failure happens outside the tire. We knew if we wanted to give customers the ability to make better operational decisions – and be a part of the future of autonomous mining – we'd need to add external telematics to the mix," says Dan Allan, senior vice president, Kal Tire's Mining Tire Group. "Pitcrew's AI, and their vision for the technology, supports our goal of solving customer challenges in practical, impactful ways."

"Autonomous inspection will be a requirement for the autonomous fleets of the future," said Tim Snell, managing director of Pitcrew AI.

The automated inspection stations monitor front and rear tires of mining trucks passing by. The AI software searches the thermal imaging video footage for anomalies such as hot spots, belt edge and tread separations and other mechanical problems. These findings are reported into TOMS. The system then automates inspection work orders as part of a self-reinforcing feedback loop and then schedules tire change work as necessary based on damage severity.

"We are really excited by the potential of what we might find when we combine the Pitcrew data with TPMS and our other data streams. Together, these tools bring incredibly valuable information about how the tires are performing and we intend to build predictive models that will enable Kal Tire and our customers to make better and earlier decisions about preventive tire repair or replacement, and that will have a significant impact on driving haul truck productivity and safety," said Christian Erdélyi, TOMS system and implementation manager at Kal Tire.

After a successful demonstration of system operation in hot weather regions in Western Australia, Kal Tire worked with Pitcrew to develop a cold weather version capable of withstanding temperatures of -45C. A test 'winter model' is now operational in northern Canada.

"There is also great potential for this real-time inspection technology in underground mines where doing regular equipment inspections can be challenging as well as to support the growing move towards autonomous mining. We recognize that this is new technology and how important it is to get it right, especially in the autonomous space," said Erdélyi. "That's why we're investing resources so heavily in this solution. Our vision is to offer Pitcrew as an integrated solution along with TOMS as part of Kal Tire's service offering."

2021 was a grim experience for high-volume lubricant consumers, with prices

for oil, grease, chemicals, coolant, DEF and related products rising in double-digit, multiple increments throughout the year. But however important the price of lubricants may be, the financial impact of poor choices or incorrect usage can eclipse the purchase cost of these products. When a major piece of equipment breaks unexpectedly from a lubrication problem and immediate replacement of that asset isn't possible, the total cost of the failure from lost production, expedited parts delivery, unscheduled labor and related expenses can reach into the million-dollar range at large-scale mining operations.

Various levels of lube-service management and monitoring services designed to help customers achieve total cost of ownership (TCO) savings through lower maintenance costs, reduced equipment downtime, and productivity improvements are available from every major lubricant supplier, such as ExxonMobil's Mobil Serv suite, Chevron's Lubewatch oil analysis service or TotalEnergies' TIG 6 system.

Here's how Thejas Srinivasan, commercial brand advisor–fuels and lubricants, for Canada's Imperial Oil Corp., explained Mobil's approach during a show-floor interview at MINExpo 2020 (Imperial is 69.6% owned by ExxonMobil): "Our Mobil Serv suite covers various types of services and part of that is our field engineers working with maintenance managers to optimize their strategies. We've been able to work closely with customers to help extend their PM intervals. If you don't have to bring equipment in for an oil change or a filter change [as frequently], and if you can eliminate half the PMs that you're doing, that's more time that the fleet can be out in the pit."

"Under our Mobil Serv umbrella, we're launching a new digital product called Mobil Serv Asset Management. It's a product that's really meant to enable maintenance managers to look across the entire fleet to understand how compliant they are with their maintenance tasks. This new system also integrates with legacy systems, some of which can be very cumbersome and difficult to use. This is an app-based, mobile-friendly product. When you have a technician out in the field who completes a task, he clicks a button to record that it's been done. If he sees a piece of equipment that needs work, he can click a picture and you can set it up so it automatically generates a work-order. It's a very slick new technology and a lot of mines are expressing interest in it."

Upgrade to Minimize Upkeep

Although not technically a "plan," one of the most effective ways of reducing maintenance is simply to buy wisely – not just consumables, but primary production equipment, repair parts or service upgrades, as well – with a goal of minimizing maintenance concerns by taking advantage of improvements in equipment design and available services.

The potential benefits of upgraded machine design are illustrated by Caterpillar's recently-introduced D10 dozer, which features a larger engine oil sump that extends oil change intervals, and new push arm bearing inserts that are claimed to improve reliability and reduce overall rebuild time. In addition, Cat said its new 992 wheel loader offers extended major component life and up to 10% lower maintenance costs through features such as improved hydraulic systems filtration and pump prognostics for the implement pump that reduce machine downtime. The new loader displays the remaining useful life for the engine air filter, allowing technicians to plan ahead for machine servicing. S·O·S fluid sampling ports are accessed from ground level and filters are organized by type and change interval to increase maintenance efficiency.

Cat also announced in 2021 that it was expanding its portfolio of Customer Value Agreements (CVAs), a selectable package of support and maintenance agreements that can be tailored to meet specific customer needs. Among the new CVA offerings are Maintenance for Mining, with which Cat will deliver the right parts at the right time, kitted for each maintenance interval, lowering total cost of ownership by optimizing drain intervals; and powertrain, undercarriage and hydraulic hose CVA options that variously provide zero upfront cost, protection beyond standard warranty coverage, inventory management and other benefits depending on the specific CVA, some of which are available globally and others on a regional basis.

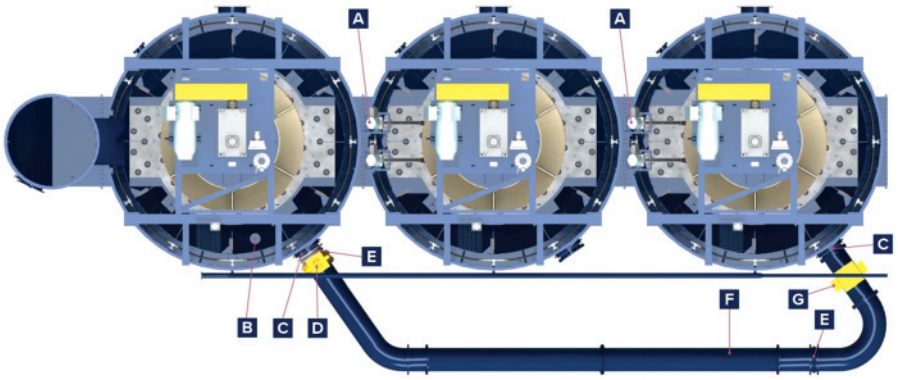
At MINExpo, Adam Kropp, senior product manager–aftermarket at Komatsu, called attention to the benefits offered by OEM repair or replacement parts, which may have been redesigned or upgraded from the original and can often provide better service life and improved performance. Using the company's line of large-capacity mining shovels as an example, he noted that Komatsu's Delta Max crawler shoes have a 20% life increase over the standard Delta shoe, with design features that include a solid roller path with a filled core to help increase shoe life by increasing the resistance to crush; raised roller path, to improve overall system clearance to help extend life; and larger pin size that is up to 35% stronger than standard pins for increased fatigue life. The shoes can be installed on any P&H 4100 series shovel with the Delta undercarriage system.

Kropp noted that the company takes customer requests for machine improvements seriously and pointed to a lubrication system upgrade – in this case, a positive pressure grease system that the company designed in response to customer input and recently added to the catalog for its 2350 series hybrid-drive wheel loaders – that in some applications has provided up to a 200% increase in the life of that model's hoist cylinders.

Opportunities for improvements in maintenance planning and performance through parts and service upgrades aren't limited to the mining side of operations. Inside the plant, grinding mill and flotation cell maintenance, for example, can be risky from both a safety and production-loss viewpoint, as well as labor-intensive if spillage or leakage occurs. Maintenance-focused software and hardware products designed to control and reduce that risk are available for both applications.

ABB just released a new version of its Ability™ Predictive Maintenance solution for grinding, described as a unique advanced digital service to maintain, assess and analyze gearless mill drive (GMD) systems. According to the company, the system is now cloud-based instead of sited on premises and includes a new mobile application that allows real-time notifications on fleet status. The Grinding Connect mobile app, available for iOS and Android, lets mine operators monitor performance at any time and from any place.

ABB said the product provides easy access to GMD system parameters and allows visualization of performance considering past activity and real-time data and assesses future maintenance requirements. It aims to extend the lifetime of grinding assets through better use of resources. It facilitates greater data gathering; the data sample per mine is increased and analytics and trends are more reliably defined. The solution offers fully custom-



FLSmidth's Flotation Bypass system provides a way to bypass a single flotation cell for service without need to shut down the entire line. Major components include: (A) upstream/downstream isolation flange, (B) Multi-Sense level sensor. (C) modified manway hatch, (D) knife gate valve, (E) flexible expansion joints, (F) Piping segments, and (G) pinch valve.

izable dashboards, alarms and events, all available on the mobile app.

The company pointed to Predictive Maintenance for Grinding's successful use at the Project Riotinto copper/silver mine operated by Atalaya Mining in Andalusia, Spain, where it's being applied in combination with a long-term service agreement, or LTSA, to support Atalaya's SAG mill operation. In recent years, Atalaya has depended on higher mill throughput and metals recovery to offset lower grades of ore, and the LTSA, according to ABB, provides lifecycle management to plan, coordinate and execute services, including corrective, preventive and predictive system maintenance, rapid response to emergency calls and an adaptive approach to meet modifications in production, maintenance or shutdown schedules.

For flotation circuit maintenance, FLSmidth offers Flotation Bypass, a custom-designed system that provides a means of bypassing an individual cell in a flotation cell bank without the need to shut down the entire line for extended periods.

The bypass system, according to the company, is an uncomplicated operation that works on the same principle as a typical gravity-based dart valve system. It does not need to be connected to the plant's main control system. The bypassed cell is safely isolated from the others by installing an isolation flange on the upstream and downstream dart valve openings. Key benefits of the system include reduced downtime and improved safety, as maintenance work can be performed on isolated cells without risk of slurry overflowing the cell. Its modular design allows the system to be moved up or down the flotation bank to bypass all but the first cell.

Conveyor Tech Can Cut Maintenance Needs

A customer poll conducted a few years ago by a major conveyor-component supplier showed that conveyor systems are the most problematic mine asset type in terms of reliability. And, as R. Todd Swinderman, CEO emeritus of bulk material handling solutions provider Martin Engineering, pointed out recently, conveyor systems are getting wider, faster and longer, requiring more energy to operate and needing better control of throughput. Plant managers must closely review which new equipment and design options align with their long-term goals for the best ROI.

In most cases, with only a marginal adjustment to belt speed, operators quickly discover unanticipated problems in existing equipment and workplace safety, commonly indicated by a larger volume of spillage, increased dust emissions, belt misalignment and more frequent equipment wear/failures. These problems – all of which have direct impact on maintenance requirements – often can be alleviated by new technologies and improved design, according to Swinderman.

For example, as belts get longer and faster, modern tracking technology becomes mandatory, with the ability to detect slight variations in the belt's trajectory and quickly compensate before the weight, speed and force of the drift can overcome the tracker. New upper and lower trackers utilize innovative multiple-pivot, torque-multiplying technology with a sensing arm assembly that detects slight variations in the belt path and immediately adjusts a single flat rubber idler to bring the belt back into alignment.

Faster belt speeds can also cause higher operating temperatures and increased degradation of cleaner blades. Larger volumes of cargo approaching at a high velocity hit primary blades with greater force, causing some designs to wear quickly and leading to more carryback and increased spillage and dust. In an attempt to compensate for lower equipment life, manufacturers may reduce the cost of belt cleaners, but this is an unsustainable solution that doesn't eliminate the additional downtime associated with cleaner servicing and regular blade changes.

Swinderman noted the latest trend in belt clean blades: Heavy-duty engineered polyurethane blades made to order and cut onsite. Using a twist, spring or pneumatic tensioner, the primary cleaners are forgiving to the belt and splice but are still highly effective for dislodging carryback. For the heaviest applications, one primary cleaner design features a matrix of tungsten carbide scrapers installed diagonally to form a 3-dimensional curve around the head pulley. Field service has determined that it typically delivers up to 4x the service life of urethane primary cleaners, without needing re-tensioning.

Looking further ahead, an automated system can increase blade life and belt health by removing blade contact with the belt any time the conveyor is running empty. Connected to a compressed air system, pneumatic tensioners are equipped with sensors that detect when the belt no longer has cargo and automatically backs the blade away, minimizing unnecessary wear to both the belt and cleaner. Additionally, it reduces the labor needed to constantly monitor and tension blades to ensure peak performance.

It's clear, he concludes, that automation is the way of the future, but as experienced maintenance personnel retire, younger workers entering the market will face unique challenges, with safety and maintenance skills becoming more sophisticated and essential. While still requiring basic mechanical knowledge, new maintenance personnel will also need more advanced technical understanding. This division of work requirements will make it difficult to find people with multiple skill sets, driving operators to outsource some specialized service and making maintenance contracts more common.