MINED OVER MATTER
The Not-Too-Distant Future of Autonomous Operations
The mining industry has shown a growing interest in automation

As self-driving vehicles continue to mature, and the Internet of Things (IoT) and wireless connectivity become more widespread, the mining industry has shown a growing interest in automating haul trucks and other mobile equipment. Today, a number of companies have fleets of autonomous trucks, trains and loaders at mine sites, or are piloting the use of these vehicles.
These efforts are a great leap forward from traditional practices, but they are just scratching the surface of how autonomous systems can be used in mining. With constantly advancing technology—and especially the increase in the intelligence of systems—autonomous operations have the potential to significantly increase efficiency and productivity.

More importantly, they will provide miners with an opportunity to meet growing demands for environmental and social goals, including increased safety and sustainability.

To reap those far-reaching benefits, miners should look beyond automated vehicles and bring autonomy to a range of mining activities, thinking of autonomy as an embedded, fundamental capability. Doing so will make mining more productive, safe and sustainable—and, ultimately, more competitive.
Mining’s changing imperatives

In the mining industry, “purpose” has become an increasingly critical factor for a variety of stakeholders.

Consumers are demanding responsibly sourced products from companies that provide fair and safe employment for their workforces, while looking after the environment and the communities in which they operate. And those consumers are far more informed than they once were, thanks to the internet and social media.

Investors, too, are weighing in. Increasingly, they are assessing companies on social factors, such as their environmental record, carbon footprint, greenhouse gas (GHG) emissions and energy consumption, along with their safety record and workforce benefits. Investors are also seeing value in behavior that leads to less risk and more reward—and they are becoming less willing to invest in companies that do not measure up.
Safety is increasingly important to governments and local communities as well. While the industry has nearly halved the number of annual fatalities over the last decade, there is still a long way to go in eliminating fatalities altogether—and stakeholders would like to see those statistics improve.

These pressures are evident in the growing demand for companies to assess their performance against a Triple Bottom Line—one that measures social, environmental and financial performance. And some mining companies are starting to respond. BHP, for example, has announced that it is going to begin using social value when assessing business plans for its operations.1

The growing pressure for environmental and social action is likely to accelerate in the next few years, putting new demands on miners. At the same time, the traditional pressures to be efficient and cost-competitive are still very much in force. Autonomous operations have the potential to succeed on both fronts—but the extent of that success will depend on how new autonomous capabilities are built and deployed.
Autonomous operations: A broader view

Today, a number of mining companies are exploring the use of automated equipment at mine sites.

These initiatives often focus on individual pieces of equipment and, especially, the automation and remote operation of haul truck fleets. These efforts are, for many, still in the early stages, with just three percent of mobile equipment in the industry being autonomous.\(^2\)

In Accenture’s view, autonomous mine operations can and will go much further. Rather than just automating equipment, autonomous operations will encompass entire processes—in engineering, production and supporting business activities—that manage themselves and adjust to changing conditions with little or no human intervention.
Consider, for example, how the operation of trucks might evolve as mines embrace a broader view of autonomy.

Today, an automated truck will follow a pre-programmed path from one point to the next. It is not connected to other pieces of equipment around it, and it is operated through a central control system, with humans frequently needing to correct its actions.

In a more advanced stage, autonomous trucks will operate largely on their own and automatically adjust their paths to accommodate obstacles and variations in conditions. Each truck will communicate with a central control system, where the coordination of various pieces of connected equipment will be handled by remote human operators.
Finally, with full autonomy, the individual trucks in the fleet will be connected to one another with a situational awareness of their own state and all surrounding pieces of equipment.

Operational decisions and responses to changing conditions will be handled by the system, with the goal of optimizing the entire operation for the best overall outcome. Humans will still oversee this activity, but little to no intervention will be required.

While the deployment of automated and autonomous operations is still relatively limited, experience is already demonstrating that autonomy can enhance productivity and reduce costs in many ways.

Autonomy typically increases equipment utilization rates because it enables continuous operations; autonomous trucks, for example, do not have to stop to let humans rest. Looking at specific activities, mining companies report productivity improvements of 15 to 30 percent from autonomous hauling. In addition, maintenance costs can be reduced through more consistent machine operation. One heavy equipment manufacturer reports that the tires on its autonomous trucks last 40 percent longer because those vehicles experience less sudden acceleration and abrupt steering movements.

RESOLUTE MINING IN MALI
Perhaps the fullest example of autonomy at work is a Resolute Mining operation in Mali. There, the company operates the world’s first purpose-built, fully autonomous, sub-level cave gold mine. The entire production operation—drilling, charging, blasting, loading and trucking—is carried out via an autonomous system.

This has reduced the cost of gold production by $135 per ounce and cut mining costs by 30 percent.
While these examples are relatively isolated, they provide a sense of the potential value that the broader use of autonomous operations could deliver.

Autonomous operations can help miners meet increasingly important social goals as well. More efficient and productive operations go hand-in-hand with greater sustainability. Autonomous operations have the potential to reduce fuel consumption and GHG emissions due to more efficient transportation and a reduction in the equipment starts and stops that are required to accommodate humans.

Efficiency in drilling and other operations can help reduce the consumption of water and energy, as well as the generation of GHG emissions and waste. And having more employees working remotely rather than flying in and out of mine sites can help reduce a company’s carbon footprint.

Meanwhile, increased autonomy will improve safety simply by reducing exposure to risk, as fewer operators use heavy equipment or work in hazardous areas. Problems such as operator fatigue, or errors in judgment that lead to accidents, will be largely eliminated.

Overall, the World Economic Forum has projected that automation and robotics will cut injuries in the mining and metals industry by approximately 10,000; connected worker technologies by approximately 22,000; and remote operating centers by approximately 12,000 over the decade ending in 2025—a period when autonomous operations have just been getting a foothold.6
Building the business case

To demonstrate the potential value opportunity of any autonomous operations initiative, it is important to compute the tangible benefits for each case.

Taking autonomous trucks as an example, the primary gain influencers can be divided in two dimensions:

**Cost Reduction Factors**
- Fuel
- Tires
- Maintenance
- Driver labor costs
- Asset lifetime improvement (leading to cost reduction in fleet replacement)
- Roads preparation
- Fleet size reduction

**Revenue Increase Factors**
- Truck physical availability
- Truck utilization
- Truck overall equipment effectiveness increase (a function of availability and utilization)
- Truck operating speed increase
Of course, the investment in updating the fleet needs to be considered. This includes the cost to retrofit conventional trucks with autonomous hardware and software, or the cost to replace old trucks with fully autonomous ones.

That means, trucks designed without an operator cabin that are able to drive in forward or reverse direction without maneuvering, converting the extra space and free weight into more transport capacity. Other parameters considered are truck operator wages, which vary from one country to another, ore market value that is seasonal, fuel and tires costs, etc.

A good way to calculate the overall benefits is simulating the current and future mine operations using a Monte Carlo simulator.

The distribution function for each parameter will be characterized by its minimum, maximum, mean and the standard deviation. The correlation between factors also needs to be considered, for example, the percentual fleet size reduction is dependent on the life-of-truck increase.

This simulation model needs to be built to each specific case, considering the fleet size, operators’ wages and other parameters of the given operation. There is academic literature available online, showing the results of generic simulations.
The building blocks of autonomy

Bringing more autonomy to mining will require technologies ranging from the IoT to extensive connectivity.

But the key to taking autonomy to the next level will be the increasing use of intelligence in systems, in the form of artificial intelligence (AI); machine learning; robotic process automation; descriptive, diagnostic, predictive and prescriptive analytics; and scenario modeling.

These technologies allow systems to understand the data flowing through operations, enable situational awareness, develop near-real-time insights into operations and determine what options to consider. They can be used to support human operators and, ultimately, guide automated decision-making and responses to changing conditions—a capability at the heart of truly autonomous operations.
Advanced analytics, machine learning and scenario modeling are already embedded in some mining operations, and they are being tried and tested in others.

These efforts provide glimpses into how these intelligent technologies will enable more automated decision-making. For example, these technologies are now being used to:

• Assess large volumes of drill core data, mine survey data, bulk sampling and soil and stream sediment samples to refine ore-body models and, ultimately, help guide more successful exploration.

• Enable autonomous mine design by using real-time data and AI-based insights to simulate and analyze various scenarios and optimize designs for productivity, safety and environmental impact.

• Draw on integrated data from production scheduling, earth observation (e.g., drone and satellite), maintenance and weather to optimize scheduling, blending, loading and shipping to meet customer specifications and delivery dates; thus minimizing demurrage and storage at ports.

• Guide Advanced Process Control in mineral processing by using flow sensors and analytics to identify the optimal settings for parameters to improve recovery.
To make effective use of these technologies in autonomy, mining companies will need to form and work with an ecosystem of partners.

Autonomous operations require more than point solutions. They involve a mix of technologies—and often, emerging and rapidly evolving technologies. Companies should seek to work with start-ups, original equipment manufacturers (OEMs) and other suppliers to develop and integrate technologies—and to move from research to prototype to implementation of autonomous capabilities. And they will need to continually orchestrate that ecosystem to keep up with changing technologies and requirements.

Miners will also need to look beyond the technology itself and consider the people using the technology. Increasing autonomy will drive a shift in the types of skills the workforce needs—and in the nature of the work itself. For example, the mining workforce today is largely field based, working onsite in dangerous and often unpleasant environments. However, the establishment of Remote Operation Centers (ROCs) means more and more operational and technical people are—and will remain—in the company’s city offices, reducing the personnel required onsite.
In general, mining jobs will become less blue-collar and more white-collar in nature. For example, mechanics who now respond to maintenance problems will instead work alongside AI to predict failures and perform preventative repairs. And many operators will move from the hands-on running of a given machine to remotely overseeing multiple pieces of highly autonomous machinery. And while there will be fewer operators involved, people are likely to be needed in a range of new roles in maintenance, data processing, operational control, mine planning and so forth.

Mining companies can re-skill the workforce to keep up with these changes and some are already doing so. For example, Accenture has worked with a South African mining company to develop a future-ready workforce strategy. Using various innovative techniques, this will help the company upskill every one of its more than 15,000 employees and prepare them for a digital future.

Looking ahead, such re-skilling initiatives will be ongoing and continuous, because the speed of innovation—accelerated by AI—will mean that the types of skills needed in the industry will evolve constantly.
As companies explore increased autonomy, there are several factors to keep in mind—factors that will be instrumental to success. Companies need to:

**Focus on Value**

The autonomous path to value will be as different as each business. Having clear visibility of the key value drivers is critical to avoiding false starts and matching stakeholder expectations.

**Address the foundation**

To take advantage of intelligent technologies, companies should ensure their IT architectures are ready to support communications between various systems and types of equipment. They should also assess the interoperability of systems, which is key to integrating operations across the mine and the value chain. A lack of standardized technology and tools in the industry can make this a challenge, which means companies will have to work closely with ecosystem partners and OEMs to weave systems together. Finally, companies need to assess cyber security requirements, because a breach of autonomous systems could mean losing control of systems and processes.
Ensure data readiness

Being able to use data from various sources is critical to AI and analytics-based insights and decision-making. Companies need to consider their data-handling capabilities to capture and manage ever-growing volumes of data, while ensuring the data used to drive decision-making is accurate and trusted. Data will need to be clean, consistent and refined into datasets that can be analyzed readily. And data flow will need to change, from being linear and controlled by various disciplines and segments of the value chain, to a multidirectional flow across disciplines. Overall, ensuring data readiness is a key prerequisite—without it, autonomous capabilities will be limited, at best.

Manage the change

As a rule, technology changes faster than people, and the shift to autonomy could leave employees behind if not carefully managed. Mining companies can help their people feel more comfortable with new approaches by communicating clearly, building trust and preparing them to succeed in the new environment. Companies can also apply these concepts to local communities, to manage fears about the potential impact of autonomous operations on employment and safety—and to help maintain the license to operate granted by the community.
Evolving toward autonomy

The move to autonomy will require significant change. Miners should prepare a vision and roadmap for implementing autonomous operations.

This is not to say the change needs to be done all at once, or that all operations need to become autonomous. Instead, miners can move forward in gradual, targeted steps. Companies can focus on building autonomy in a small number of areas, or even just one area—that is, some portion of the roadmap. To start, companies can initially focus on areas where the opportunity for impact or success is especially high, such as operations where there are higher levels of risk, or bottlenecks that cause delays and drive up costs. Another opportune area is where the necessary data-management capabilities or workforce skills are in place already.

Companies can assess the value of initiatives through the lens of Accenture’s Triple Zero purpose: Zero Harm (human safety and wellbeing, community and social trust and cyber resilience), Zero Loss (productivity, capital projects, digital return on investment and continuous improvement) and Zero Waste (sustainability, circular economy and physical waste-reduction benefits). This framework provides insight into how actions and initiatives can support Triple Bottom Line reporting.
By considering such criteria, companies can find areas where there is the right mix of potential value, complexity of change and time needed to implement autonomous capabilities.

Once the desired level of autonomy has been brought to the targeted area, the company can then move on to the next area—and so on until the roadmap is filled in and the overall effort is complete. This approach allows the company to keep its big-picture autonomy goals in mind while focusing investments, providing opportunities to test and improve autonomous capabilities, and effectively move forward at “two speeds.” This approach keeps the core mining operations and the business running while gradually infusing autonomous capabilities into those operations.

For miners, the widespread implementation of autonomous operations will represent a significant break from the past—and it is coming soon. The technology is advancing quickly, and the demands of Triple Bottom Line reporting are only growing.

This means mining companies need to move ahead rapidly—and embrace new autonomy-based ways of working that will be fundamental to competing in the years ahead.
References

1. BHP News Release, October 2019: Social Value Briefing

2. Peter Bryant and Satish Rao, Clareo and Twin, 2019: Accessing the Fast and Furious Pace of Autonomy to Transform Mining


5. Resolute Mining ASX Announcement, July 2018: Syama All-In Sustaining Cost reduced to US$746 per ounce

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