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Behind the Mining Productivity Upswing: Technology-Enabled Transformation

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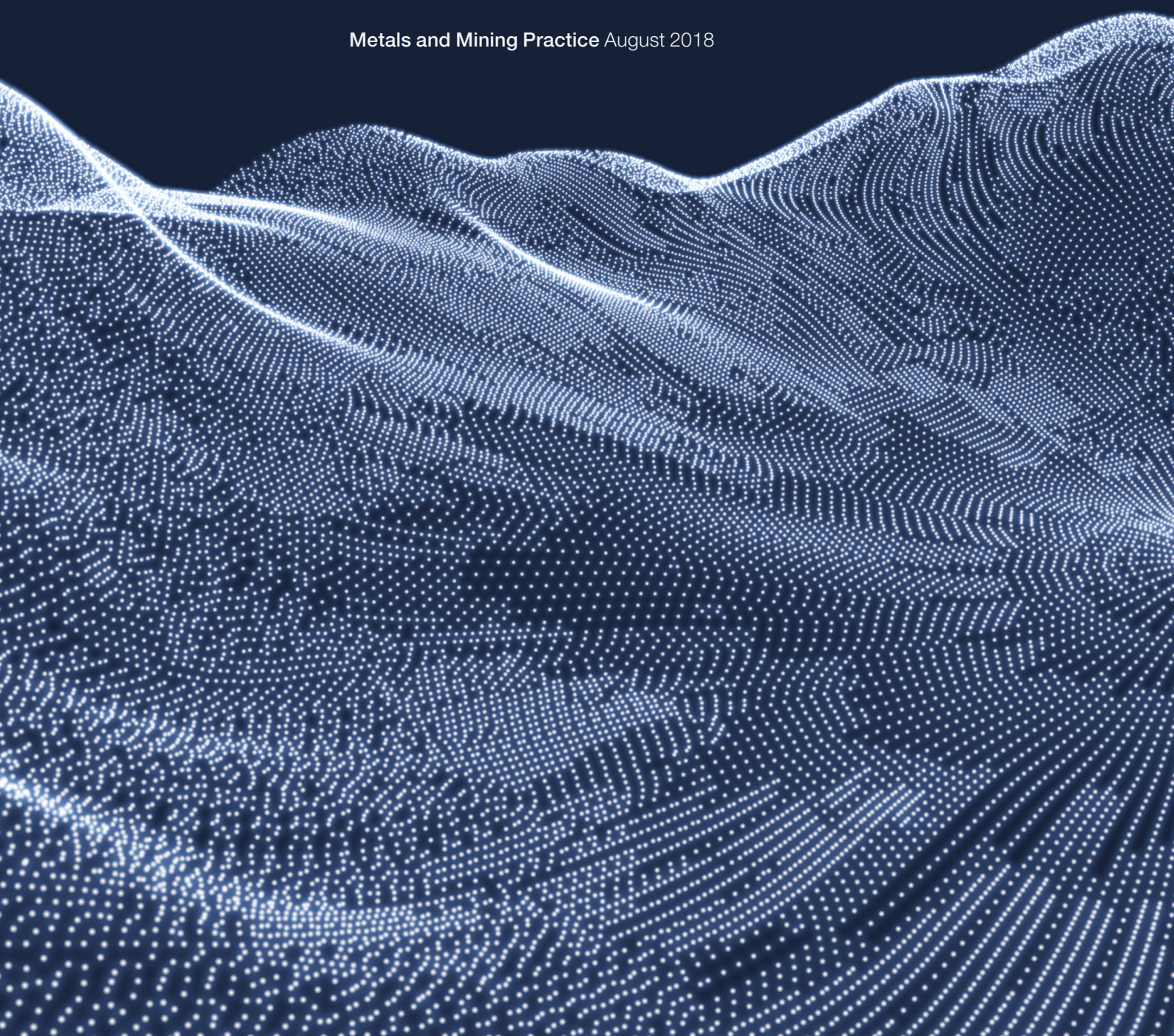


Behind the Mining Productivity Upswing: Technology-Enabled Transformation

McKinsey Metals & Mining published a 2015 paper that predicted a technology-enabled transformation of the mining industry. The paper identified some potentially game-changing innovations that we believed would revolutionize the way mines operate and deliver much-needed productivity gains.

Since then, many of these innovations have lived up to that potential. Digital technology—when implemented with management and mindset changes—is leading to meaningful operational improvements. For instance, advanced analytics and sensors are helping lower maintenance costs and decrease downtime while boosting output and chemical recovery. Robotics and semi-autonomous equipment are taking humans out of mines, reducing costs and risk. In Western Australia, miners using autonomous haulage technology have reported a 20 percent improvement in productivity.

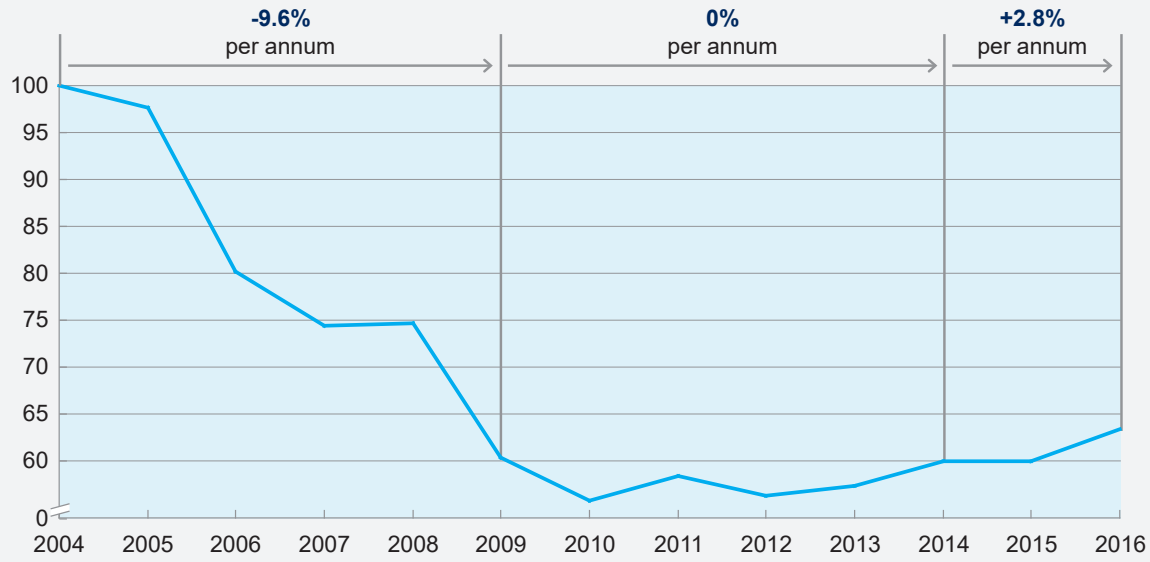
Not coincidentally, according to McKinsey research, overall mining productivity rose about 2.8 percent per year from 2014-2016—a period of modestly rising output. Two main trends underlie these productivity gains: an increase in labor productivity that has enabled a 3 percent annual reduction in headcount, and tightly controlled capital spending and expenditures for non-labor operations. [See Figure 1, Productivity Curve Upswing.]

Some of the credit for this improvement must be given to the maturation of lean management, lean operating systems, and Six Sigma improvements. But those improvements will be harder to sustain. Every year, the work becomes more difficult. Ore grades are declining, while water scarcity has threatened to strand assets in the ground, and operating licenses have become more difficult to obtain.

Figure 1: Productivity Curve Upswing

Since 2014, mining productivity has reversed course with a gradual increase.

MineLens Productivity Index (MPI); 2004=100



SOURCE: Company reports and websites; McKinsey analysis; MineLens

Technology—particularly artificial intelligence (AI) and machine learning, automation and robotics, mobile digital, the Industrial Internet of Things, and modern data architecture (including the cloud)—can help the industry meet these and other challenges. It may also help reduce the industry's environmental footprint, move workers out of harm's way, turn uneconomical reserves economical, and make work less repetitive and less strenuous.

Yet many companies are still struggling to embrace tech-enabled transformation. In our experience, getting the tech right is just part of the puzzle. There are many examples of companies that have invested in technology and not seen improvements because they neglected the other vital engines of tech-enabled transformation, management systems, and culture.

Three engines for driving technology-enabled change

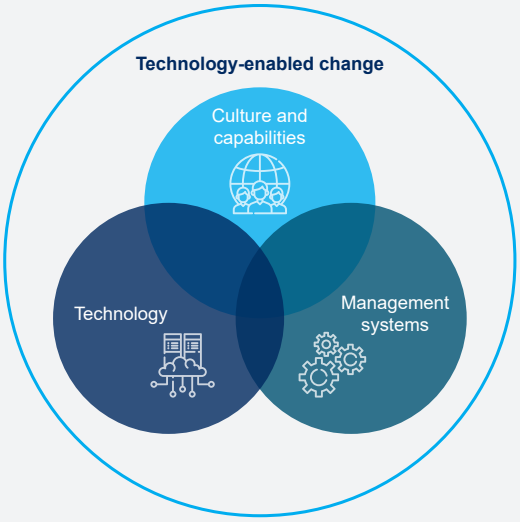
Achieving sustainable change requires more than a focus on the technology. Just as with lean or Six Sigma-driven improvement, companies need to adopt a holistic approach to transformation. There is no technological silver bullet that companies can buy to achieve their goals. Instead, there are three interdependent engines that drive either a transformational or smaller-scale technology-enabled operating system change. [See Figure 2, Digital Excellence in Mining.] These are:

1. **Harness technology,** including digital, analytics, and automation across the organization, to solve the key challenges of productivity, safety, customer satisfaction, and supply chain management.

2. **Adapt the management systems** (such as work processes) to enable the company to realize the potential offered by the new technologies.

3. **Overhaul the culture and capabilities** to achieve a more agile, responsive organization that can get value from and adapt to modern technologies.

Figure 2: Digital Excellence in Mining



1. Harness technology

The many improvements mining companies have achieved by harnessing modern technologies include:

Improving throughput and recovery

At some mines, advanced analytics systems are ingesting all the data in the concentration environment and using it to improve processes. Instead of achieving the local optimum through automatic process control, this approach delivers a global optimum. Doing that can boost yield energy throughput. Today, it's not unusual to see opportunities to raise mineral recovery by 1 to 3 percent and increase throughput by 4 to 8 percent, while reducing energy consumption. This can mean a productivity boost of 5 to 10 percent, which equates roughly to opening a new mine if applied across a typical mining company's footprint, without the capital cost.

One metal mine is using advanced analytics and machine learning to develop an "industrial controller of controllers" to drive up throughput and mineral recovery. The company is collecting data from more than 150 sensors for medium to large concentration plants. An algorithm predicts the behavior of a plant and offers a

series of recommendations to optimize based on controllable variables. The plan is reviewed by the plant supervisors, who adopt the suggestions that make sense and question those that don't. The impact of the implemented changes is measured on an ongoing basis to refine the program.

In another example, a metal mine used Industrial Internet of Things sensors combined with a centralized data repository and advanced machine learning, to boost chemical recovery from the extraction process by 10 to 15 percent. Sensors collect real-time data from the waste, and the machine learning model calculates the optimal parameters for recovering (for instance) sodium hydroxide, boosting performance above that which operators were previously able to achieve. This has saved millions of dollars' worth of chemicals and reduced the environmental impact of the tailings.

Optimizing maintenance

Technology is helping mines conduct maintenance when it is needed rather than on a fixed schedule. One company used sensors and machine learning to implement predictive maintenance in very large (20-ton) heat exchangers. The model was able to predict when the exchangers would fail, reducing maintenance from once every 70 days to as long as once every 160 to 200 days. Given that there were dozens of heat exchangers, the cost savings have been substantial.

Maintenance workers can benefit from technology as well. Workers responsible for pumps now can carry a phone or tablet that knows where the workers are and the assets on which they're working. The system can bring up the maintenance history of a particular asset, display a work order, and show the steps that need to be carried out to complete the job. This may include details such as the torque level for tightening a nut, or instructions for inserting an O-ring. In the years ahead, augmented reality will increasingly serve this purpose, even having an expert from the asset's manufacturer appear (virtually) to help the worker.

Reducing operating costs

Some of the most far-reaching changes in mining are likely to emerge from the use of robotics. Autonomous equipment operates continuously, with less variability and virtually always within the manufacturer's recommended tolerances, reducing maintenance as well as headcount. Additionally, compared to human-led processes, robotic consistency can be more amenable to continuous improvement methodologies. This has a broad impact on a variety of processes, ranging from road maintenance to how to back into a shovel location.

Commercial autonomous haul trucks now have been proven viable for open pit mines that have a suitable cost structure. These trucks drive themselves between loading and dumping. Another increasingly common machine is the autonomous blast-hole drill, which will drill a complete pattern without intervention. In a production environment, groups of three or more autonomous bulldozers are now able to coordinate overburden removal.

Underground, mines are starting to use tele-remote load, haul, and dump (LHD) machines. Bigger mines have moved from pilot-scale deployment to adopting LHD as their new standard. For one mining company, autonomous haulage system trucks have yielded a 20 percent productivity increase. Another early adopter has recently decided to expand its fleet of autonomous vehicles based on their productivity results.

Automation will help operators be more efficient and focus on developing new expertise. For example, instead of using ever-larger equipment, operators can optimize size to balance maintenance costs with haulage cost per ton.

Boosting productivity and overall equipment effectiveness (OEE)

Coordinating activities in underground mining has always been a challenge given the difficulty in knowing where people and assets are and how much progress they have made. It has become increasingly realistic to combine off-the-shelf technologies with in-house solutions to create a system that improves transparency, safety, performance monitoring, and overall equipment effectiveness. By deploying underground networks—using WiFi or 5G wireless technology, for example—a mine's supervisors can communicate with work teams in real time. This single innovation can have far-reaching ramifications, provided it is implemented in tandem with the other two key engines of technology-enabled transformation: adapting the management systems and overhauling the culture. [See "How digital communications can change the way a mine operates."]

2. Adapt the management systems

Companies must commit to transforming their management systems to nurture innovation and embrace change and technology. For example, a mining company that is using advanced analytics to increase yield and throughput also needs to modify how metallurgists, plant operators, and maintainers work together to embed the new tools and insights into their daily workflow. Otherwise, the actual operation of the plant does not change, and the bottom-line benefit cannot be achieved.

The organization sometimes requires modifying, too. Traditional mining operations tend to be organized around separate teams responsible for production, maintenance, planning, and the like. This approach is not appropriate for a digital organization, as it leads to slow and inferior decision making. Each team sees only its part of the whole, and when problems arise (as they always do), it works against collaborative and cooperative thinking and action. Most importantly, teams that work in siloes know only what they know; they are isolated from the data that drives innovation.

How digital communications can change the way a mine operates.

One of the biggest logistical challenges mines face is communicating with workers and coordinating operations, especially underground where radio does not work. By deploying underground networks—WiFi or 5G wireless technology, with sensors throughout the mine relaying information in real time—a mine's supervisors can communicate with work teams in real time. This eliminates the need to provide a set of instructions that have to be carried out across an entire shift, and lets supervisors react and adapt to changing conditions, allowing an underground mine to function like a modern, sophisticated open-pit operation.

This approach, often known as Short-Interval Control, relies on wholesale tech-enabled transformation that includes the technology plus new talent and mindsets. Once in place, this allows for the deployment of linear algorithms to optimize equipment dispatch, maximizing equipment productivity and achieving mining objectives.

Modifying behavior and mindsets is key to harnessing the benefits of Short-Interval Control. In an environment where information is far more accessible than ever before, companies can examine where decisions are made, and by whom, and empower their workers to make informed, data-driven decisions, quickly and safely.

Embracing technology means that individuals who have traditionally not had much need to work together are now highly dependent on each other and need to be organized in a way that allows for this. We have found that the most effective way to take advantage of new technologies is to reorganize workers into "squads" (when appropriate; safety is always a paramount concern) that include people with varied and complementary skills. This working team focuses on a specific process or set of assets — say, a leaching operation — and has a range of skillsets that allow them to make more informed decisions and meaningful changes faster.

Squads benefit from including or having ample access to coaches, data scientists, programmers, and whoever and whatever else they need to achieve their goals. They perform best when they are empowered to make decisions and deploy resources. One company reaped significant improvements by enabling its teams to invest up to $100,000 without additional approvals.

3. Overhaul the culture and capabilities

Technology-enabled transformation calls for a break from ingrained habits, and a change in mind-sets, behaviors, and capabilities.

Making changes to where decisions are made and who makes them requires a change-management program. An effective plan will enable employees to understand how a technology-enhanced system will make their lives better, safer, and more productive. This understanding has to be reinforced through formal mechanisms, and managers must model new behaviors. [See "How one company changed its culture and infrastructure."]

Of course, harnessing technology also means training employees and hiring new staff with advanced skillsets to fill a variety of new roles. Data scientists are needed to develop sophisticated analytics models to identify improvement levers.

How one company changed its culture and infrastructure.

To implement a tech-driven transformation, the CEO of a large mining and chemicals operation established two digital studios. One studio, in operations, had four objectives: 1. to pursue advanced analytics at scale; 2. to push automation to its fullest extent; 3. to develop a series of apps and tools that would facilitate processes like maintenance; and 4. to adopt an agile operations model. A second, central digital studio is developing tools for support functions such as human resources and procurement.

As part of the transformation, the company recognized it needed to overhaul its culture, including a greater level of shop-floor engagement. Augmenting skills is key. In the first year of the transformation, the company attracted about 50 new, highly qualified professionals to help with implementation. It established an agreement with a local university to develop new capabilities in the region.

The operations studio is aimed at developing a "lighthouse digital plant" to generate enthusiasm for the rest of the company. It has deployed agile management, a methodology intended eventually to be implemented across the organization. Working with cross-functional squads has resulted in quicker decision loops, greater engagement, more new ideas, and more satisfied employees.

The current identified impact of the transformation effort is positive to the tune of more than $200 million, the majority coming from operations.

If a mining company is using an agile development approach, other skills and roles are needed. One such role is the product owner, who has multiple responsibilities, including acting as the voice of the end-user, testing and reviewing each iteration of a product. Another is the scrum master, who oversees the design process, fostering cooperation across roles and functions and removing obstacles. [See Figure 3, The New Miners.]

Today, these skills are scarce, so companies will have to develop their own capabilities. They can do this, for instance, by creating advanced analytics academies to establish data science skills, such as coding. Companies can also deploy translators who have the skills needed to interpret systems for other employees at the mine. In many cases, companies will be able to harness existing talent to fill the translator role, drawing on younger digital natives or others with a passion for technology. A U.S.-based base-metals client found an in-house metallurgist who was passionate about technology and quite sophisticated on highly relevant technical aspects of machine learning models. The company trained her as a machine learning controller of controllers. Her hobby enabled her to design a high-quality user interface for use in a processing plant.

Human resource departments must play a vital role in shifting the mining culture, enabling these new classes of professionals to thrive and realize their potential. Retaining these employees is also essential. Company results improve when capabilities are built not just on a project basis, but for the long-term.

No silver bullet

Management teams must realize that tech-enabled transformation is a journey unique to every company and mine, not a one-off application of use cases. There are no silver bullets and no one list of technologies that every company should implement. There will be hundreds, and ultimately thousands, of ideas, improvements,

Figure 3: The New Miners

New skillsets kick-start transformation and implement solutions effectively.

NOT EXHAUSTIVE

Data Scientist

Develops advanced analytics models to identify improvement levers

Product owner

Acts as the voice of the end user; tests and reviews each iteration of the product

Digital Navigator / Translator

Acts as organizational behavior change-agent and collects user feedback during rollout

Team (aka squads)

Delivers potentially shippable software at every sprint

Scrum master

Oversees design process, fosters cooperation across roles and functions, removes obstacles

UX designer

Conducts initial user experience walkthroughs; designs solutions to meet users' needs

and use cases. Some of these can be done now; others will unfold as a company's capabilities and technical architecture develop. Leaders should also expect some initiatives to work and others not to work. They should not lose faith; transformation requires continuous and determined effort.

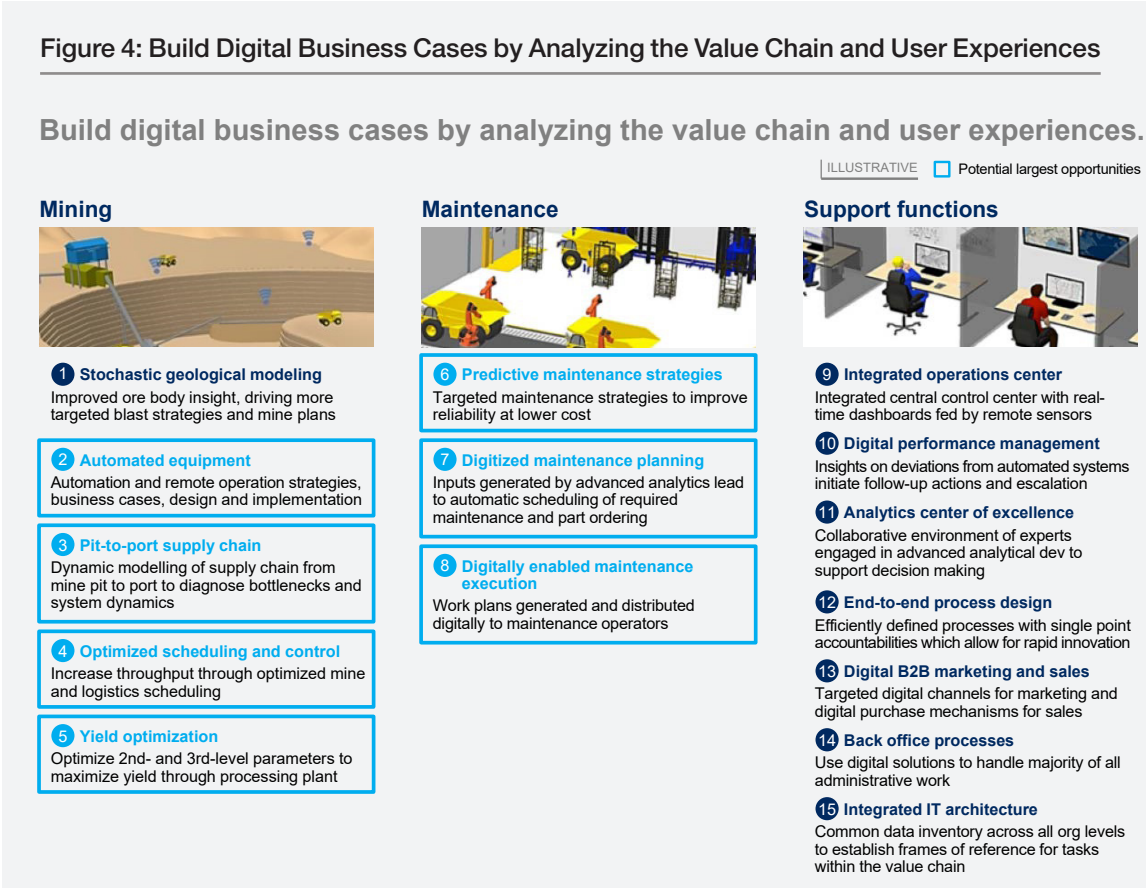
Where companies choose to embark on the journey will depend on the maturity level of their process controls and data systems; some companies will need to improve and stabilize their underlying systems. As the transformation unfolds over time, companies will learn, and their capabilities will grow. Technology will evolve, too, and those that embrace the management and cultural changes central to technology transformation will have the skillsets—and more importantly the mindsets and processes— to evolve with it. They will continue to get better at driving productivity and improving safety.

The maturity of specific technologies is also a critical consideration. Leaders will need to determine which are suitable for application today versus in the near- or midterm future. No mine will want to get caught in an unexpected R&D project.

We recommend a company start by identifying a use case that will provide a high return on investment. Today, the best opportunities tend to be in automated equipment, pit-to-port supply chain improvements, optimized scheduling and control, yield optimization, and maintenance, including predictive strategies, digitized planning, and digitally enabled execution. [See Figure 4, Build Digital Business Cases by Analyzing the Value Chain and User Experiences.] Of course, initial and subsequent undertakings need to be part of a broader plan and ambition.

Tech-enabled transformation opens up a whole new horizon of possibilities. It equips companies with novel levers, tools, and opportunities to improve safety, productivity, and ways of working. The rewards will be far-reaching for companies that commit to it and approach it wisely.

Figure 4: Build Digital Business Cases by Analyzing the Value Chain and User Experiences



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Designed by US Design Center
metalsandmining_practice@mckinsey.com