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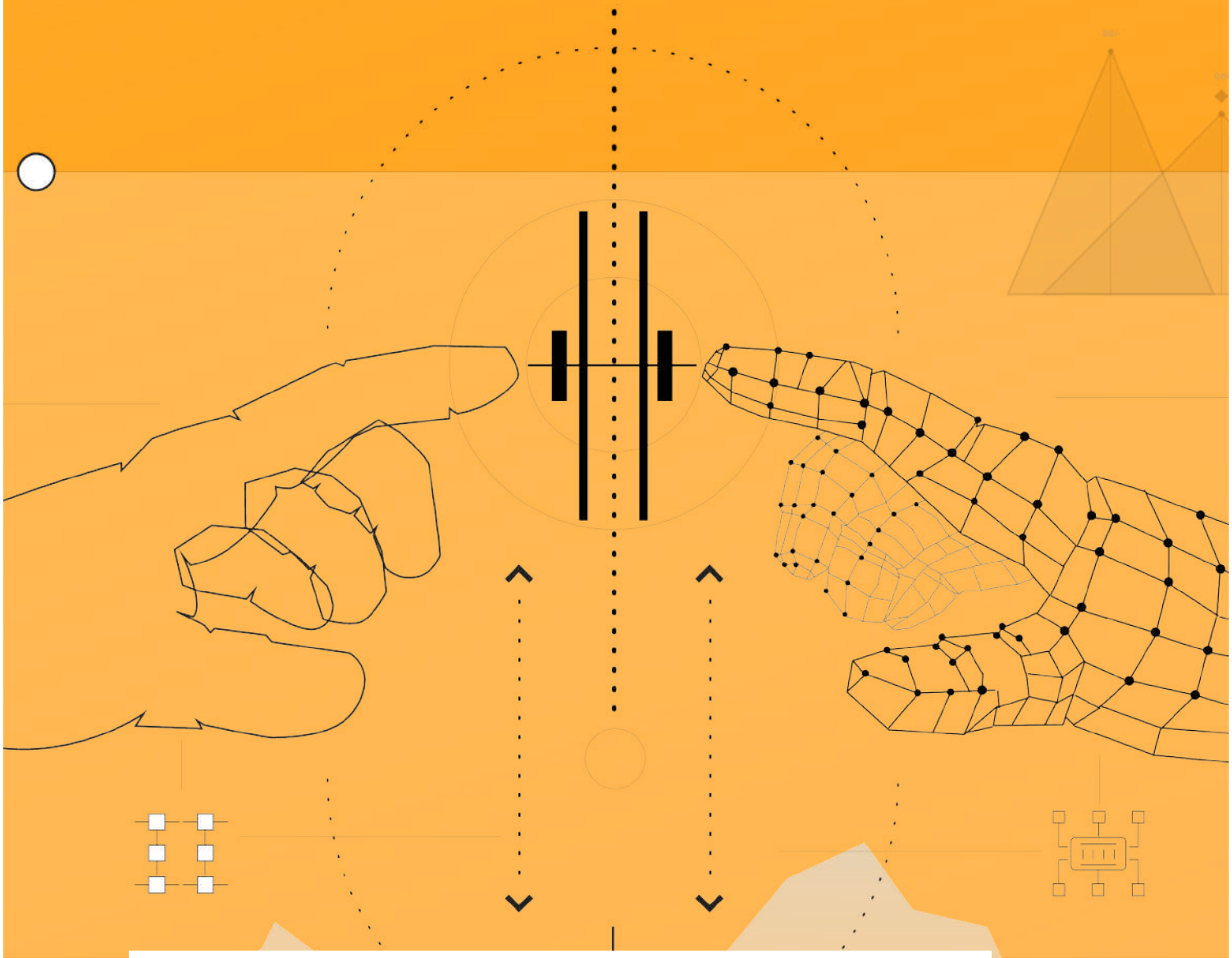


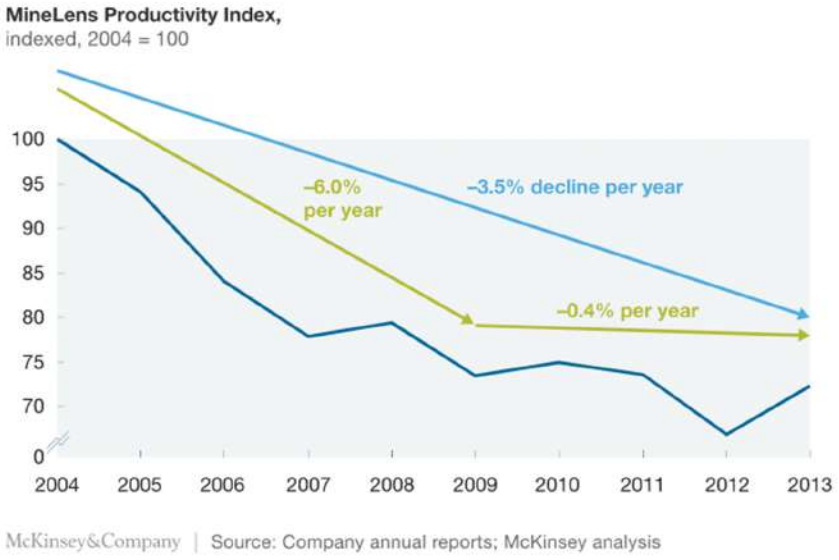
MINING IN THE DIGITAL AGE

Contents

Introduction

The global mining industry is under pressure. During the commodities supercycle of the 2000s, mining productivity fell to its lowest in more than 30 years. Due to an unprecedented increase in commodity prices, the sector focused on production at any cost. McKinsey research shows a 3.5% drop in productivity per year from 2003 – 2014[1]. Today, commodity prices are far below its 2011 peak, and this performance is untenable. The exit from the supercycle has caused the industry to shift its focus to improving productivity by sweating incumbent assets, but this strategy will only go so far. There remains significant untapped potential for productivity improvement in mining.

McKinsey research shows a global decline in mining productivity over the past decade. Digital technologies have the potential to take today's mining operations to new levels of performance across the whole mining value chain.



Despite the challenges, there are opportunities. Digital technologies have the potential to take today's mining operations to new levels of performance across the whole mining value chain. By embracing digitization, the industry will evolve with newer business models that can deliver improved productivity, cost savings and safety advances.

Digital innovation is reshaping industries by disrupting existing business and operating models. In this white paper, we explore some of the key digital technology themes that have the potential to revolutionize mining operations in the next decade, and help miners face up to the challenges of volatile market conditions. These technology initiatives include automation and robotics, digitally driven workforces, analytics and intelligence, and an integrated technology operating model. We also look at recommendations from the World Economic Forum for successful digital transformation in mining.

> Harnessing the potential of digital technology will unlock value across our business, helping us grow our free cash flow per share. In so doing, we will make ourselves into a leading twenty-first century company enhancing productivity and efficiency at our mines, and improving decision-making and performance across every area of our business.

John L. Thornton
Barrick Gold Corporation
Businessweek, 13 September 2016

Global Mining Industry: Context

The mining industry is recalibrating to a set of strong headwinds after the commodity boom peaked in 2011. From volatile market conditions to resource scarcity and environmental mandates, the challenges facing the industry has forced miners to rethink the way they operate. In this section, we look at some of the major dilemmas the industry is grappling with – per a report by the World Economic Forum on Digital Transformation in the Mining and Metals Industry in 2017 [World Economic Forum Report][2].

Market Volatility and Weak Global Demand

The global commodities boom in the early 2000s was driven primarily by the rapid expansion of the Chinese economy. However, as China's economy gradually shifted away from resource-intensive manufacturing, there was a slowdown in demand growth and a consequent fall in commodity prices and mining profits. The surge in demand for metals and minerals during the century's first decade encouraged massive capital investment to boost production volumes. A majority of projects that started out during the boom years did not reach production capability until after prices dropped. Changing market conditions and sluggish demand growth has resulted in a steep decline of profits in the mining industry.

Resource Nationalism and Regulations

Resource nationalism refers to the policies and regulations imposed by a country's government to maximize the benefits gained from the natural resources of a country - sometimes to the detriment of private companies. In the mining industry, this can range from rising taxes, permitting fees, export duties, etc. Although this is not a new phenomenon facing the mining industry, it has been increasing due to the economic slowdown in the recent years.

Relative to several other industries, mining companies are subject to stricter and more costly regulatory requirements in all areas of operations. As community and social groups continue to raise concerns about the environmental impact of extraction and processing operations, winning a social license to operate further escalates costs for companies.

Aging Workforce and Talent Shortage

The shortage of technical skilled labor – including project designers, mining geologists and engineers, is one of the most pressing concerns in the mining industry. A high percentage of the industry's workforce is aging. While experienced workers may have deep industry knowledge, they are less comfortable adapting to digital innovations and collaborative work. Millennials, on the other hand, tend to have a strong understanding of digital technologies, but may have a thin knowledge of mechanical-physical operations, and be less compliant with traditional corporate hierarchies. A shortage of skilled workers to take on complex mining jobs puts pressure on existing staff to do more with less, reducing employee productivity and increasing costs of retaining existing talent.

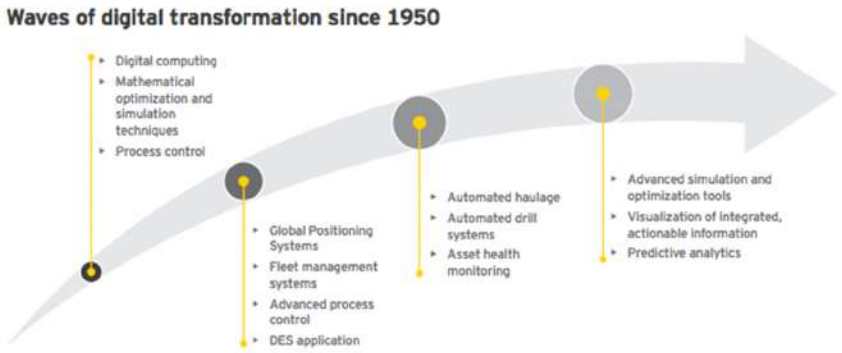
Resource Scarcity and Quality

One of the major challenges facing the mining industry today is that there are fewer high-quality ore deposits left to develop. New deposits exist mostly in remote and difficult-to-access areas. Consequently, the costs, lead times and risks associated with developing and operating new mines are increasing. Many existing mines are maturing, resulting in the extraction of lower ore grades, and longer haul distances from the mine face. As ore grades decline, production costs for each ounce or ton go up significantly. According to the World Economic Forum Report[2], the average cost of producing copper has risen by >300% in the last 15 years, while grade has dropped by 30%.

The Industry's Response to Challenges

The pace of technology-driven change in mining is affected by a number of factors such as the inherent complexity of operations, geographically dispersed and remote operational sites, and capital availability, among others. A McKinsey report[3] cites that compared to other industries, especially customer-facing ones, the mining and metals sector is considered to have lower levels of digital utilization. Over the last few decades, the mining industry has embraced the introduction of new technologies such as mainframes and personal computing, Global Positioning Systems (GPS), fleet management systems, data storage and cloud computing. Although mining equipment is more sophisticated than in the past, many companies continue to operate the same way.

Despite the industry's booms and busts, the response has primarily been around maximizing volume during the boom, and slashing costs during the downturn. The nature of mining operations has remained the same for decades.



Source: EY and Graham Walker, Consultant, Productivity and Value Chain, Bad Wolf Advisory

During the mining supercycle, productivity fell to its lowest in more than 30 years. Due to an unprecedented boom in commodity prices, the sector focused on production at any cost. However, the more recent exit from the super cycle has caused the industry to shift its focus to improving productivity by sweating incumbent assets, but this strategy will only go so far. Despite the industry's booms and busts, the response has primarily been around maximizing volume during the boom, and slashing costs during the downturn. The nature of mining operations has remained the same for decades. Navigating the industry's mounting challenges and achieving a breakthrough on productivity performance has required the industry to move beyond the status quo and rethinking how mining works.

The Way Forward: Digital Innovation in Mining

The mining industry is going through an intense period of change, in which digital and technology innovations have the potential to provide new levels of operational excellence and sustainable competitive differentiation. Emerging technologies can help the industry evolve with newer business models that can deliver improved productivity, cost savings and safety advances.

In this section, we discuss some of the digital innovations that, over the next decade, have the potential to revolutionize mining operations and deliver exceptional shareholder, customer and environmental value. These technologies have long been in the works, and are now affordable enough to be deployed widely across the industry.

1. Automation and Robotics

According to a report by Deloitte[4], the core operational processes in the future mining value chain will be highly automated and a wide range of digital capabilities will be deployed. Advances in the capabilities of robots and automated machines have made it possible to take over activities traditionally carried out by human-controlled machinery, and offer the potential to reduce overall costs, improve productivity and enhance personnel safety. The most notable technologies in this space include exploration drones, 3D printing, smart sensors and robotic trucks, drills and trains.

"Greater use of autonomous machines could create $56 billion of additional value for the industry (from 2016 – 2025), through an increase in output, since they can operate 24 hours a day, 365 days a year at a constantly high productivity level. In both mining and metals, increased automation will create value for the industry through reduced personnel costs. ~10,000 injuries will be avoided through autonomous operations from 2016 – 2025."

Source: World Economic Forum Report[2]

3-D printing is the process of making physical objects from a digital model using a printer. Though still in its nascent stage in the mining industry, this technology has the potential to transform the maintenance supply chain for mines by offering quick access to a broad range of critical spare parts during equipment failure. Production of spare parts on-site and on-demand can reduce lead times and eliminate the cost-intensive process of transporting parts to remote sites in the event of equipment failure.

Smart sensors using IoT technology can be embedded in mining equipment to monitor equipment health and trigger alerts to predict failures before they occur, giving the ability to react at the right time. Real-time operational information collected by these sensors also facilitates sophisticated decision-making at the operations center. The increasing use of IoT in mining will churn out large volumes of data related to production processes, operational environment, safety and other aspects of operations. Analyzing this data can provide useful insights on process variability and deviations from expected operating conditions in real time, allowing miners to take actions that drive higher process efficiencies and combat safety threats.

Drones are used to conduct aerial surveys of mining sites, and relay geophysical imagery and data to surveyors without interfering with regular operations. The usage of drones in mining spans visual inspection of equipment across a site to identify maintenance needs, monitoring of ore bodies in real time and providing surveying and mapping data, among other operator-free tasks. As opposed to traditional surveying techniques, drones can vastly reduce the time spent by surveyors on site inspections, thus enabling safer operations.

Robotic trucks, drills and trains can increase worker safety by operating autonomously in extreme conditions, while also boosting the efficiency of operations by reducing idle time and human error due to fatigue. Autonomous versions of mining dump trucks leverage the latest computing systems to haul heavy materials and transport it between various locations with accuracy, while drills can navigate from hole to hole and set up and drill a quality blast hole without operator intervention.

2. Digitally-Driven Workforce

Mobile technologies have been at the core of innovative solutions that drive productivity improvements across many industries, and mining is no exception. The ubiquity of connectivity, coupled with the rapid proliferation of mobile devices and considerable advances in their capabilities, has helped mining companies introduce digitally enabled ways of working. Connected mobility can empower field, remote and centralized workers in real time. Key technologies in this space include remote operations centres, connected mobile devices and wearables.

"Connected worker technologies are expected to have a significant impact on efficiency, costs and workforce safety. The potential value addition for the mining industry stands at ~$59 billion from 2016 – 2025. A vast majority of this value will come via improvements in workforce productivity since activities can be performed in a more targeted and efficient way based on real-time data. ~22,000 injuries will be avoided through the use of connected intelligent devices from 2016 – 2025."

Source: World Economic Forum Report[2]

Mining operations are geographically dispersed, and the ability to aggregate accurate data and share it across the enterprise in real time can facilitate better mine planning, collaboration and decision-making. **Connected worker technologies** such as mobile devices and wearables make this possible. By equipping workers with connected, intelligent wearables and mobile devices such as tablets, wearable glasses and watches, mine management can benefit from on-demand access to critical information in real time.

Some examples include operator usage of a tablet to record shift tasks and progress, instead of multiple paper-based entries that are prone to manual errors. Mobile-based data collection allows for quick validation and distribution of production data across key personnel like mine supervisors and managers, and makes possible a real-time response to issues that could affect production. By detecting deviations from expected operating standards in real time and driving rapid and focused operational improvements, miners can significantly reduce downtime and drive higher process efficiencies. Tablets can also be used to track the precise location of equipment through integration with a GPS transponder. This helps optimize current shifts and plan upcoming shifts.

The use of wearables has the potential to boost safety throughout the industry. IoT-linked wearables such as helmets and caps can be used to examine the biological condition of workers, particularly truck drivers and machine operators who are at risk from fatigue-related injuries. Smart watches can be used to indicate a worker's GPS location in the event of an emergency, thereby aiding rescue operations. Other intelligent wearables can monitor and communicate environmental conditions such as air quality and the presence of toxic fumes, and trigger alarms if a hazard is detected.

Remote Operations Centers (ROCs) are centralized, connected control rooms that provide an offsite environment for mining personnel to collaborate on operational planning, scheduling and execution of activities. ROCs provide video feeds, communication systems and other digital tools that enable employees to monitor and control remote site operations in real time, reducing the number of site visits and onsite personnel required for these locations. From the ROCs, personnel can

assign and dynamically reassign mining equipment such as loaders and haul trucks, monitor machine health and schedule maintenance, and track production targets, among other tasks. Working remotely also keeps mine personnel away from hazardous locations. Remote operations are paving the way to a safer and more productive future for mining.

3. Analytics and Intelligence

Mining companies generate volumes of data from equipment and processes, but only a fraction of this data is actually used to improve decision-making. Recent advances in data analytics and machine learning technology have enabled miners to leverage data from sources within and beyond the value chain to provide real-time decision support and insights about the probability of future events. Key technologies in this space include artificial intelligence and machine learning (AI/ML), simulation modeling, digital twinning and advanced analytics for production optimization and predictive maintenance.

"Though effective analytics are still in their infancy, they are starting to add value to mining and metals operations and are expected to grow in importance after 2025. The potential value addition from Advanced Analytics and Simulation Modelling for the mining and metals industry stands at ~$10.6 billion from 2016 – 2025.

Source: World Economic Forum Report[2]

Artificial intelligence refers to computing systems that work and react like humans. The application of machine learning AI has far-reaching potential for the mining industry. By using satellite imagery and geophysical maps, machine learning can help answer questions such as 'where to explore' and 'what lies under the ground' during the prospecting and exploration phase. Additional applications include the ability to warn operators and maintenance crew of critical equipment downtime in advance.

Digital twinning will give mines the ability to create digitized versions of components, that are updated in real-time with sensors or tags on the physical equipment. The ability to create a digital representation of a physical object or asset can provide important data about the asset's health. The data gathered can streamline a mine's maintenance program, by predicting potential outages before they happen, thereby reducing the risk of downtime. Coupled with the Internet of Things, a smart digital twin can even trigger a 3D printer to have its physical replacement ready for the next scheduled operation.

Simulation modeling allows mining companies to analyze their processes in a virtual setting, and project operational performance using what-if scenarios, thereby reducing the time and cost associated with physical testing. Such analysis can highlight current performance levels, bottlenecks and opportunities for improvement.

Advanced analytics can look at immense data sets for trends, and identify opportunities for improvement that humans cannot see. By bringing together all of a mine's extensive but underused production and process data, advanced analytical techniques can help identify operational bottlenecks or waste patterns, enhance predictive maintenance and increase efficiencies of day-to-day operations.

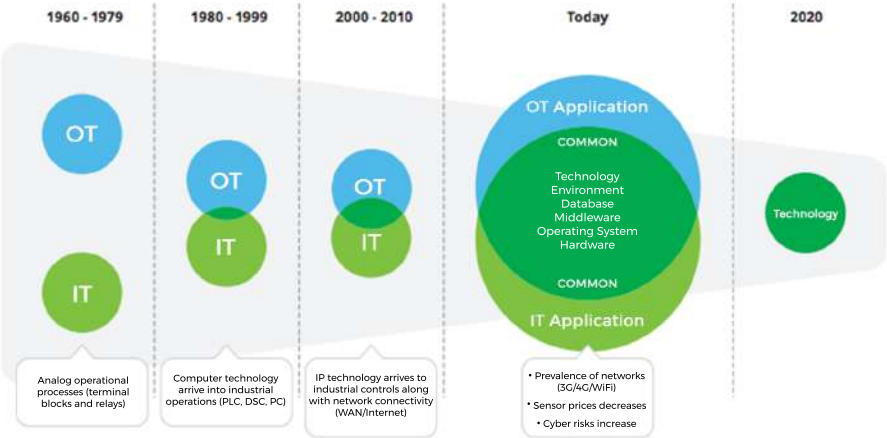
4. Integrated Technology Operating Model

To compete and prosper in a digital future, mining companies need to adopt an integrated technology operating model by connecting information technology (IT) to operational technology (OT) and exchanging data throughout the supply chain and beyond. Key technologies in this space include IT/OT convergence and asset cybersecurity.

IT/OT Convergence: Historically, IT and OT have been managed as separate domains in mining. The emergence of digital technologies and the increased importance of data in mining operations are causing the line between IT and OT to blur. Many companies are now focused on leveraging the convergence of traditional IT and automation-focused OT for productivity gains. IT and OT are coming together via the Internet of Things, which connects objects to the internet via RFID tags and sensors. Operational teams are deploying solutions that we would traditionally see in the domain of IT vendors – such as mobility and data analytics, and driving utilization of datasets from sensors embedded in mining equipment.

"The mining industry could benefit from approximately $5 billion in avoided costs assuming that asset cybersecurity centers can prevent 50% of cyberattacks."

Source: World Economic Forum Report[2]



Source: The Digital Revolution by Deloitte[4]

Asset Cybersecurity: Due to rapid advances in automated operations and connected mobility, mining companies are becoming increasingly vulnerable to cybersecurity breaches. The integration of operations technology with wider business and enterprise systems means that cyberattacks will extend beyond enterprise systems into the operational environment itself, and can have a significant impact on the business by causing equipment damage, operational shutdowns, health and safety risks, as well as data loss and damage. Although challenging, it is imperative that mining companies establish effective security protocols to protect their assets, which comprise connected computing devices, personnel, equipment, applications, telecommunication systems and information stored in the cyber environment.

Factors Driving a Digital Disconnect

According to advisory firm Ernst & Young (EY), digital transformation will be a critical enabler to address the mining industry's productivity and margin challenges. However, EY's global report 'The digital disconnect: problem or pathway?[5]' points out that digital advances in mining are out of sync with the scale of opportunity for many companies. While 84% of the 700 respondents to the report have considered, or were starting on, their own digital path as part of their day-to-day business, just 31% of respondents in the sector said digital is high on the agenda at their organization, while 15% said it is not on the agenda at all.

The digital disconnect in mining, also explained as the gap between the potential from digital transformation and the poor track record of successful implementations, exists because of a range of practical issues that challenge the industry. This section details some of the common pitfalls that are driving the digital disconnect in mining, per EY's report.

Source: EY "Preparing for tomorrow's digital mine today" webcast poll, with more than 700 participants, February 2017

Perception of high costs

Adopting a new digital operating model requires investment in technology, usually raising concerns among decision-makers on the value of this investment. While the perception of high costs associated with IT systems often delays decisions to embark on a digital journey, the benefits of digitization far outweigh the costs associated with this investment, with the choice of a capable technology partner.

Lack of digital education and understanding

A low level of digital awareness and lack of understanding of the potential opportunities derived through digital often results in fear and aversion to change. On the other hand, there is enthusiasm around the promise of new technologies, and the desire to appear progressive by implementing the change. However, in the rush to adopt, there is only a brief uplift in productivity or commercial value. Implementation of a digital solution requires a clear vision and detailed understanding of the implementation pathway.

Organizations seem to recognize that digital is the way forward but are grappling with:

- **The large amount of information available**
- **The costs involved**
- **The change processes**

Source: EY Digital Disconnect Report[5]

Existing systems and processes not being optimized

In many cases, companies already have a significant digital footprint in place. Before implementing new approaches, mining leaders must understand the existing digital footprint and find ways to leverage digital investments already made.

Poorly defined business model and business case

The business case for digital transformation must be value-focused and centered around real business problems that it will solve, with proof of concept to back it up. The lack of detail or an ill-defined business case may lead to skepticism among leadership in commencing digital initiatives. Additionally, a lack of clarity on what the new digital operating model will look like can stall new initiatives.

Lack of detail on the implementation pathway

While stakeholders are in agreement on the digital vision, there is little discussion and detail around a practical and effective implementation pathway to transit from the current state to this vision.

Quality of data

Data is at the core of a digital ecosystem, and is critical for decision-making across the mining value chain. There are parts of the value chain with gaps in data quality and issues in gaining access to required information.

Unclear accountability and siloed approach

Owners of digital initiatives are often not clear. Due to a siloed approach to productivity in mining, digital solutions are adopted as point solutions in the value chain, rather than as a holistic approach.

Recommendations for Successful Digital Transformation

According to the World Economic Forum Report[2], digitalization has the potential to deliver significant value for the mining industry. This value is estimated to be over $190 billion in the period 2016 - 2025. As mining companies will need to operate in an ecosystem of providers and partners, collaboration is critical for successful digitalization. In this section, we look at recommendations from the World Economic Forum for a successful digital transformation in the mining industry.

Align strategy and operations towards innovation

To thrive in the digital future, companies must move beyond spawning disconnected technology initiatives and focus instead on building out a digital strategy that is aligned with their business model, processes and organization, to encourage digital usage and experimentation.

Improve data access and relevance

To thrive in the digital future, companies must move beyond spawning disconnected technology initiatives and focus instead on building out a digital strategy that is aligned with their business model, processes and organization, to encourage digital usage and experimentation.

To seize the opportunities of a digital revolution, mining companies need to embed digital thinking, processes and structures into their entire organization.

Engage and train tomorrow's digital workforce

To thrive in the digital future, companies must move beyond spawning disconnected technology initiatives and focus instead on building out a digital strategy that is aligned with their business model, processes and organization, to encourage digital usage and experimentation.

Invest in alternative benefits, not just jobs

While digitalization will empower some workers, it will also eliminate many of the local jobs of the past. Companies must invest now in finding other ways to work with and compensate local stakeholders for the responsible use of their resources. Initiatives could include infrastructure development and education support, among others.

Forge new partnerships and strengthen existing ones

Mining is a capital-intensive industry, and partnerships can lead to new models of operation and ownership of mining and metals fixed assets that can lower capital intensity. Improving active and open partnerships is the foundation for best-in-class digitalization, and offers opportunities to overcome challenges such as industry specialization, the increased importance of local communities and high capital intensity.

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