ERICSSON

Connected Mining

A guide to smart mining transformation with private cellular technology

December 2020

In this report

This is a joint report by Ericsson, Komatsu, Epiroc and Arthur D. Little. It examines and quantifies the potential value of private cellular networks for the mining industry.

The foundation of everyday goods

Mining is one of the key elements of the global economy. No longer just about meeting our demand for fuel, mining has long been vital to meet the demand for all kinds of goods.

According to Madison Margolin in The Periodic Table of iPhone Elements, a typical iPhone needs 75 elements to function — ranging from silicon in its transistors, lithium in its batteries, to the 18 rare earth elements like yttriumin in its display.

Most of these 75 elements are obtained through mining, an industry that extracts more than 10 billion tonnes of rare minerals, coal, iron and other raw materials every year.

Globally, mining produces $1.5 trillion worth of materials, roughly 2% of global gross domestic product (GDP), according to World Mining Data 2020.

So with ongoing demand for this geological foundation of our goods, there's no doubt that the mining sector is not only here to stay, but is also a steadily growing one.

The mining sector

Taking mining to the next level

Historically, the mining industry has been fairly conservative when it comes to the adoption of new methods and technologies. This is due to both a lack of financial incentives to invest in new technologies for more operational efficiency, and a powerful regulatory framework governing its operations.

But this vital industry requires a great deal of resources and equipment to function. Companies in both of the primary kinds of mining — surface and underground — are highly motivated to monitor the condition of both personnel and equipment, and have begun to partner with original equipment manufacturers (OEMs) to implement connected use cases.

Solving new challenges, however, requires new approaches. Specifically, mining organizations need to monitor and automate heavy fixed assets; connect dispersed, diverse and very remote operations; and both empower and protect their workers.

Currently, mining automation is rapidly accelerating. And according to Mordor Intelligence, the smart mining market is projected to triple by 2025 and by then it is expected that 25% of mines will have adopted autonomous operations.

The use cases we present here are the foundation for the 'Smart Mine'. By smart mine, we define that to mean one in which the use of information, data, autonomous machines, and advanced technologies bring about higher productivity, better safety, and a reduction in operational costs during mining and processing.

Mining challenges

Avoiding the pitfalls

Mining organizations face the ever-present consideration of how operations affect the environment, adjacent communities, and the health of their workers.

Stakeholders such as shareholders, employees, investors, governmental bodies and public opinion are all putting increased pressure on the mining industry to improve productivity, safety, reduce environmental impact, and update mines to be more in sync with our digital age.

Here are some challenges that mining needs to overcome as it advances into a more connected world.

Mining challenges

Four challenges facing the mining industry

Creating a safer space

Mining often involves putting workers into potentially hazardous environments, and the US Bureau of Labor Statistics rank it in the top 10 most dangerous professions.

Stronger safety regulations along with an industry safety drive, have thankfully reduced the annual fatality rate in the U.S. coal mining industry by 90% over the last four decades, according to data from the US Department of Labor.

These safety improvements have also not come at the expense of productivity – in fact, productivity has improved, resulting in both a safer and more profitable mine.

Even though it remains dangerous, smart mining can potentially save lives. According to a white paper by Accenture & the World Economic Forum, up to 1,000 deaths and 44,000 injuries can be prevented over the next decade. This would mean reducing fatalities by 10%, and injuries by 20%.

Sustainability through connectivity

Another major challenge for mining CEOs is retaining their licenses to operate. This hinges on their ability to contain and reduce mining's significant environmental and societal effects.

That said, during the last century, the industry's safety and environmental record has improved thanks to the increased adoption of technology.

Connected workers, environmental modeling and autonomous operations enable mine operators to monitor mines and spot potentially dangerous situations early so they can be addressed before anyone is hurt.

And automating their operations allow mining companies to increase sustainability by reducing fuel consumption and CO_2 emissions.

Seeing off cyber attacks

Digital transformation remains one of the top goals in the sector. This involves the collection and analysis of big data, This is because data-driven operations will better optimize their assets, improve margins and power more long-term scenario management.

But as their operations become more digitized, mining management teams are aware they must also bolster their cybersecurity, as breaches are becoming increasingly common.

In 2017, for instance, 54% of mining companies reported a significant cybersecurity incident, according to EY Global Information Security Survey 2018-19. These frequent attacks underscore the need for the very best network security in place to protect the sensitive data of mining companies.

Customers are the new competition

Mining companies also face another disruption in the form of competition from their own customers in the technology industry.

These large companies are already well-versed in using data and smart technologies to accomplish their goals, and some have begun their own mining operations in order to find new ways of sourcing their materials.

For example, in order to reduce procurement costs, Tesla plan on expanding into mining to procure its own lithium for its vehicle's batteries. Being a key component in batteries, demand for lithium alone, is expected to triple by 2025, according to Global Projection of Total Lithium Demand 2018-2025 by Melissa Garside.

"Smart mining can potentially save up to 1,000 lives and prevent 44,000 injuries over the next decade".

Creating Mining 4.0

Carving out Mining 4.0

Mining will only adapt to our new digital age when it innovates how materials are extracted, transported, and processed.

For example, autonomous and remote operations involving haulers, load-haul-dump vehicles and drill rigs cannot only improve efficiency, but also keep human beings out of harm's way.

And over time, mine management can further optimize operations by collecting and analyzing tracking data on the precise location and performance of vehicles, equipment, and personnel. Additionally, data can be collected on the location and grade of the material, revealing the number of tonnes and level of waste within the value chain.

It's still early in the adoption of smart mining technologies, but there are already a wide array of systems and products available that provide significant savings, increased efficiency, and improvements in safety. And these technologies can yield tangible benefits for investors, employees and other stakeholders.

But one thing we do know for certain is what these mines of the future will be built on: connectivity.

Creating Mining 4.0

Putting the wheels in motion

It's important to remember that mines cannot afford to shut down for long periods of time while deployment occurs. Instead, it must take place without significantly disturbing overall mine productivity. And if legacy technologies and processes cannot co-function with smart mine capabilities, the mining organization will see fewer benefits.

Naturally, these use cases can be most easily deployed in a greenfield investment or as a retrofit over time to the current fleet of vehicles, upgrading or replacing them with autonomous machines.

Levels of opportunity

The retrofit opportunity is larger for surface mining than for underground operations.

First, surface vehicles generally remain in operation longer than their underground counterparts, which enables surface operators to install sensors and connectivity equipment onto their current fleet with the expectation that they'll continue to see benefits from the upgrades for a significant amount of time.

Surface vehicles also have access to more interfaces than do their underground counterparts, such as the Global Positioning System (GPS) for location data.

Underground vehicles must rely on more advanced systems for location tracking, which in turn requires a significantly larger infrastructure investment than simply installing a GPS tracker.

Private cellular networks

The bedrock of smart mining

Private cellular networks are the connecting force that is helping forge the smart mines of the future.

Cellular does the heavy lifting

No matter what technologies are deployed, smart mining relies on a solid foundation of wireless connectivity. And that foundation is cellular.

Any network infrastructure that mining organizations deploy must be able to handle the large amounts of data that vehicles, equipment, and workers will generate.

For instance, remote drilling systems and unmanned aerial vehicles (UAVs) produce a live video feed that must be transmitted to a remote operations system. To function properly, it needs ample bandwidth and a highly reliable connection.

And voice and data communications services are mission-critical to mining operations in order to prevent injury and loss of life, and to minimize economic impacts, especially during emergency situations.

5G-ready private cellular networks are perfectly positioned to deliver on all of these requirements.

What private networks offer

As we will demonstrate, a 5G-ready private cellular network provides the richest level of connectivity needed to enable smart mining.

While many private cellular networks are 4G LTE with 5G-ready capabilities, private 5G-ready cellular networks will play a critical role in enabling smart mining by introducing high-speed connectivity, low latency and strong performance in high device density environments.

They will reduce round-trip latency by 95%, providing the high uplink speed required for smart mine use cases. That will enable 8K resolution images, capitalizing on extremely efficient image encoding algorithms.

They are also highly optimized for the Internet of Things (IoT), providing low energy consumption, strong security and high device density. And in contrast to legacy networks, 5G-ready private cellular networks provide a complete solution for licensed and unlicensed spectra, plus seamless cellular vehicle to everything (c-v2x) connectivity.

This combination of high data volume and low latency can create the business edge needed to move ahead of the competition.

What is a private network?

- An on-premises cellular network deployed for an organization's exclusive use.
- In mining, this typically includes facilities in very remote areas and underground tunnels, both of which are not typically within public cellular range.
- Most private cellular networks today are 4G LTE networks with 5G-ready capabilities. Private networks based on 5G cellular technology are expected to become widely available by 2021.

Use cases

Our five smart mining use cases

What follows are five use cases that our research, in partnership with Komatsu and Epiroc, have identified as the most beneficial near-term applications for smart mining technologies. In each case, we identify how it would benefit the baseline mines we'll describe on the next page. The five we have chosen are:

1. Autonomous vehicles
2. Real-time condition monitoring
3. Remote controlled drilling rigs
4. Unmanned drone inspection
5. Smart ventilation control

Methodology

Since 2017, Ericsson, in collaboration with Arthur D. Little, has released a series of studies examining the value that cellular connectivity and 5G can create for industries.

In this study, we've extended the collaboration to include industry leaders Komatsu and Epiroc, with the aim to further crystalize insights in smart mining.

This joint 2020 study is built on a bottom-up, deep-dive analysis of five high-value use cases that address the most imminent pain points in the mining industry.

To gauge the net economic, social, and environmental value, we defined two baseline mines; a surface mine and an underground mine, based on concrete and validated KPIs from actual mines and then analyzed from the bottom up, the incremental value created by each cellular connectivity-enabled use case, from deployment until operational steady state*.

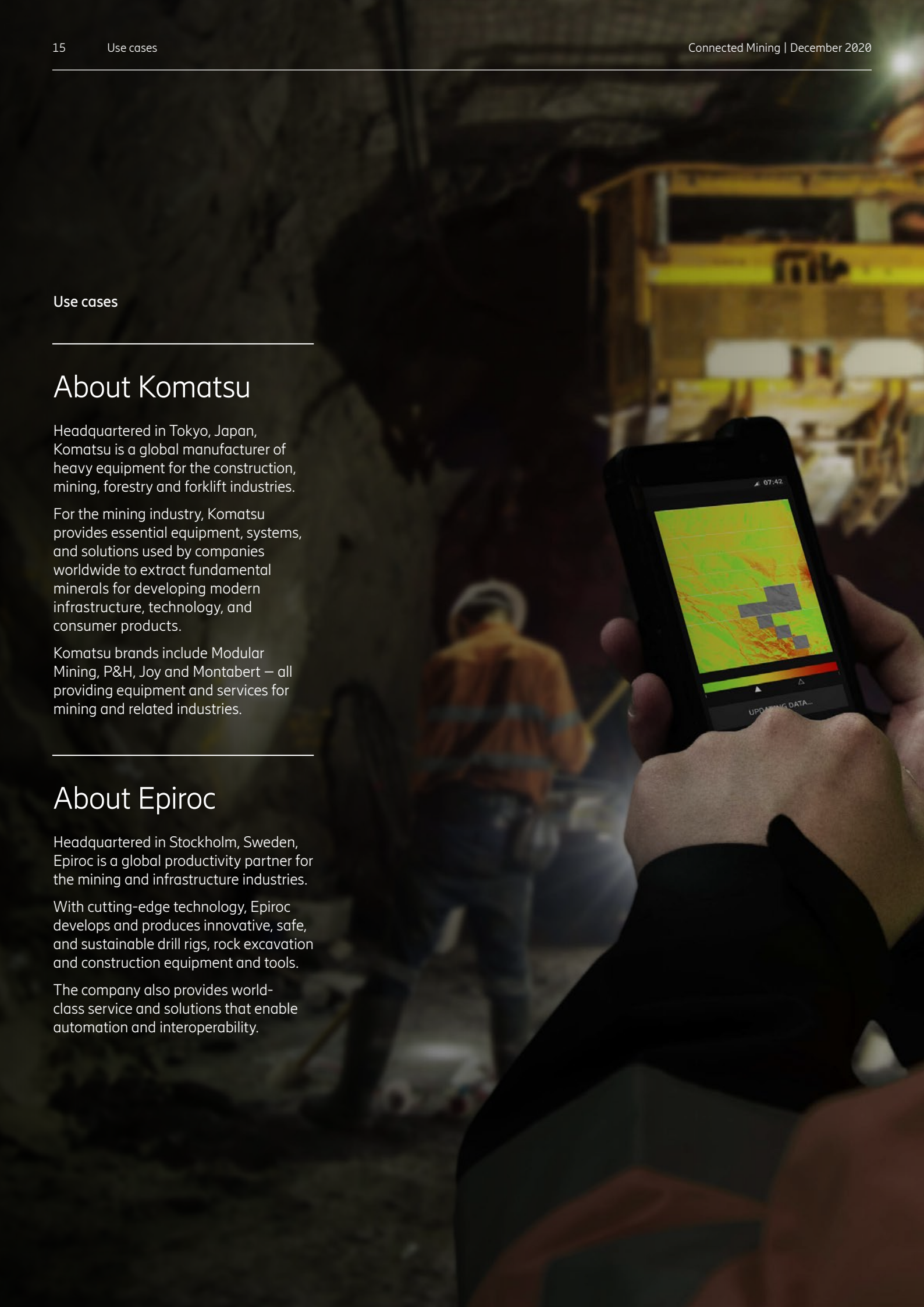
The analysis and output values are thoroughly validated by Komatsu, Epiroc, and other experts.

The incremental value from each use case is aggregated to a total benefit for:

- **Surface mine:** A gold mine in Argentina with 25 million tonnes of annual production, revenues of $530 million USD, and gross profit of $170 million.
- **Underground mine:** A gold mine in Brazil with 2 million tonnes of annual production, revenues of $195 million USD, and gross profits of $85 million.

These two baseline mines are large enough to showcase the effects of all the use cases in order to provide granular simulations of key mining metrics.

* **Steady state net value** is a combination of the terms "steady state" and "net value". **Steady state** means the use case is fully deployed, so the full benefits are activated, and only the operational costs are active (no additional CAPEX-investments). **Net value** is the value after subtracting all costs from the value of the benefits, i.e. the real "savings".



Use cases

About Komatsu

Headquartered in Tokyo, Japan, Komatsu is a global manufacturer of heavy equipment for the construction, mining, forestry and forklift industries.

For the mining industry, Komatsu provides essential equipment, systems, and solutions used by companies worldwide to extract fundamental minerals for developing modern infrastructure, technology, and consumer products.

Komatsu brands include Modular Mining, P&H, Joy and Montabert – all providing equipment and services for mining and related industries.

About Epiroc

Headquartered in Stockholm, Sweden, Epiroc is a global productivity partner for the mining and infrastructure industries.

With cutting-edge technology, Epiroc develops and produces innovative, safe, and sustainable drill rigs, rock excavation and construction equipment and tools.

The company also provides world-class service and solutions that enable automation and interoperability.

Autonomous vehicles

Driving up efficiency

Safer and more productive mines with autonomous vehicles

"Due to limited driver visibility, haulage accidents account for up to 25% of all mining deaths".

The road to smoother haulage

While expensive safety precautions are in place within industrial mines, the process of transporting ore from the mine to adjacent deposits and then to the processing plant still poses significant risks to workers.

The vehicles used for haulage are large and often have limited visibility. So not surprisingly, haulage accidents account for up to 25% of all mining deaths, according to the U.S. Department of Labor's Mine Safety and Health Administration.

In underground mines, load, haul and dump (LHD) operations account for 8% of all injuries, with the vehicle's driver most often affected, according to Robin Burgess-Limerick in The Ergonomics Open Journal.

Haulage is also a large cost driver for mines. According to Boliden's Mine Cost Drivers, 2008, in a typical open-pit mine, around 30% of the mining cost can be attributed to haulage.

Automation's here for the long haul

Today, autonomous haulage systems offers high levels of automation, with all core functions autonomously controlled. The trucks employ on-board sensors and backhauls, as well as local computational devices for edge computing and final control of the vehicle.

Autonomous vehicles can significantly improve efficiency and safety for a mine. Introducing autonomous haulage would not only provide safety benefits, but also a clear, positive bottom-line impact.

As of 2020, there are autonomous trucks in operation at only a relatively small number of surface mining sites. The opportunity for expanding autonomous haulage systems within the industry is therefore a large one.

"Rio Tinto saw a 34% increase in productivity when using Komatsu's Autonomous Haulage System".

Automation moves Rio Tinto ahead

Autonomous haulage is a groundbreaking productivity enhancement in mining. One example that proved this was with Rio Tinto, one of the world's largest metals and mining operations.

According to Sam Francis in Robotics & Automation, the company saw a 34% increase in productivity when using Komatsu's FrontRunner Autonomous Haulage System. Handling of the trucks improved significantly, and on average, maintenance costs were cut by 13% per operating hour. Additionally, fuel consumption also dropped.

Haulage has come a long way

Autonomous haulage has made great strides since it was first introduced in 2008. Initially, haulers had assistive and partial automation, in which some operational decisions are automatic, and the operator is provided feedback to improve efficiency of task execution.

These applications capitalized on fleet management systems and GNSS (e.g. GPS) guidance. What followed was conditional automation, with automation of core functions, in which the operator only needs to intervene as needed or for complex functions.

Connectivity is the driving force

A robust communications network is a key enabler for the system. 5G-ready private cellular networks deliver a communication network with high resiliency, availability, and low latency to provide the coverage, capacity, and responsiveness required.

Also, these networks can combine licensed and unlicensed spectra, which means the trucks can have one backhaul for all its communicational needs. Combined with the fewer number of nodes required for 5G, mines have less field equipment to maintain in most cases.

Autonomous haulage itself does not require much bandwidth, though it does require stable connectivity. However, in an underground application, with autonomous LHD, bandwidth requirements are significantly higher due to the video stream requirement. In an underground application, the net link capacity should allow for 16 Mbps minimum.

As technology matures, the path to full automation is clear. Full automation will bring all functions under automatic control, including the execution of the complete mine plan.

A smoother financial ride

Autonomous vehicles provide clear triple bottom line benefits for worker safety, the environment, and the overall economics of the mine.

The financial benefit for our baseline surface mine reaches about 1.6% of the revenue as yearly steady state net value. The return on investment by year 10 is 72%. Payback is less than seven years.

The revenue and ROI benefits come from:	
Reduced depreciation cost	44%
Reduced maintenance cost	35%
Reduced fuel cost	21%

Real-time condition monitoring

Predictably efficient

Better running machinery with real-time condition monitoring

"By transitioning from reactive to proactive maintenance, unplanned maintenance can be reduced by 25%".

The need for a well-oiled machine

Mines are harsh environments in which machine usage has a significant influence on both component lifetime and the operator's safety. According to an Analysis of Equipment-related Fatal Accidents in U.S. Mining Operations: 1995–2005, up to 90% of fatal mining accidents are related to equipment, and maintenance accounts for 41% of a mine's equipment costs.

Yet 70% of machine-specific malfunctions can be prevented by collecting and analyzing machine data, says Stephan Romeder in his article 'How predictive maintenance will drive the factory of the future'.

To provide cost-conscious and complete equipment maintenance, plans must be tailored to individual machines. When maintenance is provided only when required and new parts are automatically ordered and installed, mining companies cannot only ensure their assets are always in good condition, but also significantly reduce maintenance costs.

"Mine operators can see an average of 20% reduction in maintenance costs for equipment covered by real-time condition monitoring".

Real-time has real benefits

Real-time condition monitoring optimizes uptime and improves mine safety. By transitioning from a reactive maintenance approach to a proactive maintenance approach, unplanned maintenance can be reduced by 25%, according to Modular Mining's Maintenance Management Webinar. This lowers the overall cost of maintenance and enables mine operators to use smaller buffers in terms of equipment, which lowers overall capital expenditures.

In the same webinar, it was mentioned that by focusing on defect elimination in specific pieces of equipment instead of following a one-size-fits-all maintenance plan, mine operators can increase the mean time between equipment failures by 150%.

Given the wide array of benefits of real-time condition monitoring, mine operators can see a 20% reduction on average in maintenance costs for the equipment in scope, and, in our simulation, 80% of the equipment is eligible for real-time condition monitoring.

Unearthing data fuels efficiency

Mining equipment management systems have been around for decades. Nowadays, real-time monitoring of health and maintenance processes enable mine operators to practice proactive maintenance, which optimizes equipment uptime by greatly reducing how long it takes to troubleshoot and repair assets.

These capabilities help mines make informed decisions on optimal maintenance schedules.

Mining sites first collect data from onboard mining equipment via OEM or third-party systems. This data is collected in an on-board computer, and subsequently sent over a wireless network to a central cloud computing environment where it can be analyzed to provide visualizations and insights.

This trove of "big data" on machine conditions enables operators not only to understand the historical and current state of equipment, but also predict its future state.

Higher data for higher safety

While mining maintenance management can be operated in a limited bandwidth environment, 5G-ready private cellular networks can extend the volume of data, indicators captured and number of equipment and machines the solution can monitor. With increased bandwidth, more indicators can be captured. This includes indicators that may be indirect to the maintenance profile of the equipment, such as temperature changes.

Also, with increased bandwidth, indicators can be captured at a higher resolution, capturing and transmitting data at a higher frequency. There's a big difference between capturing and transmitting data one second every minute and doing so every second. Continuous data capture increases the density of information by a factor of 60.

In financially better condition

Real-time condition monitoring doesn't only keep your equipment in good condition. It provides clear benefits for the overall economics of the mine as well as your worker safety.

The financial benefit for our baseline surface mine reaches about 1% of the revenue as yearly steady state net value. The return on investment by year five is 288%. Payback is less than two years.

The revenue and ROI benefits come from:	
Reduced maintenance cost in mining	75%
Reduced maintenance cost in processing	25%

"There's a big difference between capturing and transmitting data one second every minute and doing so every second. Continuous data capture increases the density of information by a factor of 60".

Remote controlled drilling

Ace in the hole

Raising productivity with remote controlled drilling

"Remote controlled drilling is faster than manual drilling, which increases productivity by 60%".

The dangers of drilling

Surface and underground drilling is an integral part of both surface and underground mines, driving 5% of the mining cost of a typical surface mine.

But drilling, especially underground, creates significant risks to worker safety, the environment, and the economics of the mine.

Operators can make drilling more precise, accurate and cost-efficient by enabling remote operation and automation of drilling rigs.

Breaking new ground

The case for automation within drilling is a persuasive one. Introducing remote control and semi-autonomy in the mine for drilling produces a 75% increase in utilization, according to Epiroc's article Aitik – Strides to full automation. In this scenario, the operator initiates the process, but the drill moves autonomously between drill holes.

According to Oxford University's, Technology at Work, remote control drilling is also faster than manual, so it can increase your productivity by an impressive 60%.

Reaping rewards in Russia

For example, Apatit JSC's Kirovsk branch is a closed-circle facility in Russia that mines phosphate rock from one of the world's largest deposits, with operations ranging from ore extraction to the production of apatite concentrate, a raw material used for mineral phosphate fertilizers.

In 2018, Apatit installed Epiroc's remote drilling solutions on three production drill rigs, as well as telematics systems for remote control and monitoring of the drilling units at the Kirovsk branch. During the pilot project, a special rig control station was allocated on the surface.

As a result, the operation was able to significantly reduce risks to operators through underground drilling automation, while also increasing output of the drilling machines by 20%. The utilization of one machine increased to 95%.

Powerful drills need powerful connections

To achieve these benefits, remote drilling requires multiple connections on the same vehicle, high bandwidth for video streaming, and a reliable connection for quality of service.

What makes a 5G-ready private cellular network an ideal connectivity solution to enable remote drilling is its ability to work with both licensed and unlicensed spectrum, as well as its high uplink speed and very low latency

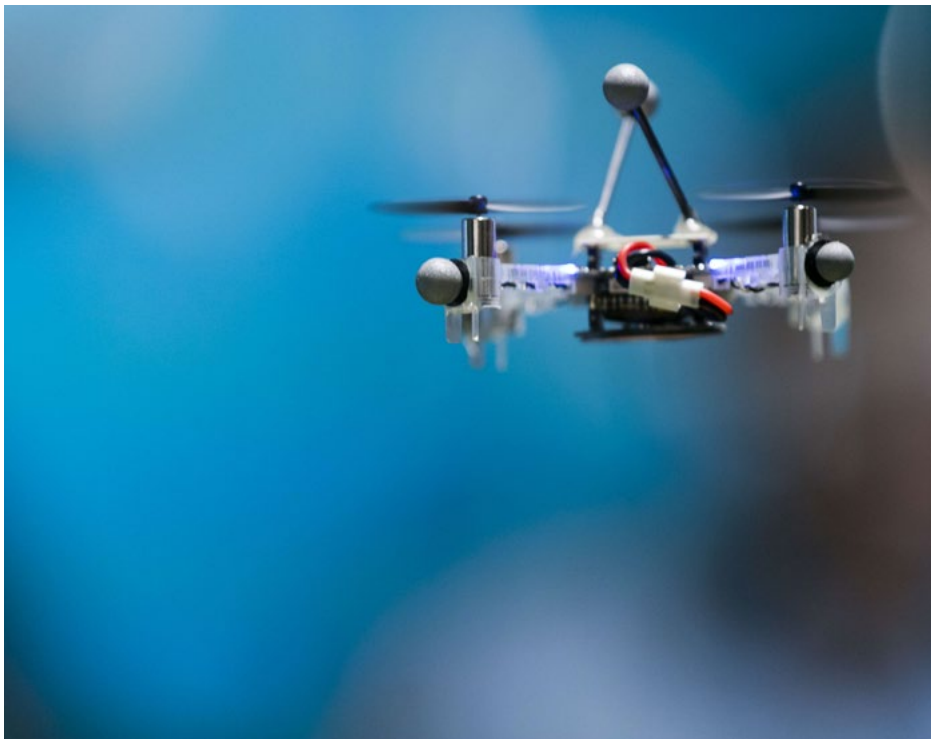
"After installing Epiroc's remote drilling solutions on three production drill rigs, Apatit increasing output of the drilling machines by 20%".

Remote raises ROI

Remote-controlled drilling provides clear triple bottom line benefits for worker safety, the environment, and the overall economics of the mine.

The financial benefit for our baseline underground mine reaches about 0.6% of the revenue as yearly steady state net value. The return on investment by year 10 is 200%. Payback is less than four years.

The revenue and ROI benefits come from:	
Reduction in depreciation cost	75%
Reduction in maintenance cost	25%



"When drones inspect areas after blasts that haven't yet been deemed safe for workers, reduced downtime costs can be lowered by 51%".

Unmanned drone inspection

Flying in the face of danger

Getting operations off the ground

Mining giants such as Rio Tinto, BHP, and Anglo American have been testing drones since at least 2016. These drones can monitor, inspect, and map underground settings that are potentially dangerous for workers.

Additionally, drones can inspect exhausted mines much faster, and thanks to the more accurate models drones can produce, operators can make more accurate and cost-efficient plans that need less backfill material.

Drone uptime cuts downtime

After blasts in underground mines, new routes must be established for vehicles. Typically, this occurs roughly once a day and causes significant downtime of about an hour.

With drones inspecting areas that have not yet been deemed safe for workers, this downtime can be cut by 7%, according to an expert estimate in an Arthur D. Little and Epiroc 2020 interview.

Drones need sky high connectivity

Using drones for mine inspection and mapping requires a robust wireless communications network, as when drones capture live video streams, they consume significant bandwidth.

In order to ensure accurate steering of the drone in-flight, connectivity must meet the low-latency and high reliability requirements needed to transmit 4K video.

Elevating your ROI

Investing in unmanned drone inspections will steer you in a better financial direction. The benefit for our baseline underground mine reaches about 0.3% of the revenue as yearly steady state net value. The return on investment by year five is 153%. Payback is less than three years.

The revenue and ROI benefits come from:	
Reduced downtime cost after blasts	51%
Reduced cost of backfilling	28%
Reduced cost for inspection of stopes	21%

"Drones can inspect exhausted mines much faster, and make more accurate and cost-efficient plans that need less backfill material".

Smart ventilation control

Breathe easy with smart ventilation

"Smart ventilation can reduce underground ventilation costs by up to 60%".

Ventilation is vital

Ventilation is the bedrock of climate control and the primary method of diluting hazardous substances in an underground mine.

This makes ventilation paramount as it's a large cost driver for underground mines. It can account for as much as 50% of their energy cost and about 15% of the mine's total cost, according to Leandro de Vilhena Costa and José Margarida da Silva in REM – International Engineering Journal.

The future efficiency of a mine can live or die on effective underground ventilation, and clearer air will create a clearer path towards productivity.

Clear air, clear benefits

Smart ventilation has the potential to heighten future efficiency, with automation providing numerous benefits. It creates a safer environment, optimizes air quality through use of sensors, and leads to an overall reduction in ventilation costs.

"By automating the control and monitoring of fans, louvers, and ventilation doors, energy costs can be reduced by an additional 20%".

An effective, efficient ventilation system can help reduce downtime in a mine by venting blast gasses faster. Automatic ventilation on-demand can reduce an underground mine's ventilation costs by 30% according to ABB Smart ventilation 2015.

By automating the control and monitoring of fans, louvers (blinds and shutters) and ventilation doors, energy costs can be reduced by an additional 20%. Real-time monitoring makes ventilation more efficient, reducing costs by another 10%. All told, smart ventilation can reduce underground ventilation costs by up to 60%.

Smart ventilation needs dedication

Smart ventilation requires a reliable, secure connection with high enough bandwidth and low enough latency to enable real-time data transmission.

A 5G-ready private cellular network supplies the low-latency, high reliability, and strong security to make it a key enabler of this use case. It provides the secure network functionality that can reach deep into any mine.

Additionally, the energy usage in a 5G set-up is optimized, allowing mining companies to monitor remote and passive parts of the mine.

Smart air, smart investment

Smart ventilation also let's you breathe easy when it comes to investing in it. It provides clear triple bottom line benefits for worker's safety, energy usage and the overall economics of the mine.

The financial benefit for our baseline underground mine reaches about 1.9% of the revenue as yearly steady state net value. The return on investment by year five is 40%, based entirely on reduced ventilation costs. Payback time is less than 4 years.

The business case

Gaining ground in any mine

These five smart mining use cases present a compelling business case for adoption. They'll allow your company to create more agility, advance your operations, and unlock new levels of intelligence. This will all lead to major triple bottom line benefits, being the case for both surface and underground mines.

Surface

For the surface mine, autonomous vehicles, real-time condition monitoring and remote-controlled drilling rigs all improve efficiency, productivity, safety, and environmental impact.

When all three use cases are deployed together and applied to our baseline surface mine, their combined annual steady state net value reaches $15 million, which represents 2.9% of the mine's revenues.

That means they'll provide a combined ROI of 207% by year 10, with total costs of $40 million USD.

Underground

Underground mines can also benefit from autonomous vehicles, real-time condition monitoring, and remote-controlled drilling rigs. But to these we add the highly beneficial unmanned drones and smart ventilation control.

And while implementation in an underground mine is associated with higher complexity than a surface mine, the payoff is far greater when compared to revenue.

If all five use cases are applied to our baseline underground mine, their combined annual steady state net value reaches $9 million, which is 4.4% of the mine's revenues.

That provides a combined ROI of 256% by year 10, with total costs of $21 million USD.

The pick of the use cases

The rock solid choices

Our research indicates that the five use cases we identified are the most important and therefore best place to start. But there are two that stand out — one in each category of surface and underground mines.

The pick of the use cases

Surface mines

Autonomous vehicles take the lead

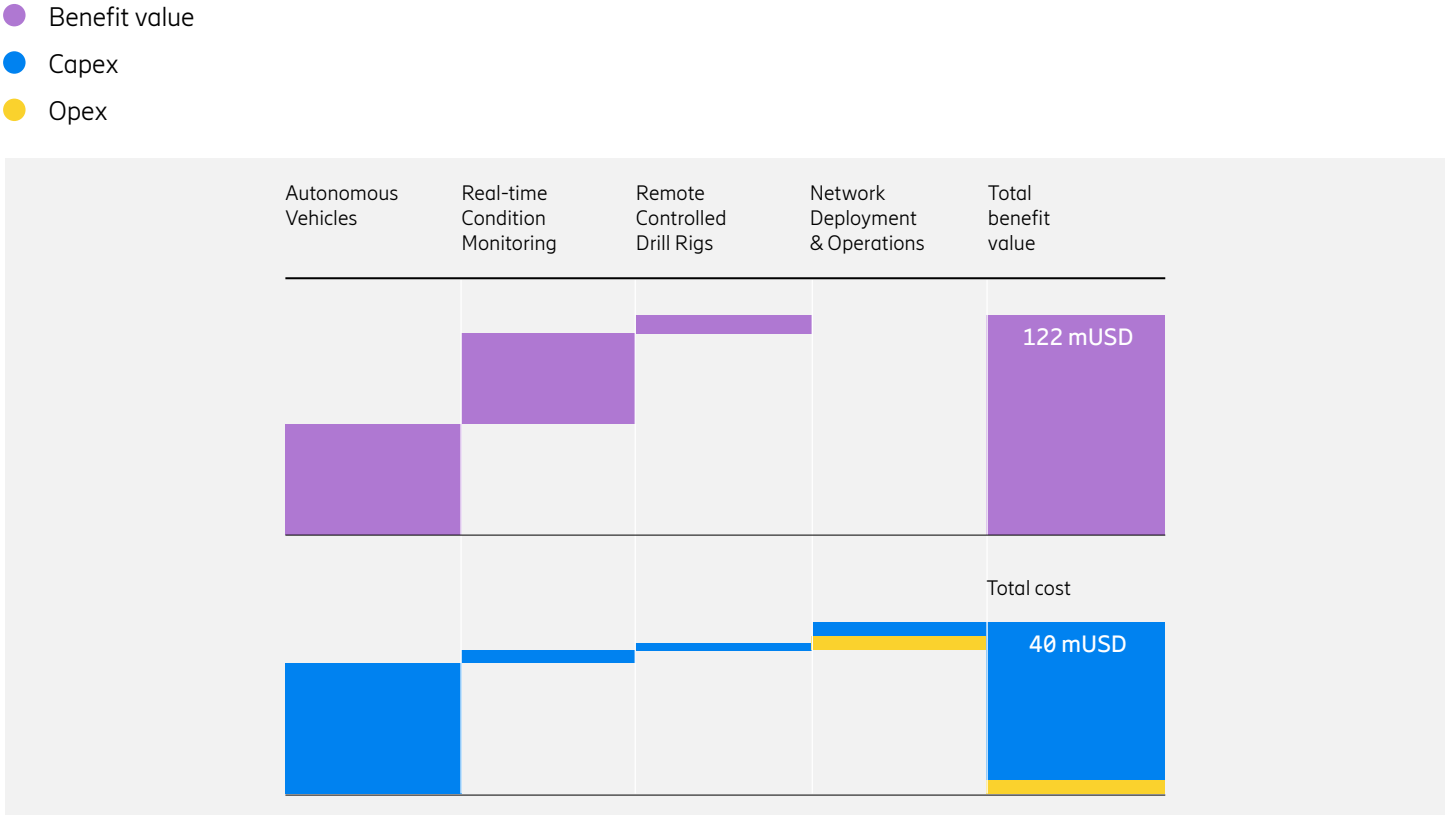
Their capacity to advance operations make autonomous vehicles the best place to start when automating a surface mine.

The combined return on investment of all three surface mine use cases is 207% and payback is less than three years.

Percentage of yearly steady state net value for uses cases in a surface mine	
Autonomous vehicles	55%
Real time condition monitoring	37%
Remote controlled drilling rigs	8%

207% ROI

Full surface mine deployment, year 10



Source: Ericsson, Arthur D. Little

The pick of the use cases

Underground mines

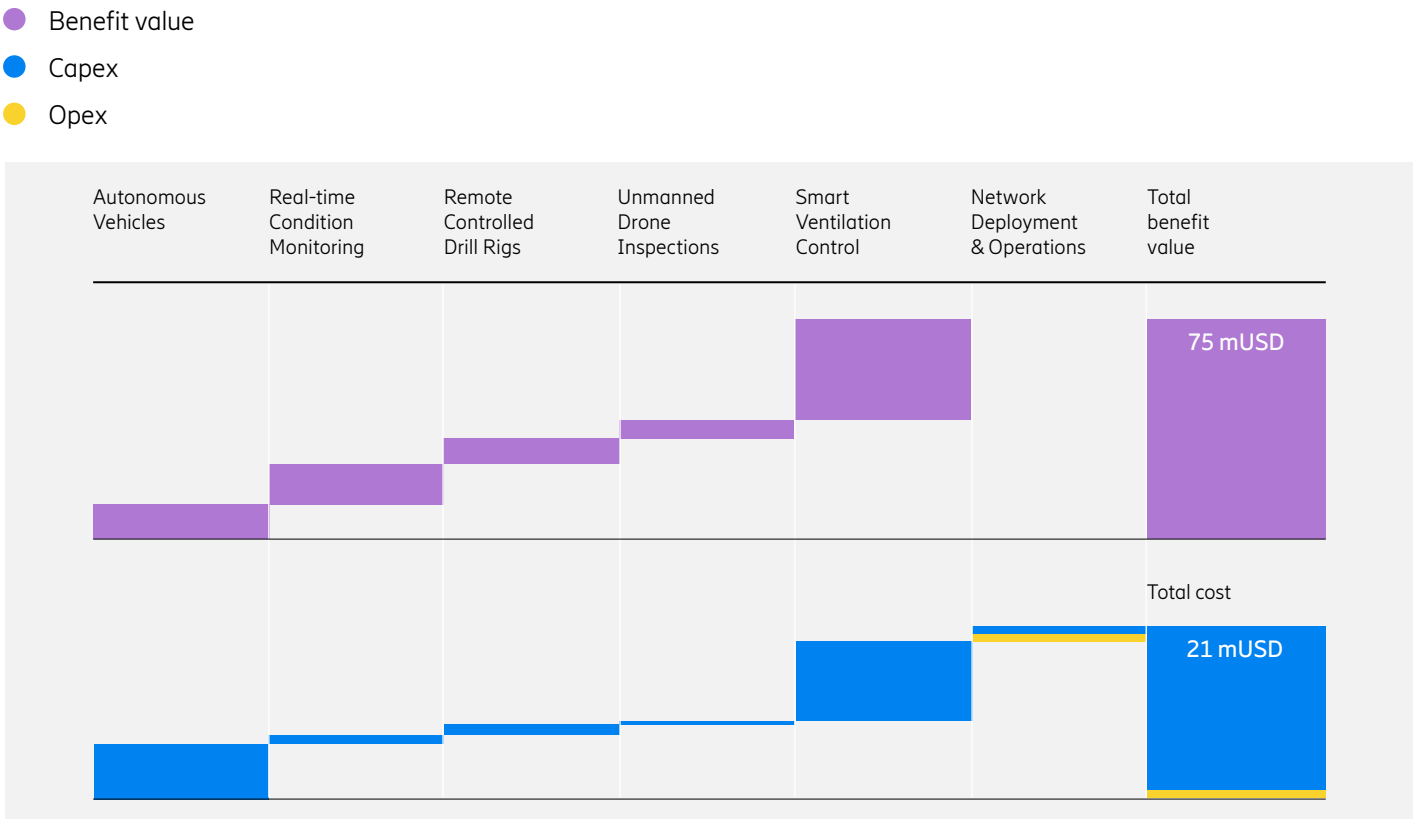
Smart ventilation is the smart choice

Smart ventilation is the most beneficial of the underground mine use cases. If all five underground mine use cases are applied, a combined return on investment of 256% can be achieved with payback less than three years.

Percentage of yearly steady state net value for uses cases in an underground mine	
Smart ventilation control	44%
Autonomous vehicles	17%
Real time condition monitoring	17%
Remote controlled drill rigs	14%
Unmanned drone inspections	8%

256% ROI

Full underground mine deployment, year 10

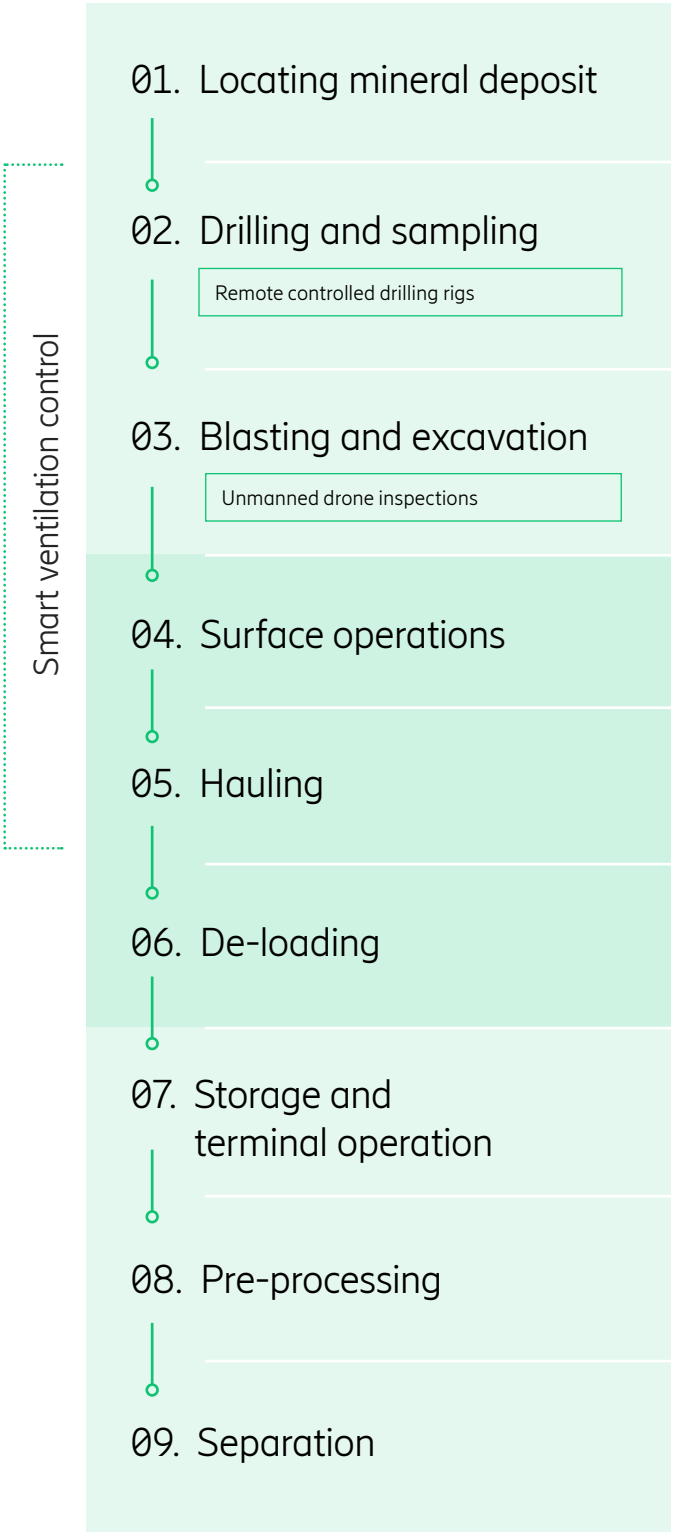


Source: Ericsson, Arthur D. Little

Combining the use cases

Smarter mining by combining

All five use cases have applications throughout the stages of the mining process. Here's what it might look like with all five working together seamlessly within one smart mine.



● Autonomous vehicles – Autonomous Haulers and Load-Haul-Dump

Real-time condition monitoring is active in all steps of the smart mining process.

01

Remote controlled drilling rigs

Once a mineral deposit is located, remote controlled drilling rigs can take care of drilling and sampling.

02

Unmanned drone inspections

Unmanned drones can conduct quick inspections after blasting, keeping workers away from areas not yet deemed safe.

03

Autonomous vehicles

Then autonomous vehicles can haul ore and minerals to de-loading zones.

04

Real-time condition monitoring

All the while, real-time condition monitoring keeps management aware of the state of each machine and even automates the ordering of parts and installation for maintenance.

05

Smart ventilation

And underground, smart ventilation control vents blast gasses and ensures the air is safe for workers to breathe.

Final word

The mine of the future is a connected one

It's clear that the financial benefits of smart mining are significant, with an ROI of 207% in ten years for our baseline surface mine, and a 256% ROI for the baseline underground mine.

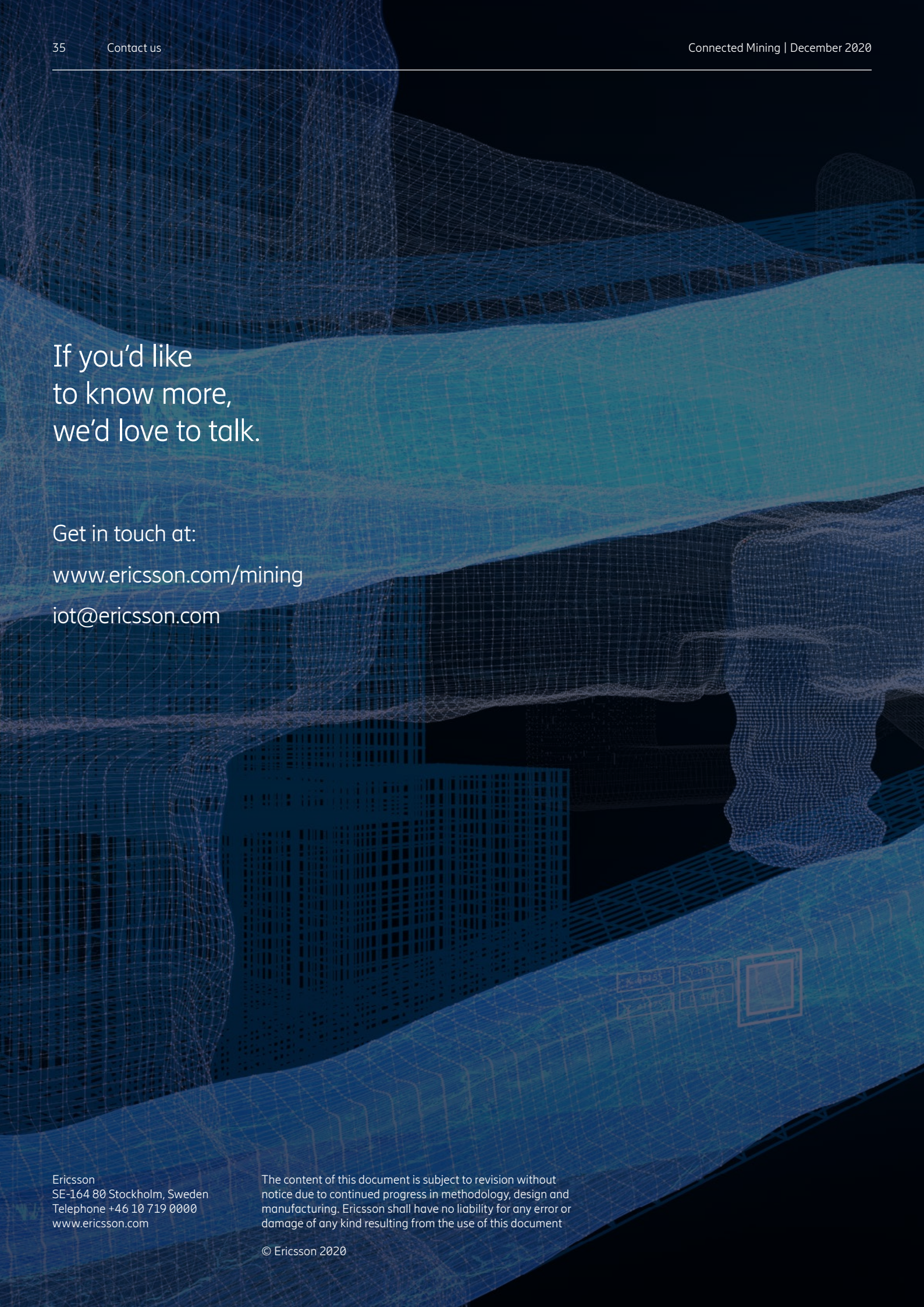
All use cases should pay for themselves in two to seven years, and if all five are deployed together, they provide complete payback within three years.

But beyond the financial bottom line, smart mining creates a substantial triple bottom line that includes improved safety for workers and a more responsible environmental impact.

Of course, bringing about these changes is dependent on the fast, reliable, secure connectivity that only a 5G-ready private cellular network can provide.

But large scale adoption of private networks has the potential to solve the mining industry's ongoing challenges and totally reshape mining from the ground up.

"All use cases should pay for themselves in two to seven years, and if all five are deployed together, they provide complete payback within three years".



If you'd like to know more, we'd love to talk.

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