The state of digital transformation in the South African mining industry

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Ten insights into 4IR

2021

A study on how the Fourth Industrial Revolution is building value in our mining industry and where it's headed.

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MINERALS COUNCIL SOUTH AFRICA

Contents

Survey methodology and participants

PwC and the Minerals Council of South Africa conducted this study to gauge how the Fourth Industrial Revolution is building value in the South African mining industry and where it is headed. The study took the form of one-hour interviews that covered 31 mulifaceted questions. The interviews were conducted by a PwC team member together with a Minerals Council staff member. Nineteen mining companies took part in the survey, with a total of 23 interviews being conducted. The interviews were carried out between December 2019 and August 2020.

Note

Percentages may not total 100 due to rounding and/or the exclusion of certain responses.

The Fourth Industrial Revolution

The Fourth Industrial Revolution — 4IR — as we will address it in this study, was named as such because of the current period of rapid technological growth, which is fundamentally changing the way we live and work. New technologies such as artificial intelligence, cloud computing, automation, 3D printing, the Internet of Things (IoT), robotics and faster wireless technologies are blurring the lines between the digital, biological and physical worlds.

Acknowledgements

The Minerals Council expresses its sincere appreciation to PwC and the thought-leadership assistance provided by Mr Jean-Jacques Verhaeghe of the Mandela Mining Precinct.

Foreword

4IR needs mining: 28 of the 29 elements used in mobile phones need mining and 14 of these elements have a recycle rate of less than 1%, making mining essential.

Just as 4IR needs mining, South African mining needs the 4IR. Over the last decade:

- multi-factor productivity in South Africa has fallen by 7.6%;
- mining cost inflation has been 2–3% higher annually than general inflation, leading to two-thirds of output being on the upper half of the global mining cost curve; and
- mining output declined by 10% and minerals sales contracted by 11%.

In addition, as we grapple with global challenges like climate change and social justice, environmental, social and governance (ESG) issues will become more important in global competitiveness assessments.

The advantage of 4IR technologies applied in a people-centric manner is that it creates new, better paid, safer, healthier, and more fulfilling jobs. This strategy is about turning 4IR technologies into allies that help people, rather than a threat to replace them.

Accelerated by the demands of dealing with the COVID-19 pandemic, organisations and individuals are experimenting with new ways of working and living, all enabled by a multitude of 4IR technologies.

As such, the pandemic provides us with the opportunity to make different decisions and do things in a better way. In this context, South African mining needs:

- a people-centric, 4IR-enabled modernisation strategy that provides solutions towards globally competitive mining;
- an accelerated, transforming innovation capacity-building programme to restore South Africa as a global leader in mining;
- public-private partnerships like the Mandela Mining Precinct to facilitate modernisation;
- innovation infrastructure, such as a test mine where innovators can turn research into globally-competitive products; and
- multi-source, significant mining innovation investments.

Recognising that 4IR is a key enabler of modern, globally competitive mining, the Minerals Council and PriceWaterhouseCoopers (PwC) collaborated to produce the first of its kind study on '4IR in South African mining'. The Minerals Council expresses its sincere appreciation to PwC and the thought-leadership assistance provided by Mr Jean-Jacques Verhaeghe of the Mandela Mining Precinct.

The purpose of the study is to better understand where the industry is with the adoption of 4IR technologies and provide guidance on the opportunities and challenges associated with the journey ahead.

The Minerals Council believes that regular reports of this nature will help decision-makers from all mining stakeholders to make better and faster decisions that will enhance the global competitiveness of mining.

Mining is an integral part of how humans, hand-in-hand with 4IR technologies, will build a socially just world and keep within its ecological limits. Using 4IR technologies to enable a more modern mining sector, South African mining will become globally competitive, attract the best talent, and ultimately contribute even more as we re-imagine our economy and society.

Roger Baxter
Chief Executive Officer
Minerals Council South Africa

Glossary of terms

Term	Definition
4IR	The Fourth Industrial Revolution
4IR ecosystem	Integration of two or more silos' information and processes which improves operating model efficiency
AI	Artificial intelligence
AR	Augmented reality — a technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view
CDO	Chief digital officer
CEO	Chief executive officer
CIO	Chief information officer
Digital twin	A simulation modelling a real-world plant, operation or piece of complex equipment that can simulate real-world outcomes.
ERP	Enterprise resource planning
ESG	Environmental, social and governance
IEEE	Institute for Electronic Electrical Engineering
IIoT	Industrial Internet of Things
IIRA (IIC)	The Industrial Internet Consortium's Industrial Internet Reference Architecture
IoT	Internet of Things
ISA-95	International standard for developing an automated interface between enterprise and control systems

Term	Definition
IT	Information technology
MCSA	Minerals Council of South Africa
MRM	Mineral resource management
NPV	Net present value
OEM	Original equipment manufacturer
Operating model	How an organisation runs itself — the process of delivering value to a customer
OT	Operational technology — hardware and software that monitors and managers the operation of machines
PdM	Predictive maintenance — the process of addressing problems before they cause equipment failures by means of analytics
PdM 4.0	Predictive maintenance involving the application of machine learning to identify meaningful patterns in vast amounts of data to generate new, actionable insights for improved asset availability
ROI	Return on investment
RPA	Robotic process automation (cognitive intelligent automation) — automating repetitive tasks via a bot (an autonomous program that can interact with systems or users)
SLO	Social licence to operate
SLP	Social labour plan
VR	Virtual reality — a simulation of a three-dimensional environment that can be interacted with in a seemingly real or physical way

Executive summary

In this, our first survey on *The state of digital transformation in the South African mining industry*, we surveyed 23 senior managers and executives across 19 mining companies, mostly members of the Minerals Council. They are among South Africa's most prominent coal, platinum group metals, gold, ferrous and mined raw materials producers. Although these companies are not representative of the entire mining industry in South Africa, we identified ten key insights that we believe are consistent with other international studies[*] and can be used by mining company executives and other decision makers to chart the course of their organisations' digital transformation journey.

Key insights

1. The CEO drives the digital agenda

CEOs are the primary driver of 4IR and the digital transformation programme in mining businesses, with many respondents describing the CEO as driving a top-down initiative-based approach. This is consistent with findings of other PwC research carried out across various industries since 2015.[*]

Beyond the CEO, the second most common approach is for either the COO or executive head for technical to drive the adoption of new technology. While a top-down approach can provide the necessary impetus, it is clear that it also involves a long buy-in process from operations personnel. But, once that buy-in was achieved, the additional support and operationally beneficial initiatives sped up adoption and ownership of new technologies.

2. Digital champions and innovators are emerging

Digital champions and innovators are already emerging in the South African mining industry, with more than two-thirds of respondents well on their way to building digital programmes. They typically have a clear strategy and are bringing together the building blocks needed to progress.

Optimising operations and reducing cost is a major driver of these initiatives, with additional goals being to collect and 'integrate' additional sources of data through technologies such as the Internet of Things and advanced process control.

Some digital innovators are already looking beyond optimisation to transformation: executing cross-functionally connected practices, sharing information and data between business functions and finding new value through collaboration. They are focusing on achieving a smart and connected mine from exploration to fulfilment, with the dominant goal of optimising and removing costs.

[*] *A list of these publications is provided in the References section on page 26.*

3. Investments in digital technologies are growing

Nearly all companies surveyed are investing in digital technologies. The average investment in digital technologies was R111m per year across all respondents. The bolder investors in digital (25% of respondents) are spending an average of R166m per annum.

The scale of their spending suggests mining companies are coming out of the starting blocks at speed and using their traditional approach of net present value to motivate these investments. With the majority of respondents in the intermediate stages of their digital journey, we expect average investment size to increase in the coming years as the benefits of 4IR transformation become clear to stakeholders.

Mining companies have clearly grasped that the key to the digital revolution is becoming more data driven. This is reflected in the surveyed companies' priorities, which are:

- connecting people and assets to provide insights; and
- connecting machines to visualise their data (condition monitoring).

These technologies are receiving the lion's share of the wallet, with platforms to manage, analyse and report from these diverse data sources also being a focus area.

4. Digital technologies are delivering real benefits

Major reasons given for investments in digital technology highlight throughput and efficiency increases, lower costs and improved health and safety. Almost 90% of companies surveyed expect their 4IR investments to yield at least a 10% throughput increase with a fifth expecting as much as a 30% increase in the next five years.

Similarly, the majority expect more than a 10% reduction in costs in the same period. While 17% expect no cost reductions, they anticipate significant increases in productivity per capita – they are relying on the higher skills base of their future workforce (at higher cost per head) to make the difference in productivity.

When asked where the benefits will come from, most respondents believe that production, engineering and asset management related investments will unlock the most value.

Supply chain and logistics seem to be relatively underestimated areas in terms of the impact of 4IR technologies in mining at present. A number of the more digitally mature companies surveyed (champions and innovators) are actively investing in emerging technologies such as blockchain, the Internet of Things and artificial intelligence (AI) in this area to unlock value.

5. The greatest benefit is expected in core operations

Mine technical functions such as rock engineering, survey, ventilation and safety, as well as asset management, maintenance and repair are the primary beneficiaries of 4IR in our study. This reflects the drive to visualise and manage operations in near real time — giving mining companies the ability to respond more quickly and 'save' a shift or lost blast.

IT functions have an important role to play in digital transformation, but we are also seeing a significant overhaul of IT — changing it from a service provided to business to a business partner that enables operations through technology.

Health and safety is another significant beneficiary, not just through collision avoidance and environmental improvements enabled by monitoring, but also in terms of improved employee engagement.

Despite only 10% of respondents currently focusing on end-to-end supply chain planning, more than 60% cited supply chain, logistics and procurement as having a highly significant role to play in digital transformation. However, current investment levels are set to change quickly as more than half of respondents believe 4IR investments in these areas will deliver very significant benefits.

6. Industrial IoT gets the biggest share of the wallet

It is no surprise that most of the companies surveyed are busy connecting people and assets to provide insights (and perform condition monitoring in their operations). These technologies are attracting the lion's share of the wallet, with platforms to manage, analyse and report from diverse data sources also gaining attention.

Similar to the manufacturing industry, mining companies do not appear to have made much progress with the adoption of AI. This is most likely because the process of introducing AI is highly complex, time consuming, and capital intensive. It also requires a comprehensive, systematic approach if it is to be successful. Despite a low adoption rate at present, we believe AI will be a major game changer in years to come, with nearly half of respondents already piloting AI programmes.

7. The workforce is changing

Nearly 95% of mining leaders surveyed believe that there will be a change in the nature of the workforce over the next five years with the transition to more skilled employees, who will also need to be paid more. While some respondents are concerned about increasing labour costs, the majority believe that the resultant productivity gains will more than offset these costs.

Digital technology is set to play a major role in health and safety, with almost 80% of respondents predicting a significant improvement in both. This will be achieved, for example, by the velocity of digital information and analysis enabling proactive responses that can identify and close unsafe working areas faster than was hitherto possible.

8. Organisational culture is keeping up with the times

Consistent with what we're seeing in other industries, digital technologies and capabilities are being embedded in the business, in contrast to the traditional model in which IT departments render a service. This will necessitate the development of new operating models.

In addition, mining companies will require new skills and will have to upskill their workforces to work in new ways. Nearly 30% of respondents are actively investing in skills upliftment in order to unlock the benefits of their digital transformation. This is an important area of progress that will not only benefit individual companies, but the mining industry as a whole.

9. There are challenges to overcome

When asked what they perceived to be the largest hurdle to 4IR implementation, more than half of respondents identified data maturity as their biggest concern. Mastery of data is critical as this revolution is founded on data availability and frequency.

Other significant areas of concern include the lack of digital skills in the workforce as well as the complexities of data custodianship and cybersecurity.

10. It's all about the data

Data is a major concern. Obtaining optimised data, i.e. 'one version of the truth', is a priority for more than a quarter of mining companies surveyed, while more than half are still in the preceding stage of linking systems together to achieve data integration.

Similarly, most respondent companies are still focused on end-to-end connectivity of systems and functions within the business to make their data available.

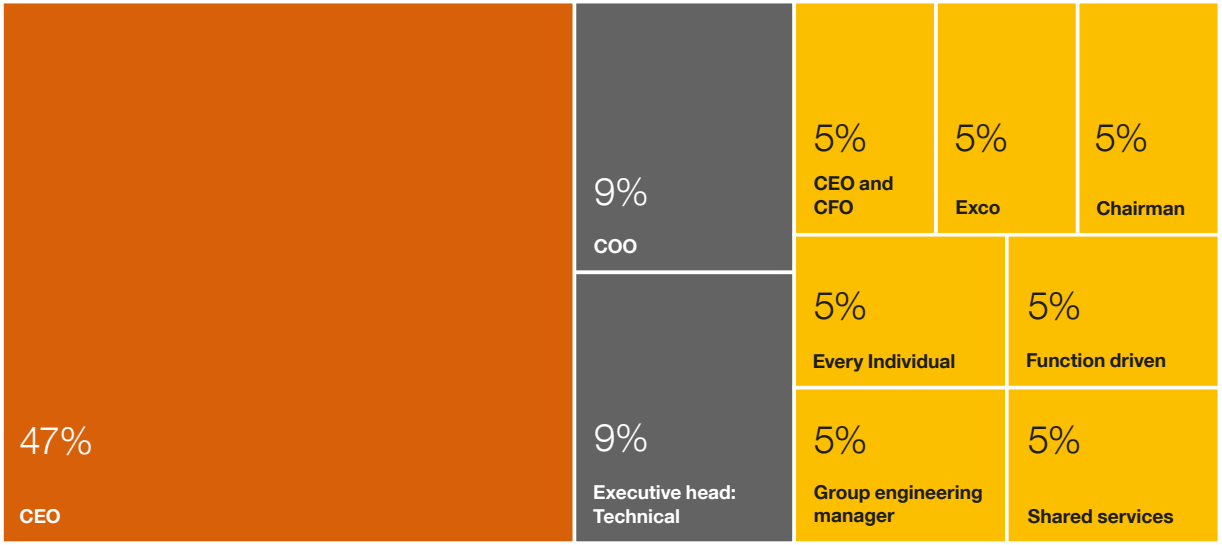
Just 15% have advanced to the stage that they are concerned about the availability of real-time or near real-time data to inform decision-making.

Study insights

Insight 1: The CEO drives the digital agenda

We found that the CEO is the primary driver of 4IR and the digital transformation programme in mining businesses, with many respondents describing the CEO as driving a top-down initiative-based approach.

Figure 1: Who drives the 4IR and digital agenda?



Source: PwC analysis

The second most frequently selected approach is for the COO or the executive head for technical to drive the adoption of new technology. This makes sense in the context of the distance between the boardroom and individual mining operations, where operations need to drive initiatives relevant to their performance goals.

Where the technical head was leader of the digital programme, they reported experiencing an extremely long buy-in process, but once established, they found having the necessary support sped up their adoption and the building of initiatives at a unit manager level.

While a top-down approach can certainly start the process and provide the necessary impetus, respondents report that the initiatives that make the most meaningful difference originate in operations.

Insight 2: Digital champions and innovators are emerging

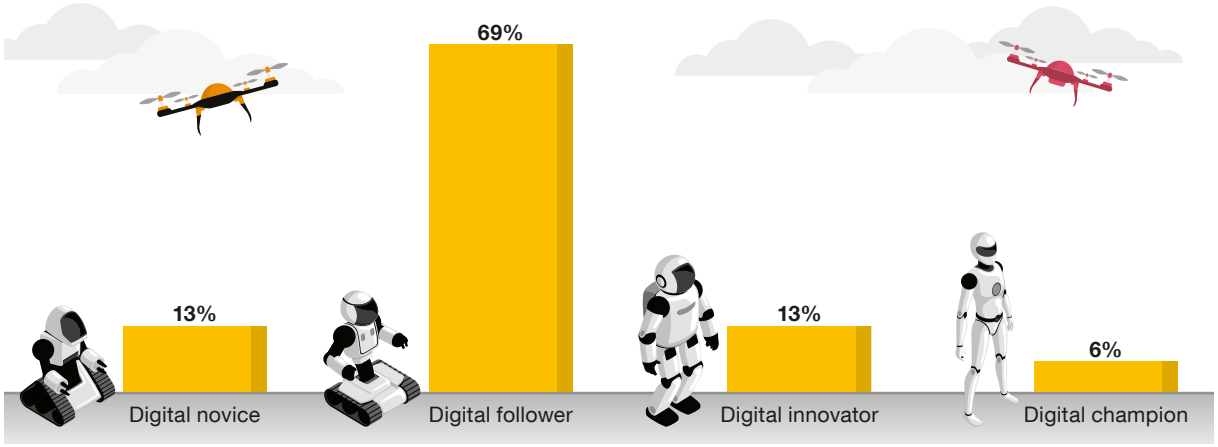
The journey to becoming a digital champion is characterised by the development of 4IR mining business ecosystems, being the network of internal and external suppliers, distributors, service providers, local communities, unionised and non-unionised labour, in addition to physical infrastructure involved in the identification, extraction and processing of minerals.

We have identified four primary drivers for digital mining: health and safety, people, production and cost. As mining companies embark on the journey to becoming digital champions where they have successful digital solutions running in all four of these drivers, they will typically pass through four levels of digital maturity.

We have identified four distinct stages of digital maturity among the respondents to this study:

- Digital novice — functional silos that are not yet connected
- Digital follower — functionally connected practices
- Digital innovator — cross-functionally connected practices
- Digital champion — fully integrated health and safety, people, production and cost ecosystems

Figure 2: Stages of digital maturity



Source: PwC analysis

A note on innovation

We consider all companies that participated in the survey to be great innovators. Hard rock, seismicity (including real-time seismic monitoring), extreme depth and the conditions under which we mine in South Africa mean that all our mines are by their very nature innovative. As a contributor from the Minerals Council observed:

> *"Anybody that can mine hard rock over 4km deep and bring it back to surface at a profit is an extremely good innovator.*

Here we are discussing innovation specifically in the context of 4IR and the returns expected by respondents from that investment.

Digital novice

Few respondents have not yet connected their functional silos and embarked on their digital journey. Companies that had cut funding to IT due to the financial impact of the COVID-19 lockdown or were mine owners, but not operators, fall into this category.

Digital follower

Most companies surveyed fall into this category. Though still in the early stages of technological maturity, they have typically developed a clear strategy and are putting together the building blocks they need to progress.

From carving out the ICT (Information and communications technology) function and repurposing it as a digital innovation office, to integrating fragmented organisations, these companies are actively moving IT out of the back office and into the realm of being a business partner.

But they are still finding their way.

Their focus on digital transformation is tied to specific goals at this stage, with respondents saying their motives are to:

- 'Optimise and reduce costs'
- 'Integrate process control and IoT (Internet of Things) devices collecting data'
- 'Take the people out of dangerous areas'
- 'Open up the black box of underground mining'.

Most digital followers say they have long-term strategic goals with five- or ten-year plans in place. Initiatives are typically driven by business cases and projected returns, but they also tend to be isolated and not always integrated into a larger plan.

Digital innovator

Digital Innovators are at the stage of executing cross-functionally connected practices. They are finding new value by sharing information and data and working collaboratively between business functions.

Respondents at this stage of the journey are actively starting to utilise their data in clever ways to support decision-making. They are also automating administrative roles and developing new revenue streams and operating models.

Their respective visions have a lot in common at this stage: They are actively working to achieve a smart and connected mine from exploration to fulfilment. What this means is that they are measuring efficiencies and savings from their investments and building a digitised integrated value chain that adds to the bottom line.

The dominant goal of digital innovators is to optimise and remove costs. Examples of this include speeding up contractor onboarding, connected pit / mine initiatives, establishment of condition monitoring data via IoT and the introduction of anomaly detection and real-time processing sensors.

Digital champion

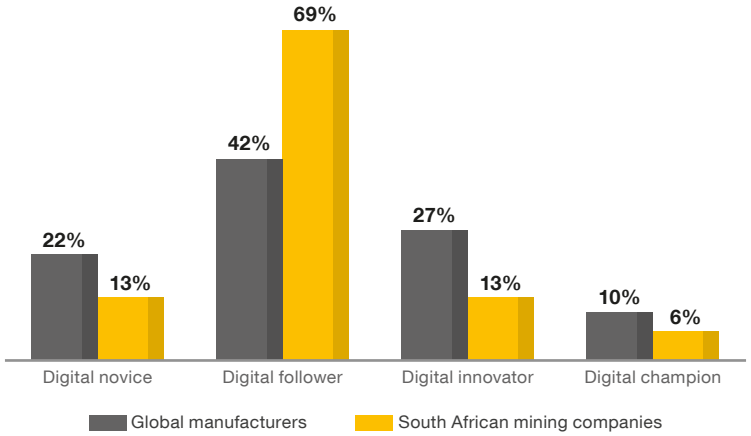
In this category we expect to see integration of the worlds of safety, people, production, and cost. Here, we would have automated data inputs that do not rely on pencil tallies in logbooks, cost optimised production that seeks the lowest cost per ton and dynamically optimises the plan in real time based on incoming data. Machinery and maintenance are predictive and learning continuously, while collision avoidance, health and safety systems are proactive.

From logistics and supply chain to onboarding, each process is digitally linked from plan to execution, visualised and tracked. Underground conventional mining is at a disadvantage here. The 'black box' of underground mining requires investment in infrastructure that can and does take many years to justify, invest in and complete. As such participating underground miners are unable to claim champion status as they are yet to make all these connections.

Given the selection criteria, just one company in this study can be called a digital champion. With a majority of opencast and some mechanised underground mining, this company is closest to achieving digital mastery. It is finding the value of technology and starting to experience the link between 4IR/digital and better bottom line results.

While we expect several companies to become digital champions in the next few years, it is important to acknowledge the complexity, cost and difficulty conventional underground mines face in becoming digital champions.

Figure 3: Distribution of digital maturity levels



Source: PwC's Strategy& Global Digital Operations Study 2018, PwC analysis

Figure 3 presents the results of this survey and a survey of digital maturity conducted among 1,100 executives of global manufacturing companies in 2018. While the level of progress across all categories is similar, most mining companies surveyed are digital followers.

Survey results show a generally higher level of digital maturity among manufacturers, which embarked on their digital journey before mining and refined it in the face of fierce global competition.

Many of the lessons learnt from manufacturing, such as supply chain visibility, management and other transferable digital expertise, are currently in the process of being implemented in mining, which may explain the low percentage of digital novices in our study.

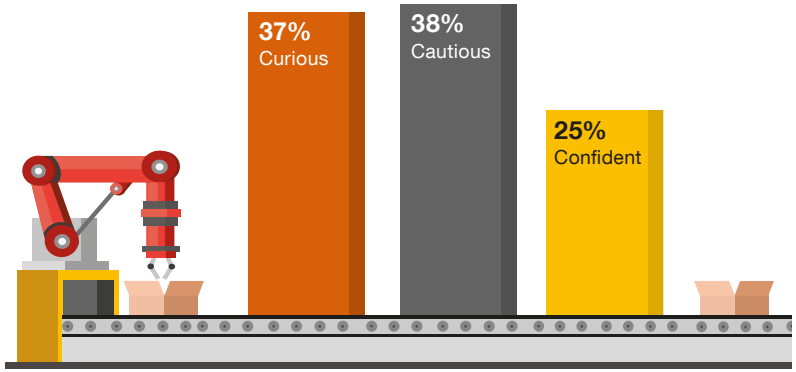
Meanwhile, digital champions are those businesses that have been able to clearly articulate and measure the value proposition of technology, building success on top of success.

Insight 3: Investments in digital technologies are growing

Although companies that participated in our survey are predominantly digital followers, we found investments in digital technologies to be growing. All companies surveyed are investing in specific initiatives to drive specific benefits, but with various levels of financial commitment. We have grouped these companies according to their level of investment:

- Curious (investment < 0.15% of turnover)
- Cautious (investment 0.16–0.3% of turnover)
- Confident (investment > 0.3% of turnover)

Figure 4: Distribution of turnover spend on digital transformation



Source: PwC analysis

Curious

This group has just started their 4IR journey and are curious investors, experimenting here and there, but typically not having a clear 4IR strategy or plan. This group, comprising 37% of respondents, corresponds to digital novices and some digital followers identified in Insight 2. For these companies, digital transformation represents a tiny fraction of expenditure — less than 0.15% of turnover. One respondent reported that due to the impact of the COVID-19 pandemic, the company had cut its entire IT budget, including digital, to zero just to survive and maintain some operations and preserve cash flow.

Average digital spend in this category is R52m per annum. One company spent nearly R250m on 4IR technologies across its global operations, however, its sheer size makes this a tiny fraction of turnover. If we remove this outlier, the average for those in the curious category falls to R13m per annum.

The low level of digital expenditure is also reflected in the role these businesses play in the development and adoption of new technologies in the industry. While these companies are overwhelmingly made up of novices or followers, two self-identify as innovators and sit on the advisory boards of OEM's (eriginal equipment manufacturers). They describe themselves as 'influencers' of innovation.

Cautious

These respondents have moved beyond experimenting and typically have clearly identified areas of their operations they wish to impact. In this group we find most of the digital followers and innovators.

This group comprises 38% of respondents and has an average spend of R95m per annum. Their larger investment numbers are accompanied by their having more active roles in OEM product development. Forty percent of respondents in this category's say they are taking a direct role in influencing OEM new product development. The remainder say they are taking active, but indirect roles such as participating in OEMs' advisory boards and pilot programmes.

Interestingly, a third of respondents in this category describe themselves as innovators that would pilot a new technology for the first time in their operations. The remainder self-identify as followers that would monitor others' adoption of a technology, and would move quickly to implement it once it is proven effective in the mining industry.

Confident

A significant portion (25%) of the respondents invest more than 0.3% of turnover in their digital programmes, investing on averaging more than R166m per annum. This group corresponds to the digital innovators and digital champions identified in Insight 2.

These companies typically have lower risk aversion and are the leaders in 4IR. They have been on the journey longer than their peers in most cases and have a clear vision of what areas will be impacted together with a clear investment strategy in each area of their business.

Confident investors have mature digital programmes and are actively seeking to innovate. All of them can tie their larger investments to larger expectations for improvement. Their digital initiatives are business case driven and measured against predicted returns in a pilot environment prior to roll-out.

Respondents in this group report adoption as the primary challenge they face. Changing the way people work is not a trivial task, and to incentivise behavioural change, users must derive some benefit from a new system or they resist adopting it.

While several respondents noted that they cannot simply add to the existing workload to obtain a stream of data, others observed that the automation of data collection alleviated the reporting burden placed on, for example, shift supervisors. This not only helped free up more time for strategic activities, but also achieved buy-in from users.

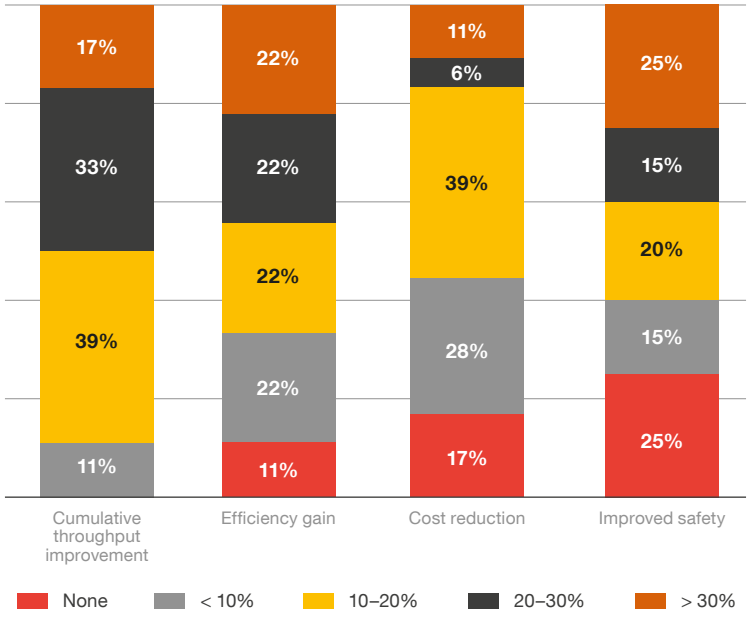
To accomplish lasting change in environments where production is paramount is a challenge because of the lack of time available to implement new ways of working. It is this hurdle that often prevents change from occurring in production areas, even in more digitally mature mines.

Insight 4: Digital technologies are delivering real benefits

We asked respondents what benefits they expected from their digital investments over the next five years in the following areas:

- Throughput
- Efficiency
- Cost
- Safety

Figure 5: Cumulative benefits expected from 4IR over the next five years

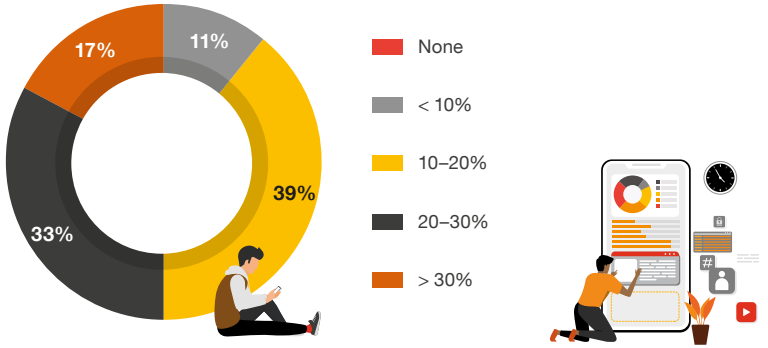


Source: PwC analysis

Throughput increase

When asked what cumulative improvements they expected from 4IR in the next five years, fewer than one in five respondents expect a greater than 30% throughput increase. These are typically larger, more diversified mining companies and they tie this increase to the expected change in the skill level of employees over the forecast period. Although they realise that costs will increase due to the need for more skilled staff, they also expect throughput will ramp up significantly to radically increase the tons per capita in their operations.

Figure 6: Cumulative throughput improvement expected over the next five years



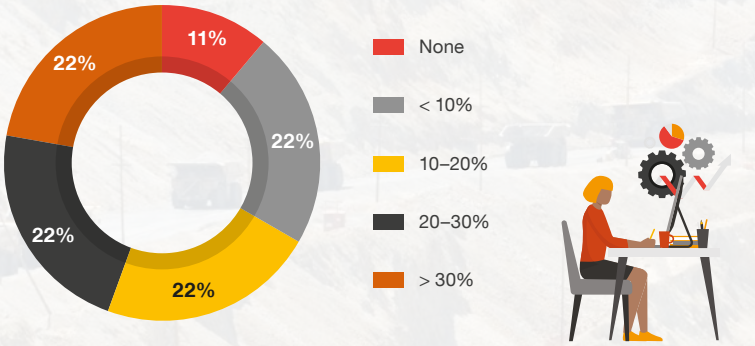
Source: PwC analysis

A third of respondents predict improvements of between 20% and 30%, while 39% predict improvement in the more conservative 10%–20% range. Just over one in ten respondents expect improvement of less than 10%. These estimates are typically the results of external constraints such as having a narrow tabular ore body or other physical limitations to output growth, however, it is important to note that all respondents expected an increase over time.

Efficiency gains

Two-thirds of respondents expect efficiency gains of at least 10% to be generated by 4IR technologies, while 22% expect these to exceed 30%. Another 22% expect them to be less than 10%.

Figure 7: Efficiency gain expected over the next five years



Source: PwC analysis

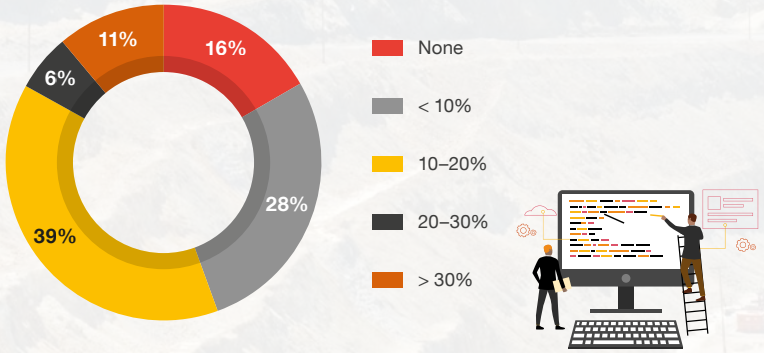
The remaining 11% of respondents don't expect their investment in digital technology to deliver any efficiency gains in the next five years. These respondents fall in the digital novice category in which digital investment is motivated by curiosity and where investment has been put on hold for some as a result of the COVID-19 pandemic.

It is important to note that one of the smaller mining companies surveyed was severely impacted by the pandemic in the first half of 2020 and informed us that they were suspending their 4IR programme until they are more financially stable.

Cost reduction

Respondents' expectations of cost reductions due to 4IR over the next five years provide an interesting contrast to the expected gains. Some respondents are unsure of the impact having a more skilled workforce will have on costs, while the 11% that anticipate cost reductions of more than 30% have specific, existing plans in mind.

Figure 8: Cost reduction expected over the next five years



Source: PwC analysis

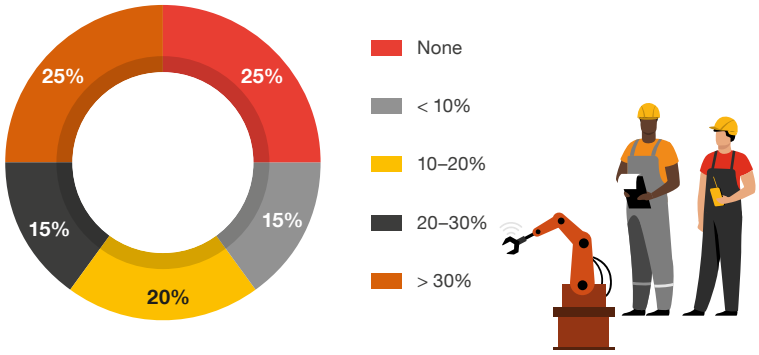
While more than half of respondents expect cost reductions of more than 10%, 16% forecast no cost reductions at all. They cited the changing workforce and investments in 4IR (as well as annual price inflation) as the reasons for this. For them, the benefit lies not in cost reduction, but in massive increases in productivity per capita, thus justifying the higher paid, higher skilled workforce of the future.

Improved safety

Safety is always a primary concern in the mining sector and this was reflected in our survey results, in which 83% of respondents identified a direct relationship between their 4IR investment and having a safer working environment.

A quarter expect more than 30% improvement in their health and safety performance over the next five years due to the positive impact of digital technology. It is important to note that the 25% that expect no improvement over the next five years have already invested in this area and are maintaining their already high levels of focus.

Figure 9: Improved safety expected over the next five years



Source: PwC analysis

Several respondents cited improved safety as a primary driver of their 4IR investment. On further questioning they spoke of two primary types of investment, the first being technologies like automated collision avoidance for heavy equipment that is 'fail safe' — for instance shutting down a loader automatically when a person is travelling in the driver's blind spot and within a certain range.

The second type is improved safety in underground conventional operations, where technology can support decision-making. For instance, systems could use the inherent velocity of data combined with automation to correlate reports and identify unsafe working conditions or specific mine conditions that require immediate intervention. These systems could identify unsafe working areas by analysing daily reports and pre-emptively close them before a worker is endangered.

Other expected benefits

Over and above the quantitative questions asked in our survey, we also asked participants to tell us in their own words what they wanted to achieve with their 4IR technologies in the next five years.

Better accuracy of metal accounting

Nearly a third of respondents expect to increase the accuracy of metal accounting and inventory accounting in their companies. Using technology, they plan to track these metrics across the value chain, providing management with the data required for fast, effective decision-making in real time.

Radical transparency

Perhaps the most unexpected feedback was about the concept of radical transparency, which was on the minds of 10% of the respondents. Demonstrating results and where exactly they originate in the value chain is key to this concept, and it manifests both internally and externally.

Firstly, the real-time analytics and insights would help the operations to monitor and provide accurate and predictable outcomes for management. Secondly, transparency would provide investors with real-time analytics and insights at a level of detail that would enhance the accuracy of their forecasts and investment decision-making.

Reducing operational variability

Reducing risk and operational variability by using data more effectively was another benefit mentioned by respondents.

Several large mining companies expect the norm five years from now to include using real-time data and analytics to help solve complex decision-making at the face, automating face measurement and reducing 'fall of ground' injuries through improved analytics.

If one considers the 'lost' data handwritten in notebooks for decades, these respondents expect to start capturing and mining that information digitally for insights into production, blast efficiency and materials availability, impacting production and more.

Among the predicted benefits of improved data analytics in the next five years is improved recoveries, reduction of energy use, improved compliance to plan, improved productivity (automated office workflows that give more freedom to users) and in one case, the ability to grow down the cost curve.

Insight 5: The greatest benefit is expected in core operations

The functional area in which the greatest benefits of 4IR technology is expected to be delivered is in mines' core operations.

Asset management, maintenance & repair

Digital investments in asset management, maintenance and repair are expected to deliver the most significant benefits, corresponding with respondents' programmes to implement predictive maintenance, condition monitoring and augmented reality solutions, which are mentioned elsewhere in this study.

Mine support services, Including engineering

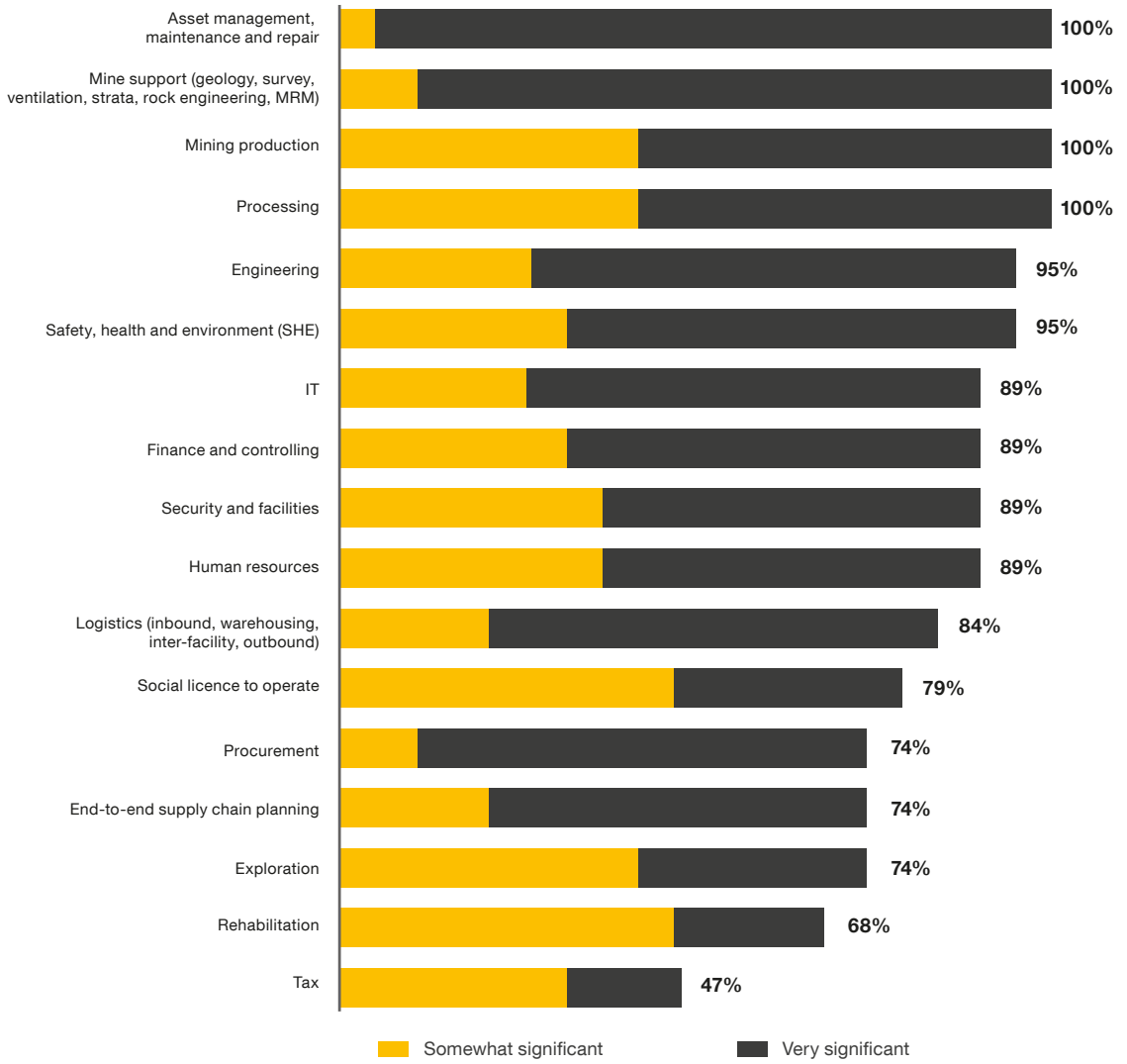
Mine technical functions such as rock engineering, survey, ventilation and safety are also expected to enjoy substantial benefits, reflecting the capabilities of 4IR technologies to help us visualise, monitor and manage complex environments.

Safety, health and environment

Safety, health & environment (SHE) also has much to gain from the deployment of 4IR technologies. Some of the key technologies expected to deliver benefits include automated safety and collision avoidance systems, but 4IR tools are also expected to deliver improved employee engagement and training such as using virtual reality and gamification to embed health and safety practices. For non-mechanised operations, the health & safety potential of 4IR cannot be overstated — by speeding up the reporting cycle through the use of mobile tools in underground mining, for example, unsafe working areas can be shut down prior to the next shift and lives saved from avoidable, reported conditions.

Figure 10: Areas in which 4IR is expected to deliver the greatest benefit

Q *In which areas of the business do you believe digitalisation/4IR will make the biggest impact?*



Source: PwC analysis

Information technology

Significant benefits for IT are expected, but this needs to be seen in the context of the changing role of IT among many miners. IT departments are rapidly evolving from a service to business (doing IT at operations) to a business partner, enabling technology transformation hand in hand with operations (IT as digital business partner working with operations). Most survey participants say they are moving towards such a collaborative model of value creation, though notable exceptions exist.

Logistics, supply chain and supply chain planning

Despite just 10% of respondents reporting that they are currently focusing on supply chain planning, logistics and end-to-end supply chain planning investments are nevertheless expected to deliver substantial benefits, with more than half of those respondents anticipating significant benefits. This is also an area that has been impacted by the COVID-19 pandemic, where disruptions have exposed ultra-lean and single-source supply chains as an important area of risk for mining companies.

Procurement

Nearly two-thirds of respondents expect investment in procurement to be of significant benefit to their companies, with a renewed focus on controlling cost and risk recognising this traditional support function's role as a key cost driver.

Mining production

Underground mining respondents emphasised the ability to get real-time or near-real-time information from underground operations, improved communications and the ability to respond to unscheduled events in time to 'save' a shift or reduce lost blasts as important anticipated benefits.

Processing operations

Processing environments also anticipate significant improvements from digital and 4IR technologies with the advent of improved manufacturing execution systems, improvements in process control systems, and much improved real-time analytics that provide visibility of plant processes and facilitate continuous process improvement. Because improved efficiencies typically impact the bottom line, this is an area of focus for most respondents.

Finance and controlling

Finance and control has of course a relatively high significance — and for most respondents is the area of the business with the greatest historical investment and most up-to-date systems.

Security and facilities

More than half of respondents expect security and facilities to derive very significant benefit from 4IR technologies. This includes typical security activities such as security screening of contractors and employees. This is a key area of focus for many respondents that struggle with the time and expense of onboarding contractors and employees, and prevention of illegal mining and other criminal activity.

Human resources

Automation and workflows facilitated by technology have the potential to significantly reduce the time to site for employees and contractors while lowering risk for miners. Self-service technologies combined with workflows and cross-industry talent pools will lighten the administrative burden. With the rise of human resources platforms, the vetting of contractors and individuals from mine to mine and company to company will be simplified and sped up. Onboarding can be transformed from both a cost and time perspective.

Social licence to operate

More than a third of respondents predict that digital technologies will significantly enhance their social licence to operate, including social labour planning (SLP). Despite recognition of the importance of respondents' commitment to local communities, this is typically not measured and is subject to interpretation. Some respondents have obligations to communities, schools, rental properties, water infrastructure and more to manage, as well as community sentiment management. There is a growing recognition of the importance of community management and sentiment analysis among respondents.

Exploration and rehabilitation

Exploration and rehabilitation are expected to be among the functions to benefit the least from digital technology, with most respondents yet to see the potential value of 4IR in these areas.

Taxation

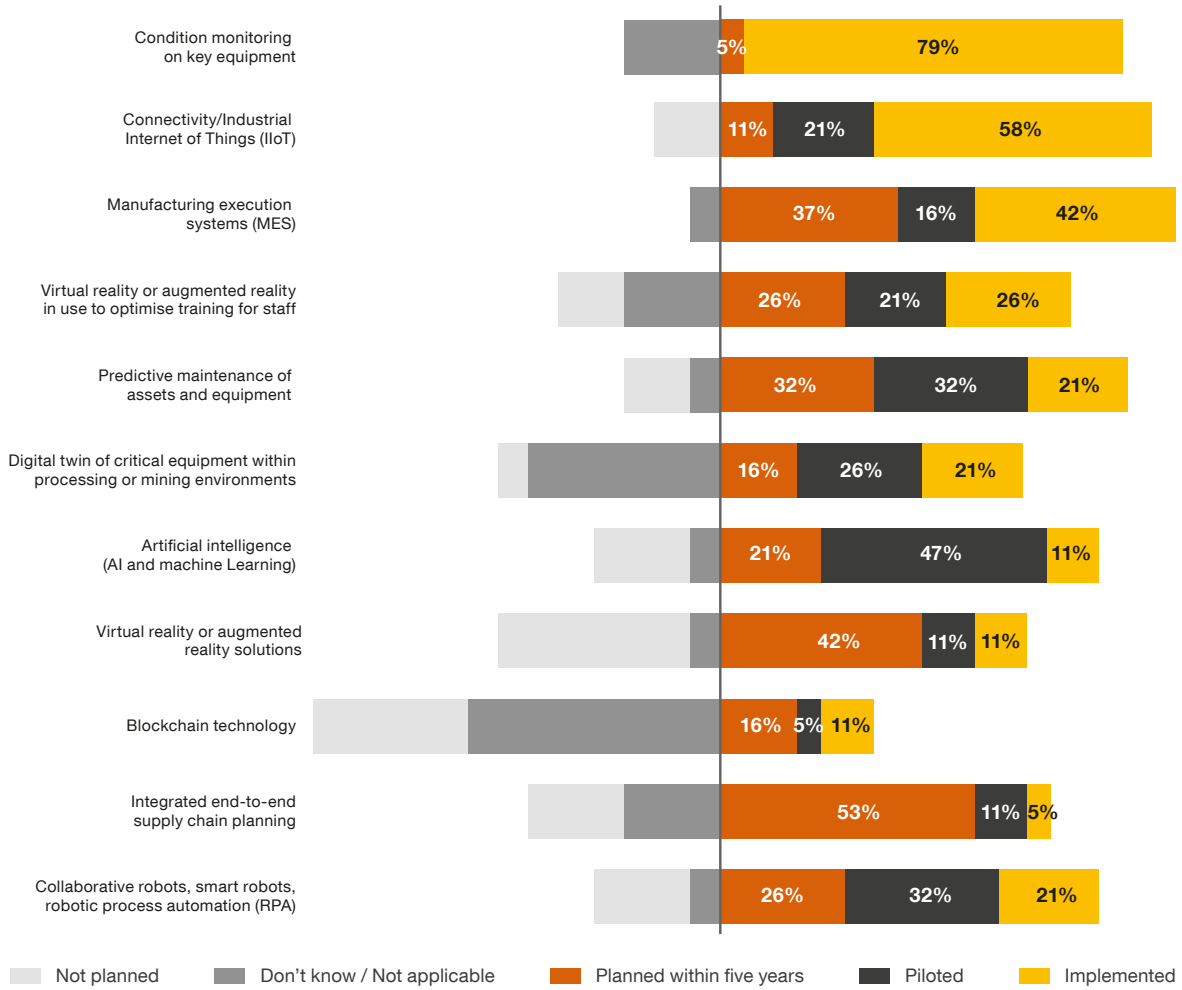
From a tax perspective we see a split according to operational types — with mechanised mining operations deriving the greatest benefit by deploying technologies such as fuel management systems, geo-fencing and dispatch systems to de-risk diesel rebates and optimise spend.

Insight 6: Industrial IoT gets the biggest share of the wallet

We asked South Africa's mining community to what extent they were using or planning to use 11 key 4IR technologies in their businesses over the next five years.

Figure 11: Extent to which 4IR technologies are being used

Q *To what extent are 4IR technologies being planned or used in our mining industry today?*



Source: PwC analysis

Condition monitoring and connectivity/IIoT

The technologies being used most are condition monitoring at 79% and connectivity and Industrial Internet of Things (IIoT) at 58%, which essentially operate on the same digital infrastructure. Mining technology leaders are actively seeking to obtain data from underground and visualise mining operations using technology. Key to this drive is the ability to collect information to build the foundations of a data-led future.

Manufacturing execution systems

The plant and processing side of mining is changing rapidly, with manufacturing execution systems (MES) being implemented by 42% of respondents. The drive towards integrated and more efficient operations relies on the data being gathered, and respondents are looking to these new technologies to enable further efficiencies and optimisation as costs continue to escalate.

The positive effects of these technologies include ongoing incremental productivity improvements, the benefits of which, with the same input materials and fixed costs, can fall almost directly to the bottom line.

Wearables leveraging augmented reality

Two of the companies surveyed are already using augmented reality to supplement skills in remote operations and underground, while it is part of the 4IR roadmap planned within five years by an additional 42% of respondents. Thirty percent of respondents have no plans to implement AR within five years and are focusing their efforts elsewhere.

Virtual reality training

Over a quarter of respondents are already using virtual reality (VR) to train staff, 21% are currently piloting the technology and 26% intend to implement VR training within five years.

Training and onboarding are costly sources of delay for mining companies, especially in high potential hazard areas and plants that require specialised external contractors. Our respondents are increasingly using VR tools in innovative ways, such as carrying out plant orientations and health and safety training remotely to lessen standing time (and related costs). Underground operations, safety and drilling training using VR are becoming more prevalent and are helping respondents to better manage their risk exposure.

A small minority of respondents also use digital tools for induction at plants, with virtual learning being applied to familiarise external contractors with a plant layout prior to arrival on site. This is an extension of existing site induction practices and does not replace physical on-site onboarding as yet.

Predictive maintenance (PdM 4.0)

Although proven as a technology, predictive maintenance solutions such as PdM 4.0 are not yet pervasively implemented. Connecting a machine and monitoring its environment and key parameters do not on their own constitute predictive maintenance, as it is only once the system has 'learned' or been 'taught' what to look out for in terms of the data it receives that it can be characterised as 'predictive'.

Furthermore, predictive maintenance requires many sensors and each piece of equipment requires a separate model that has to be taught from scratch. Having said that, much large, expensive and critical equipment like compressors, mills and conveyors are already well understood. Just 21% of survey respondents say they have successfully implemented predictive maintenance at their operations or plants.

Thirty-two percent are currently piloting predictive maintenance initiatives and an equal percentage are planning to do so within five years. This is a challenging area, with few open benchmarks for comparison at present. This situation has typically been driven by the behaviour of OEMs, which have tended to try and control and even own the data from their branded machinery, limiting customer access to the detailed data required to 'learn' from failure.

We see a trend emerging in which respondents are getting control over that data, supplementing the data with additional condition monitoring data from the environment and growing this capability. Improvements and efficiencies tend to flow to the bottom line in these situations (as more uptime is obtained) and respondents see PdM 4.0 as a source of ongoing incremental improvement that will help to maintain the competitiveness of their plants and operations.

Digital twin

Simulation modelling — the digital twin concept — is already being implemented by one-fifth of respondents. This allows them to create very accurate representations of reality, which in turn are used to run scenarios that allow them to simulate the outcomes of a given course of action.

Typically implemented on large, complex processes or equipment, the 26% of respondents have digital twins in the piloting stage, varying from simulating a single piece of equipment in a plant to modelling the employee onboarding process.

Nearly 30% of respondents have no plans to develop digital twins at all, with the implementations and pilot programmes all taking place in larger, more technologically mature mining houses at present.

Artificial intelligence and machine learning

Despite the promise of AI, as with many other industries, the mining industry also has a long way to go. The varying degrees of technological maturity among our respondents is evident when we look at the use of AI and machine learning — which is in its infancy with just 11% of respondents having implemented either technology. However, nearly half of respondents have piloted AI programmes recently, so we expect implementation levels to increase significantly over the next five years.

For AI and machine learning to succeed, respondents need to have connected sufficient infrastructure, people and equipment to provide the data points from which the technology can 'learn' and in turn provide insights. This dependency is clearly illustrated by the current emphasis on implementing monitoring and connectivity technologies.

Integrated end-to-end supply chain planning

Linked to the use of machine learning and AI, a truly integrated supply chain can be transformed through data. Many respondents are working to optimise areas of their supply chains, however, just 5% have implemented any form of technology to provide end-to-end visibility and control.

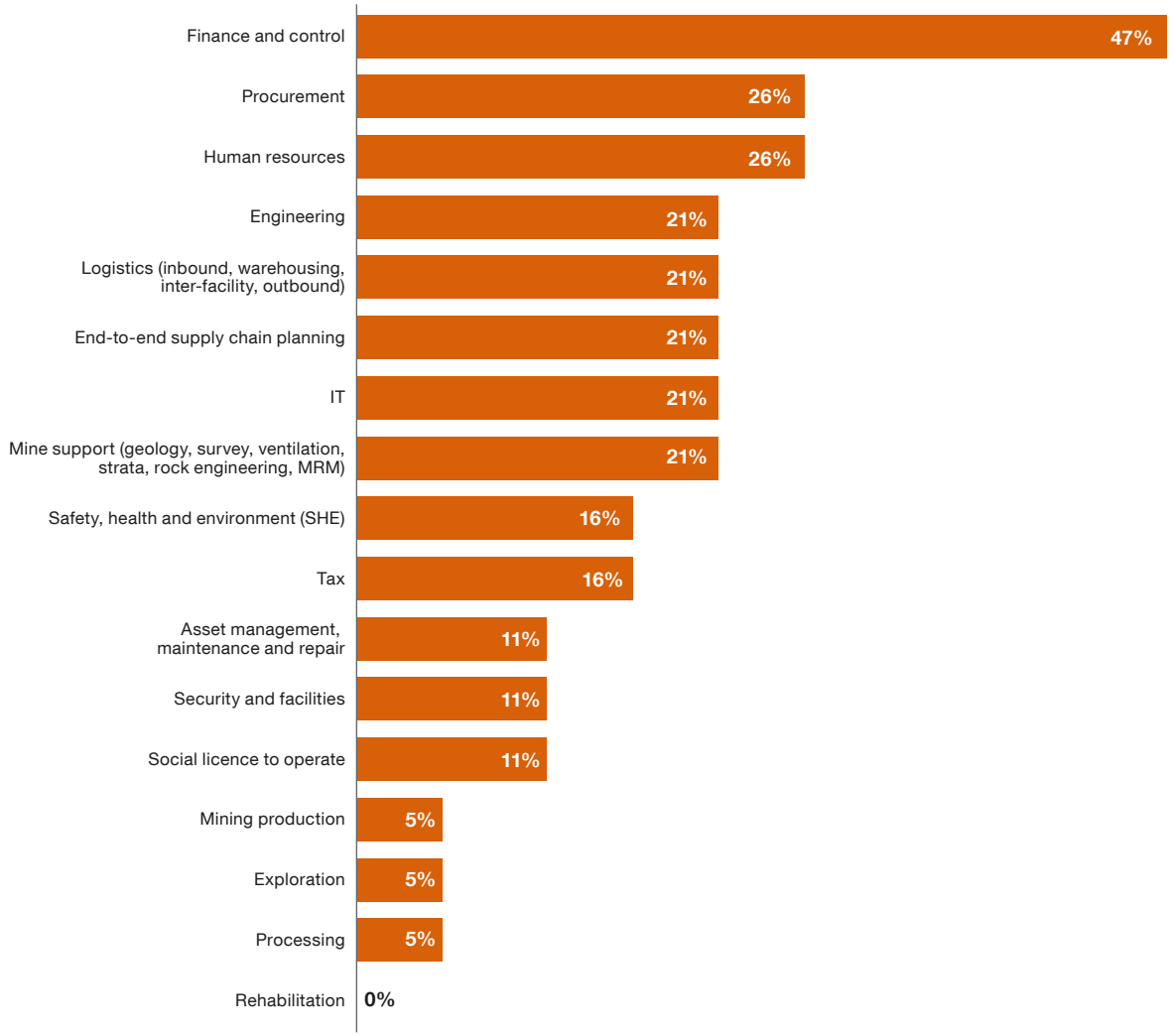
A further 11% are currently piloting solutions, while more than half of the remainder plan to do so within five years.

The focus here can yield major value — from enabling operations to systematically addressing price imbalances and contracting for goods and services, effective supply chain visibility and management lowers the cost of doing business when paired with good data and appropriate 4IR technologies.

Functions in which robotic process automation or cognitive automation are being implemented

RPA deployments appear to currently be focused on the back office, with 47% of RPA solutions so far being deployed in finance and control functions.

Figure 12: Functions in which robotic process automation or cognitive automation has been implemented



Source: PwC analysis

A quarter of RPA implementations concern human resources and the procurement functions respectively. Engineering, logistics, supply chain planning, IT and mine support functions such as geology, health and safety and rock engineering sit at 20% each.

One in ten use the technology to help them keep track of their social licence to operate, a growing area of focus in the context of South African mining and the social obligations of mining companies. The same proportion (10%) also implemented RPA in their security and facilities, asset management and maintenance departments.

Ultimately, the goal of RPA remains to lower costs, expedite routine processing activities and increase ease of management and productivity. Some respondents punt 'full automation' at some sites and are reaping the benefits. However, many seem to have adopted a cautious and incremental approach by implementing it in selected pockets and assessing the results.

Respondents emphasised the importance of properly evaluating and identifying where/how RPA can render benefits, because as one respondent observed: 'it takes a long time to get into'.

While certain respondents who would have been expected to already have implemented RPA, have not yet done so, the notion that RPA will replace human workers in performing some functions has also not materialised.

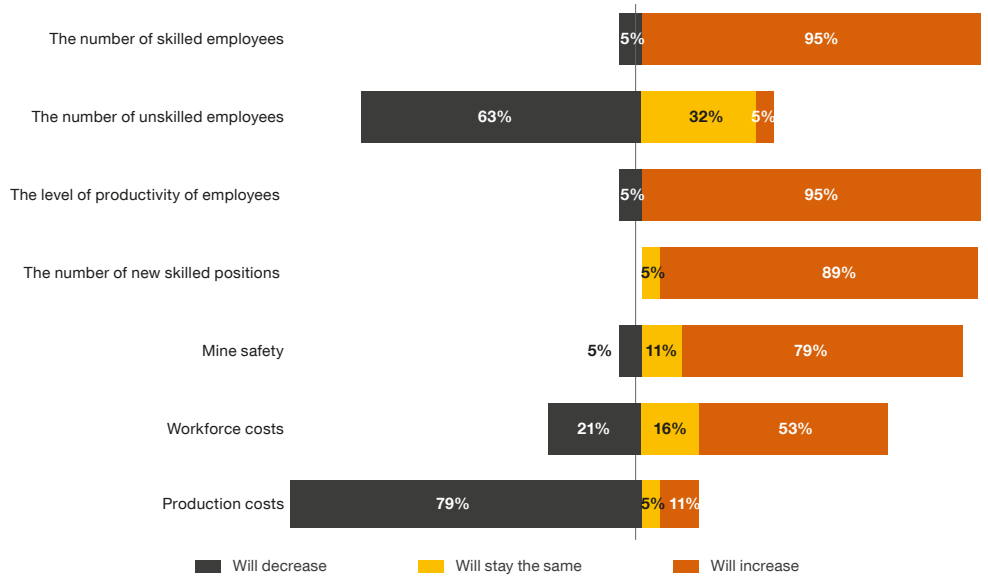
RPA typically frees up 20–30% of capacity for an individual, but cannot replace their entire role. However, the technology gives people more time to concentrate on those tasks that machines cannot perform.

Overall, respondents are cautiously optimistic that RPA can solve many challenges by freeing up human capacity. Critically, the majority confirm that they have achieved the benefits promised by RPA and that they intend to roll it out further to help contain costs in future.

Insight 7: The workforce is changing

We asked respondents how they believed digital transformation will impact their company and workforce over the next five years. What became immediately apparent is the expected impact of digital transformation on the workforce. Nearly 95% of respondents believe that there will be a change in the nature of the workforce over the next five years due to the need for more skilled employees.

Figure 13: How digital transformation will impact both company and workforce over the next five years



Source: PwC analysis

New roles, new skills

Nearly 95% of the new positions created in the industry are expected to be for skilled workers, a significant departure from the historic skills profile in mining. Respondents say digital operations are not like an IT department providing a service to a business. Rather, these digital capabilities should be embedded in the functions of the business, and specifically in the people.

The upskilling challenge

More than 60% of respondents expect the number of unskilled workers in their companies to decrease, in contrast to just 5% who expect it to increase.

This highlights the need for investment in reskilling and upskilling the current workforce — not just for different jobs, but also to equip staff to find other jobs once their specialisation is no longer required on a mine.

The benefit

As a direct consequence of digital transformation and the growth anticipated in new skilled positions, 95% of respondents expect the level of productivity per capita to increase significantly over the next five years. The remainder expect productivity per person to decrease in the context of a higher number of employees and an increase in skilled positions.

Workforce and production costs

While almost 80% expect production costs to decrease over the next five years, 11% expect them to increase since a more skilled workforce will result in a higher wage bill. However, this increase will be offset by the expected increase in productivity and efficiency.

Workforce costs generated a slightly greater diversity of views with one-fifth of respondents expecting a decrease in overall workforce costs, 16% expecting costs to remain the same over the period and 10% unsure of what to expect. More than half asserted that workforce costs would rise over the next five years, in line with the changing profile of the workforce.

Health and safety

Health and safety is one of the biggest areas of improvement anticipated over the next five years, with nearly 79% predicting an increase. This high expectation is driven by legislation to some extent, with digital and 4IR technologies also expected to make a significant contribution.

Improved velocity of data in the digital world enables proactive health and safety measures that were not possible just a decade ago. One major mining company told us it is consciously exploring new technologies in order to remove employees from areas of danger. This includes introducing technology to relocate several posts, which had previously exposed workers to 1,600°C temperatures in the smelters, behind the safety of the control room glass.

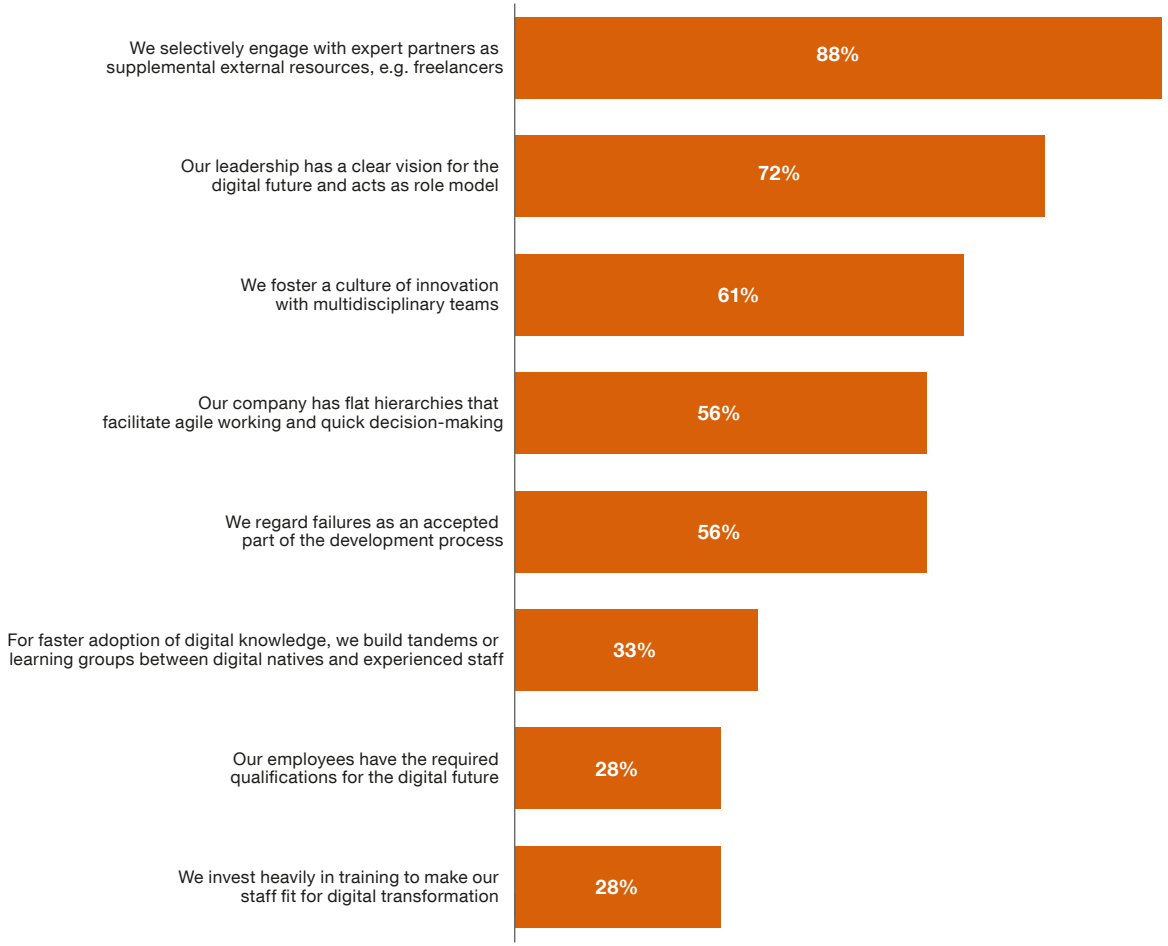
That being said, 11% predict that health and safety will stay at current levels overall and 5% that they expect mining might become more dangerous in the next five years. This feedback was received from respondents with older, deeper and more difficult mining environments and does not necessarily reflect an expected decline in mine health and safety practices. Rather, respondents feel that given their mining conditions, their record may be affected negatively.

Insight 8: Organisational culture is keeping up with the times

The pace of digital transformation is often dictated by corporate culture and organisational structures. Feedback from respondents emphasises the need for transformational change in the skills required to move the businesses forward. This is highlighted in Figure 14, which shows that less than a third of respondents believe that their employees have the requisite skills to realise the company's vision of the digital future, while 72% believe that their leadership has a clear vision for the digital future and act as role models for digital transformation.

Figure 14: Enabling digital transformation

Q *In what ways does your corporate structure enable digital transformation*



Source: PwC analysis

Overcoming the digital divide mentioned above calls for new working practices. More than 30% of the companies surveyed are already creating tandems or learning groups that team up digitally proficient staff with those less skilled to raise the level of digital know-how in their organisations. This is a trend that will likely increase as new 4IR tools are added to the working environments.

At the same time, almost 30% of these same companies are investing heavily in training to make their staff fit for digital transformation.

Just over half of respondents say their companies have flat hierarchies that facilitate agile working practices and speed up decision-making, while 61% believe they have fostered a culture of innovation with multidisciplinary teams. This suggests that while at an overall organisational level they may be perceived to be conventional, there are areas of digital excellence that exist, and which can be leveraged.

This trend towards more agile organisations is underpinned by the fact that more than half of the respondents (56%) regard failures as an accepted part of the development process towards 4IR solutions.

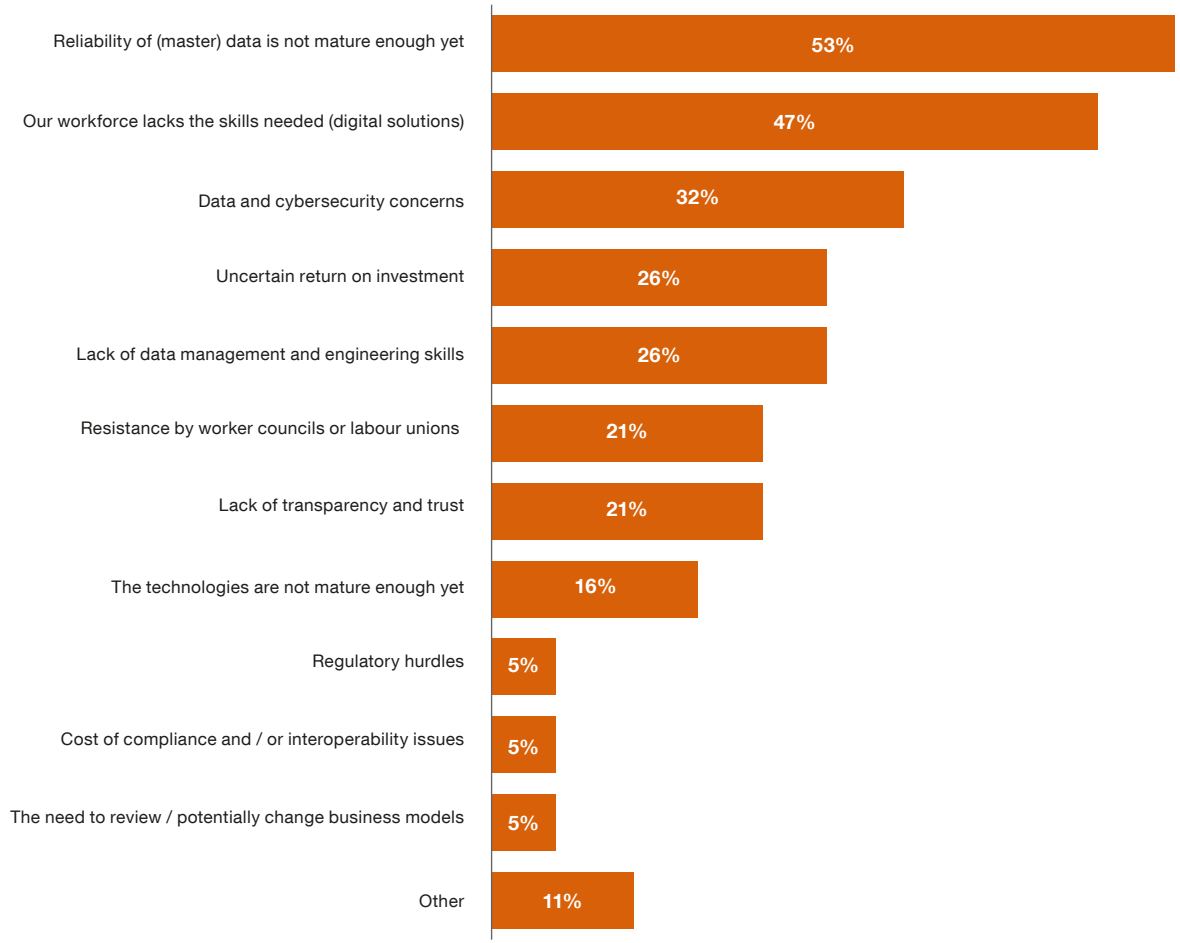
Nearly all respondents selectively engage with expert partners to fill gaps in their skills base at this point, with just over 10% either convinced they have the skills internally or unable to bring in external experts due to cash flow considerations.

Insight 9: There are challenges to overcome

When we discussed the largest hurdles to implementing 4IR technologies in their businesses, 53% of respondents told us unequivocally that their data management practices were not mature enough. Building that data foundation is key to visualisation, communication and analytics as well as being a key dependency for insights and data-led decision-making. Many of our local mining companies are yet to master their data and unlock its potential.

Figure 15: Challenges to implementing digital technologies

Q *What are the top three challenges associated with implementing digital in your organisation?*



Source: PwC analysis

The second largest challenge identified is the workforce lacking the skills to implement 4IR technologies. This issue is driven by the type of workforce that is typically brought in for mining operations, which has a low level of literacy and lacks familiarity with more sophisticated working tools such as a personal computer.

Digital technologies are very good at training people visually, even providing them experiences of environments via virtual reality, and we need to innovate in this space in order to address literacy, numeracy and digital acumen in the mining workforce. This links back to mining companies' own expectation that their workforce profile will change to include more skilled personnel over time.

The third highest barrier to entry is cybersecurity concerns. This is a very real threat — with the convergence of IT and operational technology (OT), the potential exists for transgressors to hack into networks and access potentially dangerous machinery like automated dump trucks. Other machinery could be stopped, trapping miners underground.

Just 26% of respondents called out the challenge of return on investment as an obstacle to digital transformation. The same proportion identified lack of data management and engineering expertise, which brings us back to the changing nature of the skills base in mining anticipated over the next decade. This is further underlined by the finding that 21% identify resistance by workers councils or unions as a major obstacle to implementing new technologies. This resistance is a direct consequence of the perception that the new tools would require a new, more skilled workforce.

We also asked respondents to provide comments on this question and their answers delivered a consistent message:

- 'It's all about the people' — the adoption rate of technology is related to the ability of the people to communicate the benefits, get leadership to understand the potential and get leadership to sign off on transformation.
- Lack of knowledge, lack of alignment or lack of shared vision are limiting factors in the minds of 4IR leaders.
- The age of operations impacts on the ability to deliver 4IR solutions due to the sheer scale, since some older operations cannot realistically connect their mines at a globally competitive level.

Insight 10: It's all about the data

Data management is a challenge for most respondents and decisions are often pragmatic, rather than strategic in nature. For example, rural connectivity is generally poor and mine data can often not feasibly be stored and synced as there is insufficient connectivity.

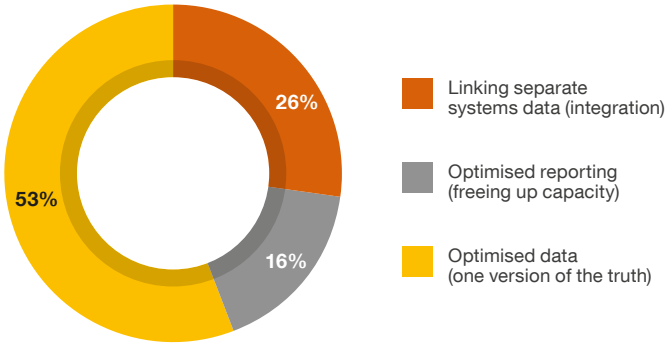
Furthermore, data infrastructure, storage, processing, and dissemination decisions hinge on the current perception of its value, as opposed to the potential prospects it could offer. This is reflected in our findings in which 21% of respondents indicate that as far as they were aware, no formalised data strategy, functionally supported by a data management office, exists in their operations.

Just under half of respondents (47%) confirmed that their organisation has a data strategy and that the functional unit responsible for it is in place. A further 32% indicated that they were in the process of implementing a data strategy.

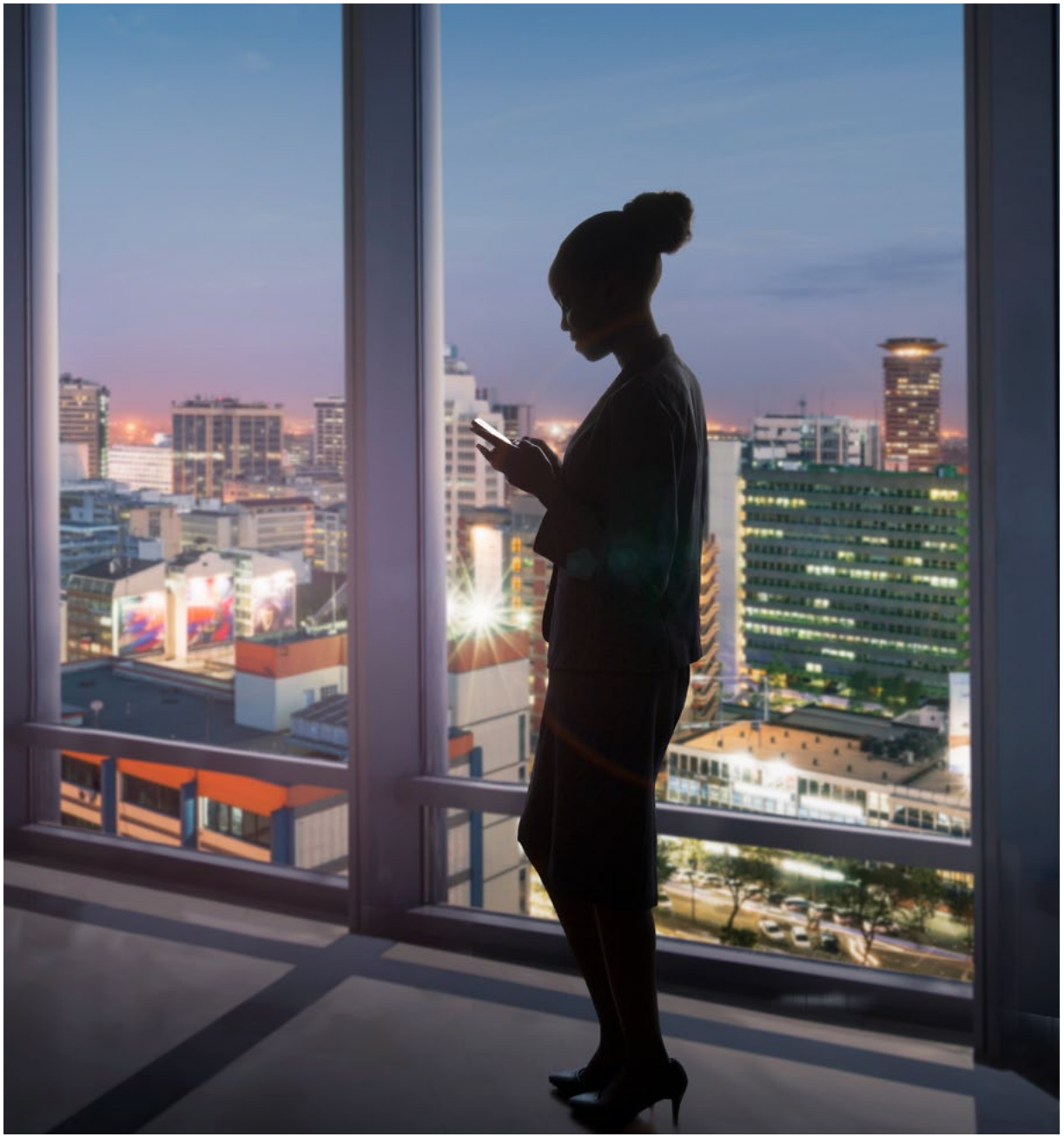
These findings reflect companies' recognition that the ability to effectively manage and leverage data is core to unlocking the value of 4IR.

Figure 16: Ability to use data for effective and efficient decision-making

Q *How would you describe your ability to use data for effective and efficient decision-making?*



Source: PwC analysis

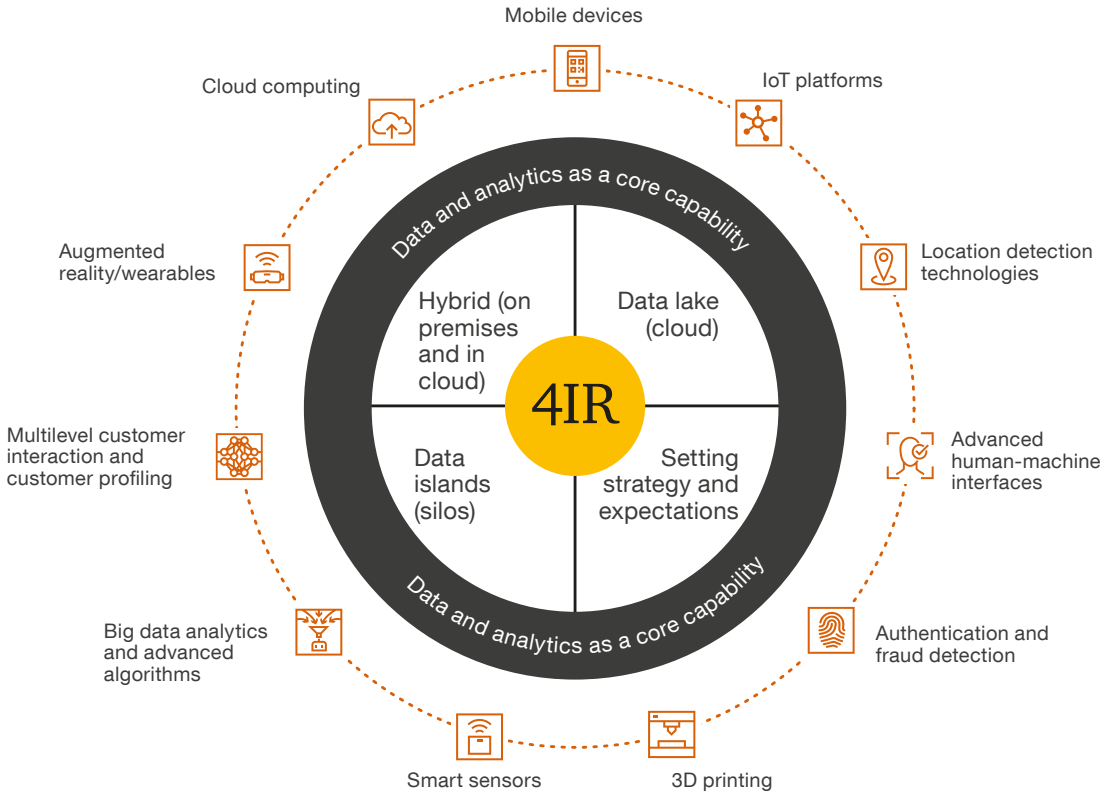


Data infrastructure

Most respondents are in transition with respect to data infrastructure, which we have grouped into four categories:

- The hybrid
- The lake
- Getting there
- Islands of trust

Figure 17: The 4IR ecosystem



Source: PwC analysis

The hybrid (let the data stay where it is)

A popular direction among respondents, the hybrid approach typically involves identifying information that is critical to the business and putting just that 'intelligence' in a central place rather than all the source data sets. Respondents typically have computing infrastructure on premises to house their calculations and data sets, but send their results to a central platform for integrated reporting. A need to maintain direct control of their data assets is a strong driver among some of the mining companies.

The lake (one version of the truth)

Respondents working towards a consistent and highly integrated data architecture that provides a single source of facts for all, is an option being embraced primarily by global or diversified mining companies. This requires moving all datasets to a central storage or data lake. Data lakes are being enabled by emerging cloud technologies and as price points are moving down, we believe this trend will continue as it is the desired end state for many data programmes.

Getting there (we know we have to, but the business case is unclear or hindered)

One respondent posited that the lack of data management in their company was 'a sore point', due to the lag in forming and implementing a coherent data strategy. Several told us that at times the business case is not taken seriously, or that cost containment is the major constraint. The COVID-19 pandemic has, however, provided an opportunity to accelerate the focus on data within current constraints as teams are dependent on good information while working remotely.

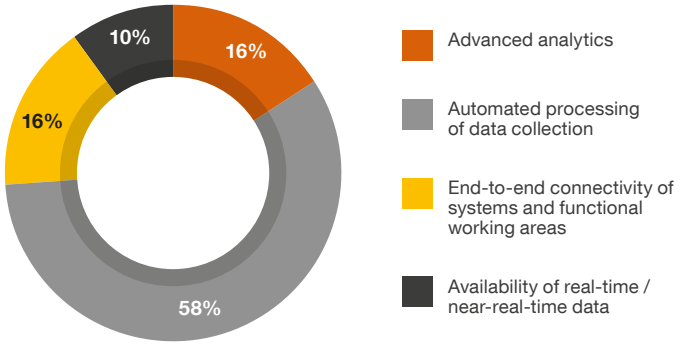
Many respondents are developing and implementing predictive data analytics, but achieving the appropriate, reliable, accurate, and timely data that would have real-time or near real-time financial implications, such as at board level, is the ultimate goal.

Islands of trust (data for decision support from credible pockets)

Respondents are unanimous that data for decision-making is a business imperative. However, when asked in what ways they believe that digitalisation and the utilisation of data could assist in effective decision-making, they identified end-to-end connectivity of systems and functional areas as priority issues needing to be addressed. Other aspects such as real-time data, automated data collection and advanced analytics can only be enabled once end-to-end connectivity (and by implication, integration) is resolved.

Figure 18: How digitalisation and data can assist in effective decision-making

Q *In what ways can digitalisation and the utilisation of data assist in effective decision-making?*



Source: PwC analysis

Data quality and trust

Where respondents perceive data quality to be in the good to high range (60%–80% rating), they believe that the data is useful for decision support.

Factors underpinning data quality and trust include the degree of data ownership and enterprise-wide coherence about what data should be sourced and utilised (relevance). The mining companies tend to trust the data sets emanating from finance and enterprise resource planning (ERP) systems (e.g. SAP) more than stand-alone tools (e.g. Microsoft Excel) and or other functions such as supply chain management. Mine planning data is typically a trusted source of information for our respondents.

Common agreement exists that:

- an explicit data strategy is required that includes having dedicated resources assigned to managing data;
- data quality (as being trustworthy for decision-making) appears to be a challenge in some of the operations;
- there are varying levels of data maturity in different parts of the businesses; and
- data-related issues are widely acknowledged and addressed, either manually through remedial actions, or via a reliance on artificial intelligence initiatives (many are still in the development stage).

Remedial actions are possible by subjectively reviewing data by means of business intelligence visualisation and having data architects/analysts in strategic functions ‘clean up’ the data, whose quality issues arise due to legacy system, volume and organisational structure. However, the occurrence of data quality issues and specifically how they are addressed, hinges on regular internal or external reviews, clear and concise presentation of data/information (dashboards), a reliance on ‘common sense’, and pattern discovery.

Data strategy and ownership

It is noteworthy that among respondent companies whose data strategy (and associated functions) is driven by a non-technical role (e.g. financial manager as opposed to an innovation lead, business information manager, CIO or CDO), our findings reveal a lagging drive towards explicit data engineering and management approaches.

Data ownership vs data infrastructure management, as clearly delineated, is an important step towards managing the data assets correctly and collaboratively. For example, our results suggest that engineering and technical leads are adept at identifying and responding to production-related problems/opportunities. Then, working with data infrastructure specialists, they are able to proactively drive the possibilities for improvement with regards to data management.

The implications of how data ownership and data infrastructure ownership is executed in mining companies present seemingly opposing perspectives on decisions such as opting for cloud, hybrid or on-premises infrastructure models and determining which automation opportunities to pursue.

Data reference architecture is a challenge

When asked which data reference architecture/framework was being utilised in their organisation, 47% said they 'did not know', a surprising revelation.

There are a number of possible reasons for this, including:

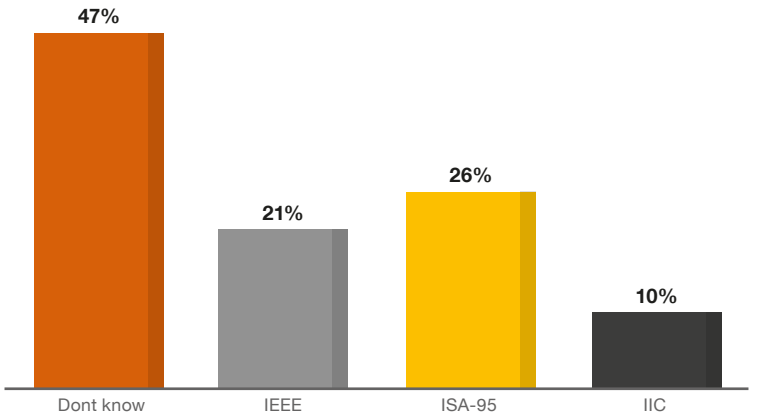
- IT/OT convergence challenges;
- data ownership vs data infrastructure management alignment challenges; and
- perspectives and/or legacy issues (systems, organisational structures and control, accountability).

The convergence of engineering, information technology and data management frameworks also appears to be a fundamental challenge — with the sheer volume of data and the disparate systems found mine to mine, any data project has to cut across all levels of the organisation and requires a common taxonomy, which in itself can present a significant obstacle to progress.

Twenty-six percent of respondents report that they adopted a data reference architecture/framework in the form of the ISA-95 model, which is typically used for smart manufacturing in the context of 4IR.

The absence of adopting and fully implementing an overarching IIoT framework such as The Industrial Internet Consortium's Industrial Internet Reference Architecture (IIRA [IIC]) corresponds to the seemingly incoherent data strategy implementations and outcomes throughout the enterprise.

Figure 19: Percentage of respondents using architecture frameworks.



Note: Some mining companies use more than one architecture framework

Source: PwC analysis

One in five respondents (21%) say they use the Institute for Electronic Electrical Engineering (IEEE) reference architectures. Of these, one reported that their company was moving over to IIC (Industrial Internet Consortium) and another was currently using both.

The preference towards a reference architecture does not seem to be influenced by the lead's role (as derived from their job titles). However, respondents who indicated that they are using, or plan to adopt IIC reference architectures were in engineering roles.

Front-end design is a fundamental challenge

To understand how preparation is key to success, we linked the use of reference architectures to how respondents rate themselves (first mover, innovator, fast follower, late follower). This brought to light a revelatory correlation: Collectively, the innovators, and first movers do not know what reference architectures they are using, besides one company that utilises IEEE and two that subscribe to ISA reference architectures.

Some fast followers also stated that they were progressing their reference architectures, but did not specify to which standard.

These findings can be interpreted in various ways:

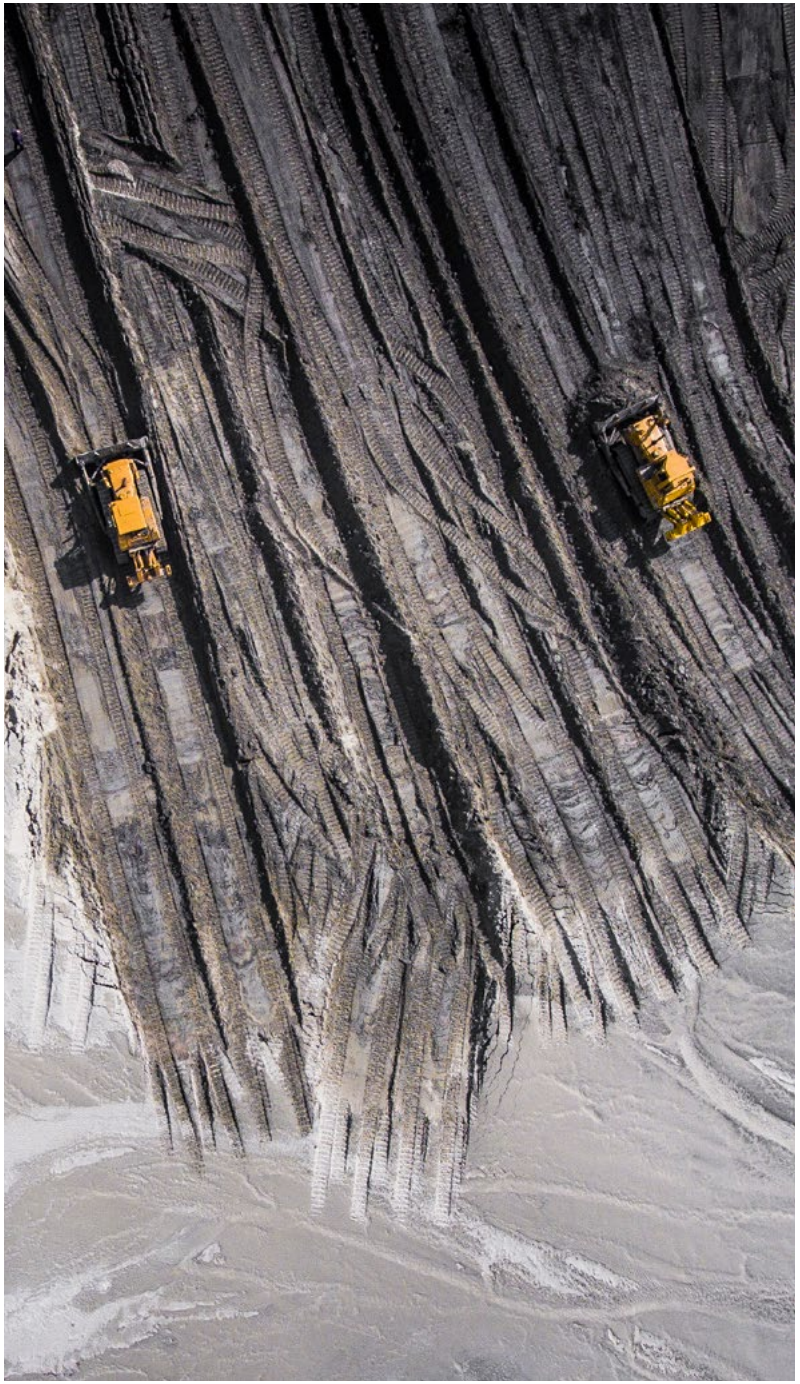
- some respondents don't actually really know what they have or are using;
- some respondents don't intentionally ascribe to any reference architecture;
- some respondents are not familiar with and/or do not apply up-to-date models; and
- some respondents believe that smart factory reference architecture such as ISA-95 can be used effectively in mining.

Though the reasons for the paucity of architectures were not explored in this study, this situation presents a challenge for the industry. With so many 'fast followers' waiting to see how it goes in other mines, this generally undisciplined approach could lead to poor examples being set — a case of first movers and innovators being the 'blind leading the blind'. Without implementation of appropriate architectures, it will be difficult for these companies to truly understand the impact and cost of their data programmes going forward.

The scenario with data/IT infrastructures is similar in that less seems to be known or planned than among those using typical engineering reference models. When asked about this area, respondents typically referred us to their IT/data management specialists for more information. This could be a case of niche expertise, or be a signal that the industry is fully aware of the potential pitfalls of data management and integration.

If data is the foundation of a future in which data supports decision-making, it must also be remembered that buildings are traditionally built from the bottom up, not the top down. With mine operations historically enjoying relative independence in terms of their hardware and software choices, architectures are not consistent across operations and offices, and without that consistency, it can be a very expensive and time-consuming challenge to retro-fit or re-design data and technology architectures into a common framework.

Ignoring this problem will not make it go away.



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