THE CHANGING NATURE OF WORK

INNOVATION, AUTOMATION AND CANADA'S MINING WORKFORCE

MIHR RHiM MINING INDUSTRY HUMAN RESOURCES COUNCIL

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Canada

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TABLE OF CONTENTS

EXECUTIVE DIRECTOR MESSAGE

Technology is rapidly transforming how we find, build and operate mines in Canada. Mining has always been innovative, and Canada's mining sector is accessing deeper, narrower, more complex and more remote deposits than ever before. Innovation and automation offer distinct and quantifiable benefits such as productivity gains, increased health and safety and reduced energy consumption – but their impact on employment is less clear.

On behalf of the Mining Industry Human Resources Council (MiHR), its Board of Directors and staff, I am pleased to share our first report on the impact of innovation and automation on Canada's mining workforce. This report is the culmination of a two-year study on the changing nature of work in mining, launched in pursuit of MiHR's vision to build an inclusive, skilled and sustainable Canadian mining workforce that anticipates and adapts to volatility and innovation.

The primary research objective of the study was to increase our understanding of how automation, innovation and emerging technologies are impacting the workforce. For over a decade, MiHR has considered productivity gains when forecasting employment and hiring requirements — however this report is our first dedicated research study on how new technology is impacting the workforce.

This report presents:

- A literature review on the innovation landscape and the potential challenges and opportunities for the mining workforce.
- A focus piece on the importance of digital literacy and essential skills in the mining workforce.
- A qualitative study including the perspectives of mining stakeholders and case studies highlighting how technology is changing the skills requirements of the mining workforce.
- A quantitative study including a new composite indicator – MiHR's Occupational Vulnerability Index (MOVI) – to gauge vulnerability across mining occupations.

This research is the first of many steps in better understanding the impact of new technology on the workforce. I thank the 125 people from dozens of mining companies, academia and other industry stakeholders who participated in the research and helped shape this report. I also want to thank Employment and Social Development Canada's (ESDC) Sectoral Initiatives Program for their ongoing funding and support.

If you have any questions or feedback on the report, please contact our research team at research@mihr.ca. I look forward to ongoing engagement with all of you, as we continue our efforts to better understand these labour market challenges and how we can address them collaboratively in the years ahead.

Ryan Montpellier
Executive Director, MiHR

Executive Summary

Like other industries in Canada, the mining sector is being transformed by new and innovative technologies. Over the last decade, mining operations began incorporating a new generation of equipment and processes that include remote operation, automation, and artificial intelligence. These innovations are changing the nature of mining work, placing pressure on the workforce to adjust to new skillset requirements, different workplace roles, and a different personnel structure. What remains unclear is the degree and timing of these changes.

Canadian mining employers and workers increasingly need innovation-focused labour market information and strategies that can anticipate how people and technology will need to work together in the future. Without that information, the mining sector risks falling behind in an increasingly competitive global industry.

This report aims to provide a more nuanced understanding of which occupations and skills are most vulnerable to technological disruption, both now and to the year 2030, using both qualitative and quantitative methods of research. The report is organized under three main themes: (1) Understanding Innovation in Mining, (2) Workers at Risk of Disruption (occupational vulnerability), and (3) Mining Skills of the Future.

For the qualitative study, MiHR gathered the perspectives of 125 mining stakeholders and developed case studies on three mining companies of interest. For the quantitative study, MiHR developed new labour market information (LMI) to assess the potential impact of innovation on Canada's mining labour market. This includes the development of a composite score – MiHR's Occupational Vulnerability Index (MOVI)—to gauge the vulnerability of 120 mining-relevant occupations, as well as a skills-to-occupations mapping to estimate the future shift in demand for selected workforce skills.

The report includes highlights from MiHR's review of the literature on the innovation landscape and the potential challenges and opportunities for mining labour. As well, it includes a focus piece on the importance of literacy and essential skills in the mining workforce.

KEY FINDINGS

Theme 1: Understanding Innovation in Mining

Today's mining processes are being transformed with the adoption of digital technologies such as cloud analytics, sensors, advanced robotics, virtual reality (VR), and artificial intelligence (AI). Although many of these innovations originated from outside the mining industry, they are profoundly influencing operational procedures, organizational structures, information systems, and management practices in mining.[1] These technologies offer significant environmental and production benefits, including lower costs and improvements in worker health and safety.

MiHR's qualitative study identified the innovations most in use at Canadian mines: data and analytics, automation, and electric and battery-operated vehicles. *Cost reduction and increased productivity* was cited as the primary reason (57% of citations) for implementing new technologies in Canadian mining, followed by improvements in worker health and safety.

Theme 2: Workers at Risk of Disruption

Stakeholders in the qualitative study concurred that disruption from new technologies will be disproportionately high for low-skilled mining workers who perform manual labour or work in repetitive jobs. Demand will shift toward more technical, knowledge-based occupations requiring a greater use of computers and software programs. Indigenous workers are highly vulnerable to disruption with the shift to remote operations and increasing demand for higher skills.

Findings from MOVI revealed:

- The greater part of the mining workforce is employed in occupations with higher vulnerability to new technologies.[2]
- The top five most vulnerable occupations are in *Production Occupations*. The most vulnerable occupation in this occupational category is *Underground Production and Development Miners*.
- Not having vocational training or post-secondary education significantly contributes to occupational vulnerability.
- Indigenous workers are especially vulnerable in several *Production Occupations* (*Underground Production and Development Miners, Heavy Equipment Operators,* and *Mine Labourers*).
- A large percentage of women in mining are employed in vulnerable occupations, namely administrative-type positions.

Theme 3: Skills for the Future

Results from the qualitative study affirm that skills requirements in mining will continue to change as a result of new technologies in the workplace. There will be an increased need for technical skills such as computer programming and systems analysis, and soft skills including leadership, collaboration and communications skills. The increased demand for higher skills and knowledge will raise the threshold for basic education and training as workers will continue to expand their knowledge and expertise into other areas of mining.

1 Bryant (2015), *The Case for Innovation in the Mining Industry*. Clareo. Retrieved from http://www.ceecthefuture.org/wp-content/uploads/2016/01/Clareo_Case-for-Innovation-in-Mining_20150910_lo.pdf

2 Occupations with a low MOVI score also have a comparatively small headcount.

MiHR's mapping of skills-to-occupations[3] to the year 2030 revealed:

- The skills that will be most prevalently in use are: (1) *Critical Thinking*, (2) *Operation Monitoring,* and (3) *Operation Control*.
- The skills used in *Operation Control* and in *Operations Monitoring* are expected to decrease yet will remain prevalent in close to 60% of the mining workforce.
- *Programming* is observed to be relatively specialized and will remain the least commonly used skill.
- Future scenarios to 2030 reveal an emphasis on *Active Learning, Reading Comprehension, Judgement and Decision Making* and *Complex Problem Solving*.

Literacy and other essential skills:

Low proficiency in literacy and other essential skills is linked to poorer outcomes in education, employment and health. Literacy and other essential skills are foundational skills, the base on which workers can develop the higher-level skills required to succeed in an increasingly digitalized mining environment. However, in the race to implement new technologies, mining companies tend to overlook the prevalence of low literacy and essential skills in segments of their workforce.

RECOMMENDATIONS

Use innovation-focused labour market information to make decisions:

Mining stakeholders need accurate and timely labour market information that captures shifts in skills requirements and occupational vulnerability resulting from digital disruption. The use of a quantitative measure of worker vulnerability (MOVI) can help decision-makers better prepare for a disruptive future and minimize negative outcomes.

Diversify the mining labour force:

The mining industry faces chronic labour shortages (current and projected) and shifts in demand for skills. The industry can diversify the labour pool by increasing the participation of women, immigrants, Indigenous people, and workers from other industries who have transferable skills.

Focus on skills development:

This area is especially critical for workers in *Production Occupations* and for Indigenous workers. Comprehensive skills assessment and targeted training should address the full scope of workers' skills gaps relative to operational needs. This training should include the development of literacy and other essential skills as they are foundational to further learning and skills development. Workers should receive technology-specific training in advance of the new technology being implemented.

Shift the discourse from crisis to opportunity:

Throughout history, miners have demonstrated adaptability, resilience and flexibility in the face of technological change. The digital transformation of mining is necessary and unstoppable – a stage in a long evolution, rather than an isolated crisis. Workers' anxieties about potential job losses need to be acknowledged. However, there is room for shifting the discourse from crisis/vulnerability to opportunity/adaptability.

The industry also needs to be forthright about the labour market disruption that lies ahead. Mining workers need a clear understanding of who is most vulnerable and why – and this should originate from innovation-focused LMI that allows for systematic monitoring and reporting of changes. With timely and accurate information, workers and workforce planners can make informed decisions about training and foster resiliency in the face of disruption.

Collaborate and share information across the industry:

Mining companies can build on each other's successes by sharing information about implementing new technologies and best practices in upskilling vulnerable segments of their workforce. Collaboration, rather than working in silos, will help to strengthen the competitive capacity of the industry as a whole.

Strengthen collaboration with academic institutions:

Academic programming related to mining occupations needs to better align with the industry's skills needs and provide more flexible program pathways to relevant credentials. An example is Rio Tinto's historic collaboration in Australia between government, industry, and educators on the creation of nationally accredited qualifications in automation.

3 MiHR mapped 10 skills of interest to 120 mining-related occupations. Three of these skills include reading comprehension, writing and critical thinking, which Employment and Social Development Canada categorizes as "essential skills". See Economic and Social Development Canada (2019), *Understanding Essential Skills*. Retrieved from https://www.canada.ca/en/employment-social-development/programs/essential-skills/definitions.html

Introduction

Increasingly, mining companies worldwide are using new and innovative technologies to increase productivity, create safer and healthier workplaces, and access deeper, narrower and more complex deposits. For the mining sector, the upside of a technological transformation is quite clear.

However, the risks and opportunities for mining workers are ambiguous. As emerging technologies fundamentally alter the nature of work, the mining workforce will need to adjust to new skillset requirements, different workplace roles, and a different personnel structure. The popular narrative of widespread job loss as a result of automation is top of mind for many workers, while advocates of innovation argue that the benefits of higher productivity and new employment opportunities will match or surpass any drawbacks.

Concurrent with these concerns is a worsening shortage of mining labour. In Canada, the industry may need to hire roughly 79,680 workers over the next decade (2020 to 2030) and 60% of hiring requirements are projected to be in extraction and milling.[4] To date, there are no industry guidelines on how Canadian mining companies can best prepare for the rapid changes that lie ahead.

4 This forecast reflects a baseline and expansionary scenario, respectively, reflective of the gap resulting from retirement exits and other shortages in the decade (2020 to 2030). See: Mining Industry Human Resources Council (2019), Canadian Mining Labour Market *10-Year Outlook: 2020*. Retrieved from https://mihr.ca/wp-content/uploads/2020/03/MIHR_National_Report_web2.pdf

THE CHALLENGE: WHO IS MOST VULNERABLE TO DISRUPTION?

The challenge for mining stakeholders is to correctly diagnose which occupations are most susceptible to future disruption. It is difficult to predict how labour demand will change for various roles in the industry. New specialized and well-paying positions will appear, but only workers with the needed skillset will thrive in these roles, while others will have more limited prospects. In the worst case, some of the workers with increasingly obsolete skills may be the same who face redundancy. Without actionable labour market information, and without strategies that can anticipate how personnel and technology will need to work together in the future, Canadian mining employers and workers run the risk of falling behind in an increasingly competitive global industry.

ABOUT THIS REPORT

To help fill this gap in understanding, MiHR conducted a two-year study on the changing nature of mining work as a result of technological innovations, focusing on the potential risks and opportunities from a labour market point of view. The purpose of this report is to provide qualitative and quantitative analysis and actionable insights that can help mining stakeholders (career seekers, employers, educators, governments, communities of interest, unions, etc.) make well-informed decisions.

The research for this report focused on three overriding questions:

1. Who will be disrupted by automation and digital technologies?
2. How will skills requirements change as result?
3. What can mining stakeholders do to better prepare for these changes?

Key Data Sources

This report uses data from a variety of public and private sources to provide key information on variables of interest including demographic characteristics and economic and behavioural factors.

Methodology

Qualitative analysis:

The qualitative study involved the participation of about 125 Canadian mining stakeholders who have direct, relevant knowledge of the Canadian mining context. MiHR conducted interviews, an online survey, a focus group, case studies, and validation sessions to capture a broad spectrum of views and expertise.

Quantitative analysis:

MiHR organized a set of labour market indicators around a framework, then aggregated the data to form MOVI. This composite score quantifies the mining workforce's exposure to disruption, taking into consideration the likelihood of displacement due to technology, as well as workers' ability to find equal or better employment. A mapping of skills-to-occupations was used to observe the workforce skills that are prevalent today and to anticipate how emerging technologies will change the skills requirements in the future.

Literature review:

In preparation for the study, MiHR conducted a comprehensive review of the literature on the impact of digital innovations on the mining industry, both globally and in Canada. The key findings from the literature review are integrated as contextual background throughout the report.

ORGANIZATION OF REPORT

- Section One, "Understanding Innovation in Mining," provides an overview of the digital technology landscape, including the potential benefits, and the application of new technologies in the mining industry, both globally and in Canada.
- Section Two, "Workers at Risk of Disruption," focuses on understanding which workers (occupations) are most at-risk of disruption as a result of the adoption of new technologies. This section presents a framework that uses a set of labour market indicators to construct MOVI.
- Section Three, "Skills of the Future," focuses on observing the workforce skills that are prevalent today and anticipates how emerging technologies will change the workforce skills required in the future. This section of the report includes a special focus piece on literacy and essential skills in mining.
- Section Four contains conclusions and recommendations.

SECTION 1:
Understanding Innovation in Mining

INTRODUCTION

This section of the report provides an overview of the digital technology landscape. It describes the scope of current and emerging innovations in the marketplace, their reported benefits to industry, and the types of technologies being implemented in the mining sector, both globally and in Canada. This section begins with key findings from a review of the literature and concludes with the perspectives of Canadian mining stakeholders who participated in MiHR's qualitative research.

1.1 BACKGROUND: DIGITAL TECHNOLOGIES IN MINING

Historically, the mining industry has undergone substantial change through innovation. Today's mining processes are undergoing further transformations with the adoption of digital technologies such as mobile devices and apps, cloud analytics, sensors, advanced robotics, virtual reality (VR), cognitive computing, and artificial intelligence.

There are various ways to categorize the ever-growing number and types of innovations. The World Trade Organization (WTO) suggests there are two broad categories of technology: (1) labour-saving technology that can complete cognitive or manual tasks without direct human involvement (e.g. autonomous trucks), and (2) labour-augmenting technology that complements the work performed by a human (e.g. autopilot).[5]

Today's mining processes are undergoing further transformations.

The World Economic Forum uses four broad categories of digital technologies:[6]

1. Automation, robotics and operational hardware:

This rapidly growing theme in mining involves the use of digitally enabled hardware instruments to execute activities traditionally carried out manually or with machinery controlled by humans. Key technologies include:

- 3D printing, automated drones, robotic trucks, trains and diggers, autonomous stockpile management, and autonomous robots for recovery of recycling material.

2. Digitally enabled workforce:

This theme focuses on using connected mobility as well as simulated and augmented reality (AR) to assist and monitor field, remote and centralized mine workers in real time. Key technologies include:

- Remote operations centres, digital simulation training/learning, connected worker/mobile devices, logistics control towers, virtual collaboration, and improvements in VR, AR, and intelligent wearable devices.[7]

3. Integrated enterprise platforms and ecosystems:

This theme entails linking operations, IT layers and tools or systems within the value chain of the larger ecosystem. Key technologies include:

- Integrated sales and operations planning; asset cyber security; the convergence of IT/operational technology (OT); smart sensors; digital monitoring; the tracking and analysis of environmental/health and safety indicators; integrated, agile supply chain; and advanced track-and-trace technology.

4. Next-generation analytics and decision support:

This theme involves using algorithms and AI to process data and improve the precision and accuracy of future projects. Key technologies include:

- Ore valuation and build simulation modelling; field development planning; production forecasting; asset performance monitoring and predictive asset management/maintenance; digital twin simulation; advanced analytics for production optimization and maintenance; AI for operations support; and self-aware mine/cognitive networks.

5 World Trade Organization, World Trade Report 2017: *Trade, technology and jobs.* Retrieved from https://www.wto.org/english/res_e/booksp_e/wtr17-0_e.pdf
6 World Economic Forum (2017), *Digital Transformation Initiative: Mining and Metals Industry*. Retrieved from http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/white-paper-dti-2017-mm.pdf
7 For example, a new technology known as SmartCap helps to gauge the fatigue risk of mining workers on-site by monitoring their brainwaves, providing real-time fatigue alarms to a central control room, which can trigger safety interventions. See: SmartCap (n.d.). Retrieved from http://www.smartcaptech.com/industries/mining

Rio Tinto's Mine of the Future[8]

Rio Tinto is a global leader in the development of autonomous technologies for use in the mining sector, as exemplified in its Mine of the Future™ program launched in 2008. The company's iron ore operations in the Pilbara region of Western Australia use next-generation technologies to enable greater efficiency, lower production costs, and improvements in health, safety and environmental performance. Key components of the Mine of the Future™ program include:

Operations Centre:

A state-of-the-art facility in Perth enabling mines, ports and rail systems across the Pilbara region to be operated from a single location. It incorporates visualization and collaboration tools, providing real-time information to optimize mining, maintenance and logistic activities.

Autonomous Haulage Systems (AHS):

More than 80 autonomous trucks are in operation at the Pilbara sites, each designed to move high-grade ore efficiently and safely. In 2018, each truck was estimated to have operated on average 700 hours more than conventional haul trucks, with 15% lower costs.[9] These trucks use pre-defined GPS courses to automatically navigate haul roads and intersections, and continuously track actual locations, speeds and directions of other vehicles.

Automated Drilling System (ADS):

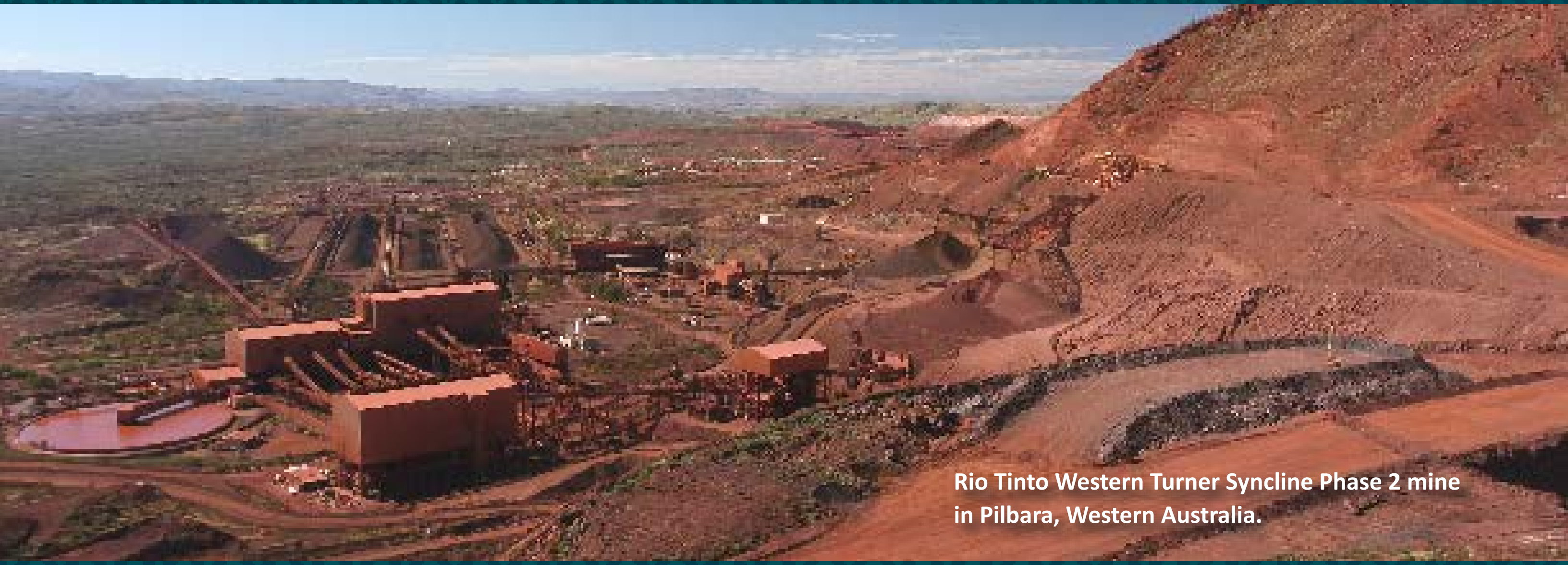
An ADS allows Rio Tinto to monitor multiple drills from different manufacturers across multiple sites from a single remote drill console in Perth. The first successful test was conducted at the West Angeles mine in 2008. There is now a fleet of 26 production drills across seven sites including the recent deployment of an additional three production drills at Hope Downs 4.

AutoHaul®:

The world's first automated heavy-haul, long distance rail network, fully deployed in 2018, is capable of moving about one million tonnes of iron ore a day. About 200 locomotives, on more than 1,700 km of track in the Pilbara region, transport iron ore from 16 mines to four port terminals. AutoHaul™ improves safety by reducing risk at level crossings and through automated responses to speed restrictions and alarms, eliminating the need to transport drivers to and from trains mid-journey, which in turn saves almost 1.5 million kilometres of road travel every year.

Intelligent Mine, Koodaideri:

Construction to begin in late 2021.[10] This US$2.6 billion iron ore project is set to be Rio Tinto's first intelligent mine. In addition to technology in use across Rio Tinto, Koodaideri has more than 70 design innovations in scope. Fully integrated mine operation and simulation systems, including digital twin technology, will be accessible in real time in the field.



Rio Tinto Western Turner Syncline Phase 2 mine in Pilbara, Western Australia.

8 Rio Tinto website. Retrieved from https://www.riotinto.com/Operations/australia/pilbara
9 See Rio Tinto, *2018 Sustainable development report*. Retrieved from https://www.riotinto.com/documents/RT_2018_Sustainable_development_report.pdf
10 The construction phase will create over 2,000 jobs. When operational, Koodaideri will employ about 600 people. See Rio Tinto, *2018 Sustainable development report*.

1.1.1 Implementation of New Technologies in Canadian Mining

Many Canadian mining companies are already using or piloting equipment automation, digital monitoring, AI, sensors, blockchain and other innovations to achieve a number of benefits including environmental, cost savings, improved access and recovery of ore, and enhanced safety.

Barrick Gold announced its "digital reinvention" in a partnership with Cisco in 2016, designating the Nevada Cortez gold mine as the test site.[11] The company installed Wi-Fi to enable the collection of real-time data from all of the mine site's moving parts and personnel, allowing supervisors to monitor all tasks and optimize coordination and scheduling. Barrick is also exploring equipment automation, including an autonomous open pit trial, introducing AI, and using predictive algorithms to enhance the precision and speed of its gold recovery.

Teck Resources uses a combination of sensors and real-time data to identify slight variations in dust particles and water quality near its sites at Carmen de Andacollo, Chile, and Elk Valley, Canada. This enables Teck to simultaneously share hourly results with local communities to better understand the environmental impact of mining, and allows analysis and reporting by government.[12] Teck is running a pilot project that uses telematics (the long-distance transmission of digital information) and Google machine learning to predict and avoid haul truck mechanical failures. The cloud-based technology could save Teck about $1.2 million annually at just one site.[13]

Goldcorp and IBM Canada recently launched IBM Exploration with Watson, a new technology that applies AI to predict the potential for gold mineralization.[14] It is also capable of using search and query capabilities across a range of exploration datasets, identifying key information that allows explorers to quickly develop geological extrapolations and propose new targets for drilling. The solution was developed using data from Goldcorp's Red Lake Gold Mine in Northern Ontario.[15] Goldcorp has also collaborated with Atlas Copco in the use of remotely operated drill technology to access a very complex ore deposit at its Éléonore mine.[16]

Vale reopened its Totten mine in 2014 as the company's first "digital mine." Totten is now one of the company's "core mines" and is used as an employee training site and a working model for other Vale operations in Sudbury that are making the digital transition. The mine uses high-speed ethernet networks and fibre optic cables to tie into new wireless technology. Everything from people to fixed and mobile equipment is tagged and tracked, allowing personnel to monitor mining processes, guard against mistakes, and identify processes that can be optimized.[17]

Yamana Gold has partnered with Emergent Technology Holdings to implement an innovative blockchain technology for the responsible sourcing of gold. The technology enables Yamana to execute supply chain contracts between miners, refiners, logistics providers and buyers in what has historically been "a very manual and inefficient process with data recorded across disparate systems and several industry participants."[18]

11 Joel Barde, "Canadian mining companies look to "test mines" to develop new technology," *CMI Magazine* (25 October 2018). Retrieved from http://magazine.cim.org/en/technology/a-digital-playground-en/
12 World Economic Forum (2017).
13 Mining.com (June 1, 2018), "Canada's Teck adopts new resource extraction technology." Retrieved from http://www.mining.com/web/canadas-teck-adopts-new-resource-extraction-technology/
14 Goldcorp merged with Newmont in 2019, and the Red Lake property has been divested.
15 Mining.com (November 2018), "Goldcorp and IBM find way to improve predictability for gold mineralization." Retrieved from http://www.mining.com/gold-corp-ibm-find-way-improve-predictability-gold-mineralization/
16 Goldcorp (n.d.), "Enhancing Productivity at Éléonore." Retrieved from https://www.goldcorp.com/English/strategy/increasing-production/default.aspx
17 Barde, "Canadian mining companies look to "test mines" to develop new technology."
18 Dale Benton (April 19, 2018), "Yamana Gold digitises the gold sourcing world through blockchain technology," *Gigabit*. Retrieved from https://www.gigabitmagazine.com/company/yamana-gold-digitises-gold-sourcing-world-through-blockchain-technology#

1.1.2 Potential Benefits

Research has affirmed that the effective use of technological innovations in mining enables companies to improve their ore body knowledge and recovery rates, leading to higher productivity and lower costs, safer work environments, and reduced energy consumption and environmental impacts.[19, 20, 21]

The World Economic Forum projects that over the next decade, digital technologies could generate over US$425 billion of value for the mining industry, society and the environment; reduce $C0_2$ emissions by 610 million tonnes; and improve worker health and safety.[22]

Randgold Resources reported a 29% quarter-on-quarter injury rate improvement since implementing autonomous technologies in several of its African mines.[23]

A recent Quebec study on mining innovation suggests that increased health and safety is the number one reason for mining companies' investment in digital technologies. Return on investment was ranked the second most important reason, followed by efficiency, replacement of obsolete equipment, and environmental concerns.[24]

1.2 QUALITATIVE FINDINGS

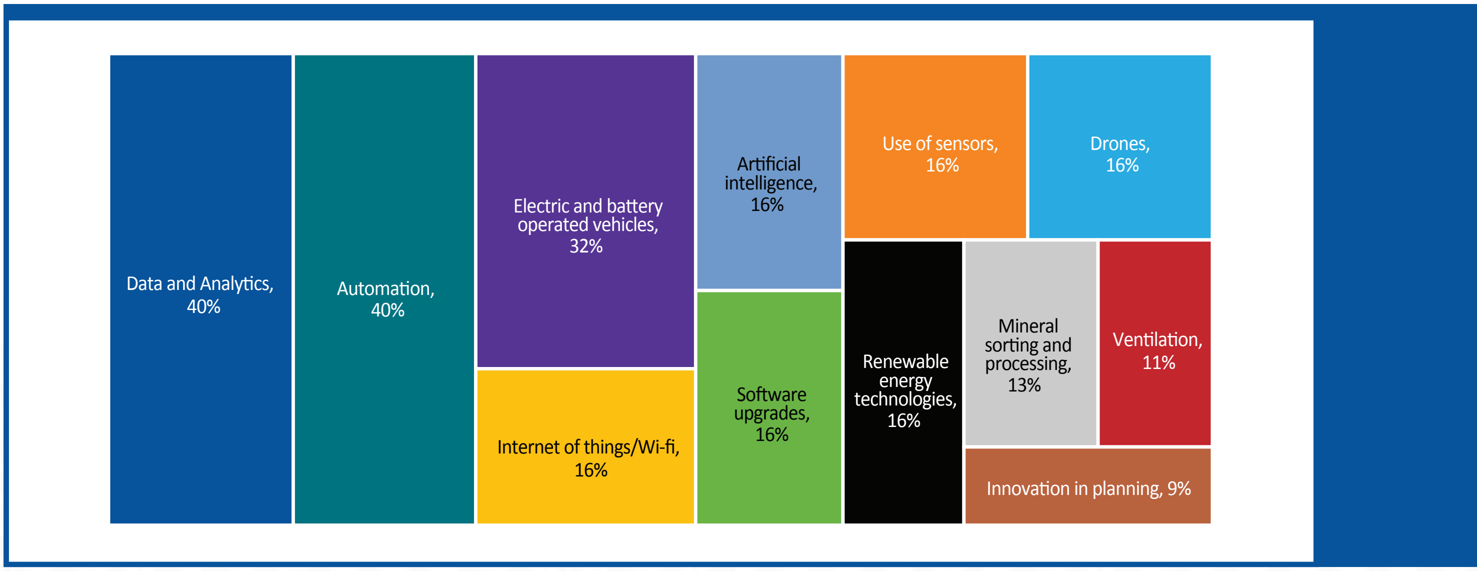
1.2.1 Technologies at Work in Canadian Mining

Stakeholders who participated in the qualitative study were asked to identify innovations in Canadian mining operations that have already been implemented or will be implemented in the coming years.

The most frequently cited innovations (Figure 1.1). were data and analytics (40%) and automation (40%), followed by electric and battery-operated vehicles (32%). Innovation in planning had the lowest share of citations (9%).

Digital technologies could generate over US$425 billion of value.

FIGURE 1.1: Innovations in Canadian Mining Operations by Share of Respondent Citations (2019)



Source: Mining Industry Human Resources Council, 2019

19 World Economic Forum (2017).
20 McKinsey and Company, "Mining's next performance horizon: Capturing Productivity gains from innovation," *Metals and Mining* (Sept. 2015).
21 Bryant (2015).
22 World Economic Forum (2017).
23 Martin Creamer, "Kibali Africa's Most Mechanised Gold Mine—Randgold," *Mining Weekly* (2 Nov. 2017).
24 Bellehumeur, Valérie (2018). Transformation numérique et compétences du *21e siècle pour la prospérité du Québec : Exemple de l'industrie minière / Digital transformation and 21st century skills for Québec's prosperity: The mining industry example.* Institut national des mines du Québec. Retrieved from http://numerique.banq.qc.ca/patrimoine/details/52327/3550609

1.2.2 Why are New Technologies of Interest to the Mining Sector?

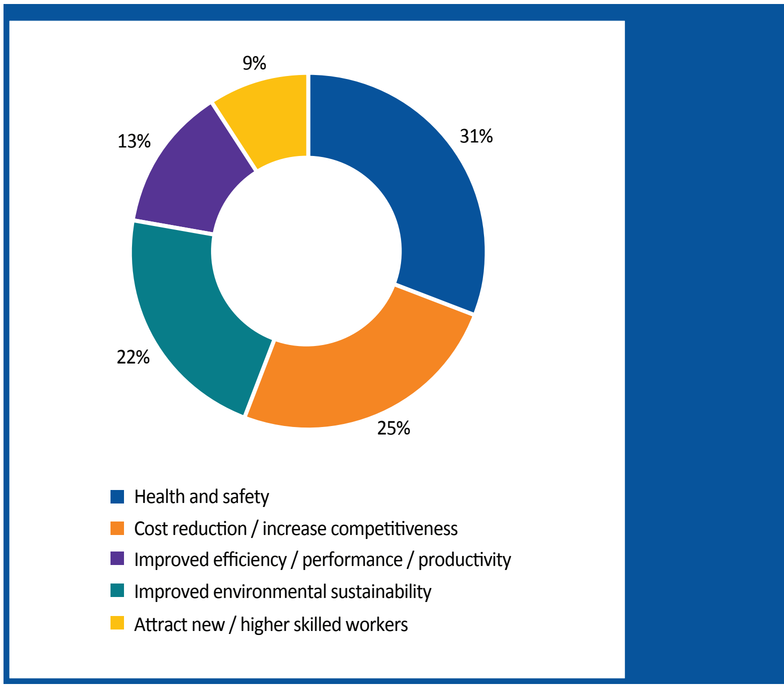
More than half of the research participants (57%) indicated that digital technologies are of interest to mining companies because they increase productivity/ efficiency, reduce costs, and increase competitiveness (Figure 1.2). As examples, they cited real-time monitoring of equipment that allows for preventative maintenance, reducing the costs associated with lost productivity in down time, and the use of drones and hovercrafts that can access terrain that previously was challenging to navigate.

About one third (32%) of respondents noted that mining companies are interested in digital technologies because they contribute to improvements in worker health and safety. With the use of automated equipment and remote operations, miners are removed from potentially hazardous conditions underground. Wearable electronic sensors can monitor workers for heat stroke, track their location, set off alarms if they fall asleep, and trigger safety interventions.

Thirteen per cent of participants indicated that digital technologies are of interest to mining companies because of environmental concerns. They cited the use of battery-electric vehicles to reduce carbon emissions and reliance on diesel fuel, and of growing partnerships with diverse technology companies to develop non-intrusive methods of exploration.

Another 9% of respondents noted that the implementation of new technologies and innovation in mining could make the industry more attractive to higher skilled workers.

FIGURE 1.2: Responses to the Question, "Why are these technologies of interest to the mining industry?"



Source: Mining Industry Human Resources Council, 2019

SECTION 2:
Workers at Risk of Disruption

INTRODUCTION

As noted in Section 1, industry observers agree that innovations will enhance worker health and safety, reduce operational costs, boost productivity, and improve environmental sustainability. However, the occupational risks and opportunities for mining workers are not well understood. New specialized and well-paying positions will likely appear, but only workers with the needed skillset will thrive in these roles, while others will have more limited prospects.

This section of the report aims to identify which workers are most vulnerable to the disruptive effects of new technologies.

2.1 BACKGROUND

New technologies that are already in use (or are being piloted) in mining are likely to reach their peak rates of deployment in the next 10 to 15 years.[25] The World Economic Forum estimates that by 2025, the rate for deployment of new automated equipment in the mining sector will be 25% compared to 0.1% in 2017.[26] Some analysts predict that the mining automation market could grow by almost 50% in the next few years, reaching US$3.29 billion by 2023.[27]

There is a large body of research on the potential impacts of automation and digital technologies on the overall labour force (for example, the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF)).[28] Much mining-specific research concludes that job losses will occur as a result of new technologies, but that the technologies will also result in the creation of new jobs. Automation is predicted to reduce the number of operational jobs in train and truck driving, drilling, and blasting (these areas currently constitute over 70% of mining employment); however, more jobs will be created in the development, observation, servicing and maintenance of remotely controlled and autonomous equipment, and in data processing and process analysis.[29]

Predictions on job losses and gains are often based on an analysis of occupations as they currently exist, and depending on the method and the assumptions used, estimates can vary by nearly half of the workforce.[30] Occupations are not static entities – they continue to evolve in response to shifts in demand and the integration of new technologies. A new technology may eliminate the demand for certain tasks, or alter the routine content of an occupation, but it does not necessarily make the whole occupation redundant.[31]

- According to a McKinsey Global Institute (MGI) study of more than 2,000 work activities across 800 occupations in the United States, about 60% of all occupations have a high share (at least 30%) of constituent activities that could be automated.[32]
- Research by the Brookfield Institute has shown that about 18% of current occupations in Canada have already automated 70% or more of their work activities.[33]

Research suggests that a very low share of occupations (across industries) have full automation potential (meaning that every activity constituting these occupations can be automated): less than 5% of occupations in the United States,[34] 9% of jobs across the 21 OECD countries,[35] and less than 1% of occupations across the Canadian labour market.[36]

25 A. Cosbey, H. Mann, N. Maennling, P. Toledano, J. Geipel, & M. D. Brauch (2016), *Mining a Mirage? Reassessing the shared-value paradigm in light of the technological advances in the mining sector.* Winnipeg: International Institute for Sustainable Development.
26 World Economic Forum (2017).
27 Markets and Markets (October 25, 2017), *Mining Automation Market by Technique, Type (Equipment, Software, Communications System), Equipment (Autonomous Hauling/Mining Trucks, Autonomous Drilling Rigs, Underground LHD Loaders, Tunneling Equipment) and Region - Global Forecast to 2023.*
28 *Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (2020)* https://www.igfmining.org/new-tech-new-deal/
29 Cosbey et al. (2016).
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34 *A Future that Works: Automation, Employment and Productivity,* McKinsey Global Institute.
35 M. Arntz, T. Gregory and U. Zierahn, "The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis," OECD Social, Employment and Migration Working Papers, No. 189, OECD (2016), Paris.
36 Lamb (2016).

2.2 THE PERSPECTIVES OF MINING STAKEHOLDERS

2.2.1 Mining Occupations Most in Demand

Mining stakeholders interviewed as part of this project agreed that demand for mining labour will shift toward more technical, knowledge-based occupations requiring greater use of computers and software programs. There will be increased demand for technical miners with specializations in fibre optics, wireless technologies, and data analytics, and for engineers, geologists, programmers (e.g., robotics programmers), electricians and systems engineers.

Mechanics and maintenance workers with digital competencies will be in high demand; their new roles will require the ability to read and interpret real-time data generated by automated vehicles and equipment, and to maintain and repair technologically sophisticated systems remotely. Table 2.1 summarizes stakeholders' perspectives on occupations which are most in demand in the immediate term and over the next five to 10 years.

TABLE 2.1: Occupations Most in Demand as Cited by Research Participants

Over the immediate term	Over the next five years	Over the next decade
• Electrical Engineers • Automation Engineers • Instrumentation Technologists • Instrumentation Technicians • Network Analysts • Network Programmers	• Strategic Planners • Programmers • Data Scientists • Geologists • IT Specialists in fibre optic & wireless technologies • Engineers • Systems Engineers • Systems Integrators • Software Experts • Data Analysts • Generalists • Facilitators • HR Experts • Instrumentation Tech, Engineers, Geologists	• Data Scientists • Data Analysts • Mechatronics Engineers • Engineers with background in Data Science / Optimization

Source: Mining Industry Human Resources Council, 2019

2.2.2 Workers Most at Risk of Disruption

A common theme that emerged from the stakeholders' responses is that automation and digital technologies will affect all occupations to some degree, but will have a disproportionately negative effect on low-skilled workers who perform manual labour or work in repetitive jobs, compared to those with higher skills and education. Manual labour jobs will become less desirable and demand will shift toward more technical, knowledge-based occupations requiring a greater use of computers and software programs.[37]

Automated vehicles and equipment will mean fewer truck drivers and equipment operators and an increase in demand for technical jobs in remote operations.

Some participants expressed concerns that the shift to remote operations and increased demand for higher skills could disproportionately impact Indigenous communities for whom mining is a major employer in northern and remote communities.[38]

37 Many of the participants emphasized that losses in jobs requiring manual labour and repetitive work will be offset by the creation of new skilled jobs – the overall employment in mining will remain about the same.

38 Large-scale mining activity in Canada is often located in northern and remote regions, on or adjacent to the lands of Indigenous communities. Among private sector employers in Canada, mining is the second highest proportional employer of Indigenous Peoples. See Natural Resources Canada (March 3, 2019), "Canada's Mines Ministers Unveil the Canadian Minerals and Metals Plan, A Visionary Plan to Inspire and Shape the Future of Canadian Mining," https://www.newswire.ca/news-releases/canada-s-mines-ministers-unveil-the-canadian-minerals-and-metals-plan-a-visionary-plan-to-inspire-and-shape-the-future-of-canadian-mining-865583788.html

2.3 OCCUPATIONAL VULNERABILITY: QUANTITATIVE ANALYSIS

Introduction

As noted, innovations offer numerous benefits to the mining industry as a whole but the potential risks and opportunities for mining workers are not well understood. Having a quantitative measure of worker vulnerability can help decision-makers better prepare for a disruptive future and minimize negative outcomes. Data-driven strategies can improve job stability for workers and establish a competitive labour pool that mining operations can effectively draw upon.

This section of the report presents a quantitative analysis aimed at identifying which workforce participants face the greatest exposure to technological disruption. MiHR has identified 120 mining-related occupations to establish a focus for the occupational analysis in this report. These occupations range from *Production and Operations* (e.g. heavy equipment operators) to *Professional and Physical Sciences* (e.g. geologists), among others. The complete list is shown in Appendix 2.

To gauge mining workers' susceptibility to technological disruption, MiHR organized a set of labour market indicators around a framework, then aggregated the data to form MiHR's Occupational Vulnerability Index (MOVI). This composite score quantifies the mining workforce's exposure to disruption, taking into consideration the likelihood of displacement due to technology, as well as workers' ability to find equal or better employment. MOVI scores make it possible to rank mining occupations by vulnerability, to understand what makes workers vulnerable, and to point to segments of the labour pool that should receive the most attention.

2.3.1. Industry and Occupational Definitions

Data presented in this analysis primarily rely on occupational (and industry-level) data collected and aggregated through Statistics Canada. Data throughout the quantitative analysis in this report are aligned with the National Occupational Classification (NOC) system to define relevant occupations of interest, and with the North American Industry Classification System (NAICS) to define the mining industry in Canada. For simplicity, this analysis primarily focuses on one NAICS code – *Mining and quarrying (NAICS 212)*.

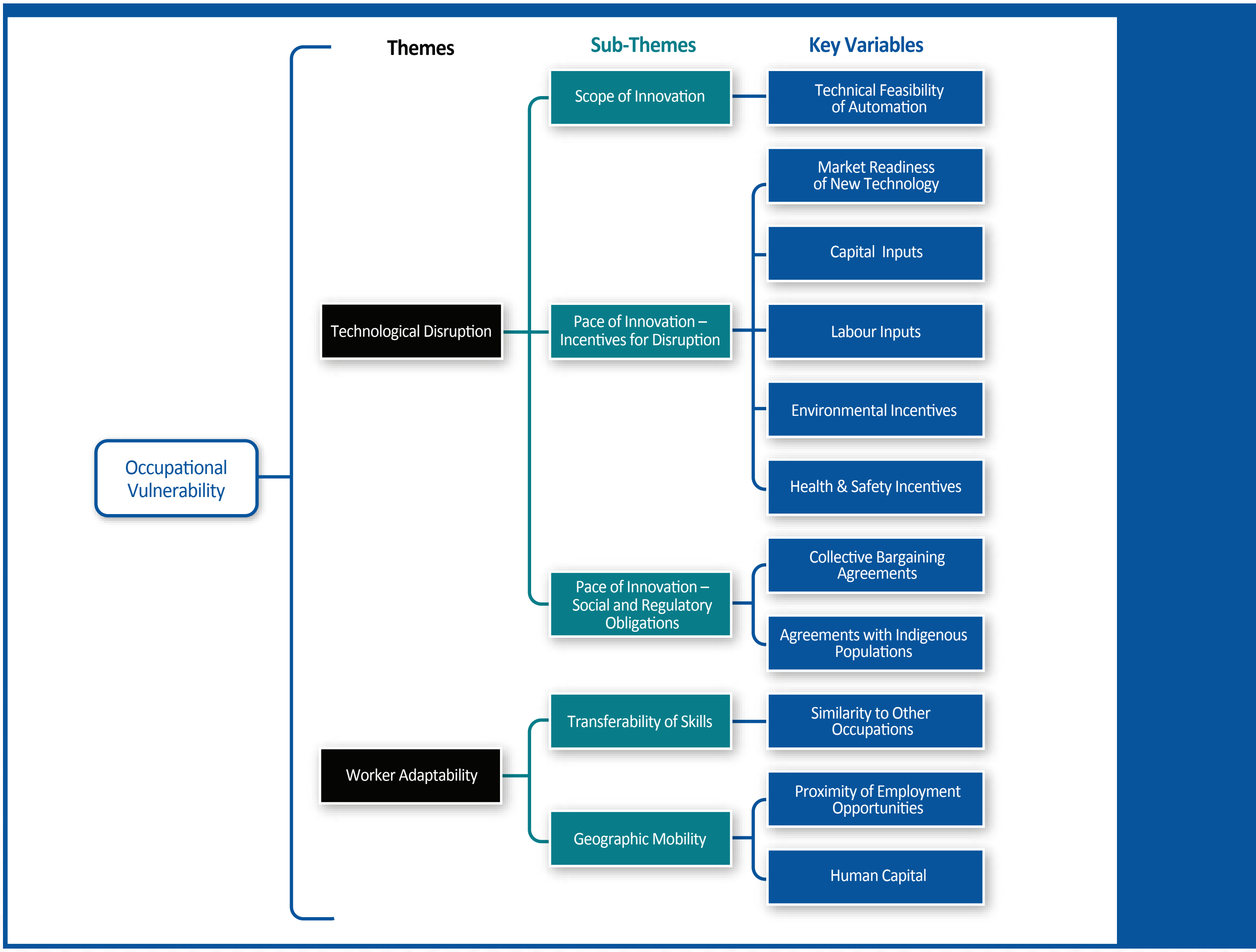
2.3.2 Theoretical framework

For the purposes of this report, MiHR defines occupational vulnerability as the state of being susceptible to the negative effects of technological disruption. A worker's exposure to these effects is multifaceted and must be analyzed on several fronts.

MiHR has established a framework to understand occupational vulnerability conceptually and to organize and aggregate data accordingly (Figure 2.1). This framework is described in detail below.

MiHR defines occupational vulnerability as the state of being susceptible to the negative effects of technological disruption.

FIGURE 2.1: Theoretical Framework for Occupational Vulnerability



Source: Mining Industry Human Resources Council, 2019

Themes of Occupational Vulnerability

MiHR's framework of occupational vulnerability comprises two broad themes: *Technological Disruption* and *Worker Adaptability*. These themes are divided into five sub-themes, which are further subdivided into 11 measurable key variables to provide a complete picture of occupational vulnerability.

Theme 1: Technological Disruption

This theme gauges the prospective magnitude and timing of technological disruptions on various occupations. New technology can take over tasks previously carried out by workers, and it can introduce new job responsibilities that require a different skillset. As more tasks are automated, and as day-to-day mining activities continue to change, some workers will face reduced demand for their labour.

Sub-theme: Scope of Innovation:

The scope of innovation refers to the greatest possible effect that innovation could have on workers. Given the latest advances, innovation has the potential to replace the labour of each mining occupation to a different degree. This potential represents the maximum reach of innovation, if it were fully deployed across the mining value chain today. The realization of this potential depends on incentives and disincentives that firms must weigh against each other.

- *Key Variable: Technical Feasibility of Automation:*

  This key variable measures the extent to which an occupation can be fully automated. The latest innovations have the potential to partially or fully automate many mining activities and remove certain occupations from the mining process.

Sub-theme: Pace of Innovation—Incentives for Disruption:

The pace of innovation refers to how quickly the potential effects of innovation are likely to be realized. This is partially determined by a mining operation's incentives and disincentives to adopt new technologies. If the benefits to profitability, worker health and safety, and the environment are substantial enough, new technologies are more likely to be adopted sooner.

- *Key Variable: Market Readiness of New Technology*

  This key variable observes whether new technologies are presently being sold by manufacturers and implemented by mining companies—a signal of their commercial viability which would accelerate the pace of innovation.

- *Key Variable: Labour Inputs*

  This key variable determines whether labour inputs represent a substantially high share of mining companies' operational expenses, providing an economic incentive to introduce new technologies that could optimize costs.

- *Key Variable: Capital Inputs*

  This key variable refers to the upfront cost of developing and deploying new technologies. A relatively large (or small) initial capital expenditure can slow down (or accelerate) the pace of innovation.

- *Key Variable: Environmental Incentives*

  This key variable considers how new technologies can be more attractive to mining companies if they can sufficiently reduce a mining operation's environmental footprint.

- *Key Variable: Health & Safety Incentives*

  This key variable considers how new technologies can be more attractive to mining companies if they protect the health and safety of workers, especially in underground settings.

Sub-theme: Pace of Innovation—Social and Regulatory Obligations:

The pace of innovation can also be determined by social and regulatory obligations that a mining operation has to fulfill. Mining companies often need to comply with certain preconditions or honour agreements (e.g. with organized labour) before they can make major changes to the structure of the workforce. This can slow down the pace of adoption of disruptive technologies.

- *Key Variable: Collective Bargaining Agreements*

  This key variable observes how existing commitments with labour groups must be considered before making capital investments that could negatively impact workers.

- *Key Variable: Agreements with Indigenous Populations*

  This key variable observes how Impact Benefit Agreements (IBAs) and other negotiations with Indigenous groups must be considered before deploying technologies that impact the labour force.

Theme 2: Worker Adaptability

This theme considers workers' capacity to adapt following technological disruption, taking into account labour mobility and transferability of skills between occupations. Some workers will be able to transition to related roles relatively seamlessly, while others may struggle to upgrade or acquire in-demand skills, switch their occupation, or avoid long periods of unemployment.

Sub-theme: Transferability of Skills:

The transferability of skills refers to a worker's ability to transfer their skillset to a different but similar occupation. In the event of job loss, workers with the most in-demand and transferable skills will have a wider array of employment opportunities and career pathways.

- *Key Variable: Similarity to Other Occupations*

  This key variable gauges the degree of similarity between a particular occupation and other occupations across the Canadian economy. A strong (or weak) overlap would make it easier (or more difficult) to find alternative employment.

Sub-theme: Geographic Mobility:

Geographic mobility refers to the ability to move closer to alternative employment, which is contingent on the geographic proximity of job openings as well as on the worker's relocation possibilities.

- *Key Variable: Proximity of Employment Opportunities*

  This key variable refers to the ease of finding alternative job opportunities within a relatively close distance. Proximity to job openings, including those in other industries, would make re-employment easier for laid-off workers.

- *Key Variable: Human Capital*

  This key variable points to the worker's ability to access other labour markets. Acquired skills and education credentials would expand workers' relocation possibilities by making it easier to find desirable job opportunities across Canada.

A quantitative measure of worker vulnerability is essential for decision-makers.

Central Themes of MiHR's Occupational Vulnerability Index

- The adoption of new technology will impact workers across the mining cycle at different times, and to different degrees.
- Innovation will at times introduce new job responsibilities, and at other times it will modify or take over a task previously performed by a human.
- Innovation will increase demand for the labour of certain workers and decrease demand for that of others.
- Depending on the occupation, workers may find their jobs enhanced, re-designed, or completely automated by technology.
- For these reasons, it is important to ascertain which workers will face the biggest challenges, and which workers are most likely to be impacted first.
- A quantitative measure of workers' susceptibility to technological disruption would allow decision-makers to plan for the future and to channel resources towards workers who need it the most.

2.3.3 MiHR's Occupational Vulnerability Index (MOVI)

When coupled with data, the theoretical framework presents a comprehensive and quantifiable understanding of occupational vulnerability to technological disruption. MiHR has weighted and aggregated the data from these indicators to form one composite score—MOVI.

A composite indicator makes it possible to compare mining occupations by vulnerability, to examine which worker groupings are likely to be disrupted, and to point to segments of the labour pool that would most benefit from resources. A quantitative measure of worker vulnerability is essential for decision-makers to get ahead of the imminent disruption that the labour market is bound to experience.

2.3.3.1 Practical Considerations

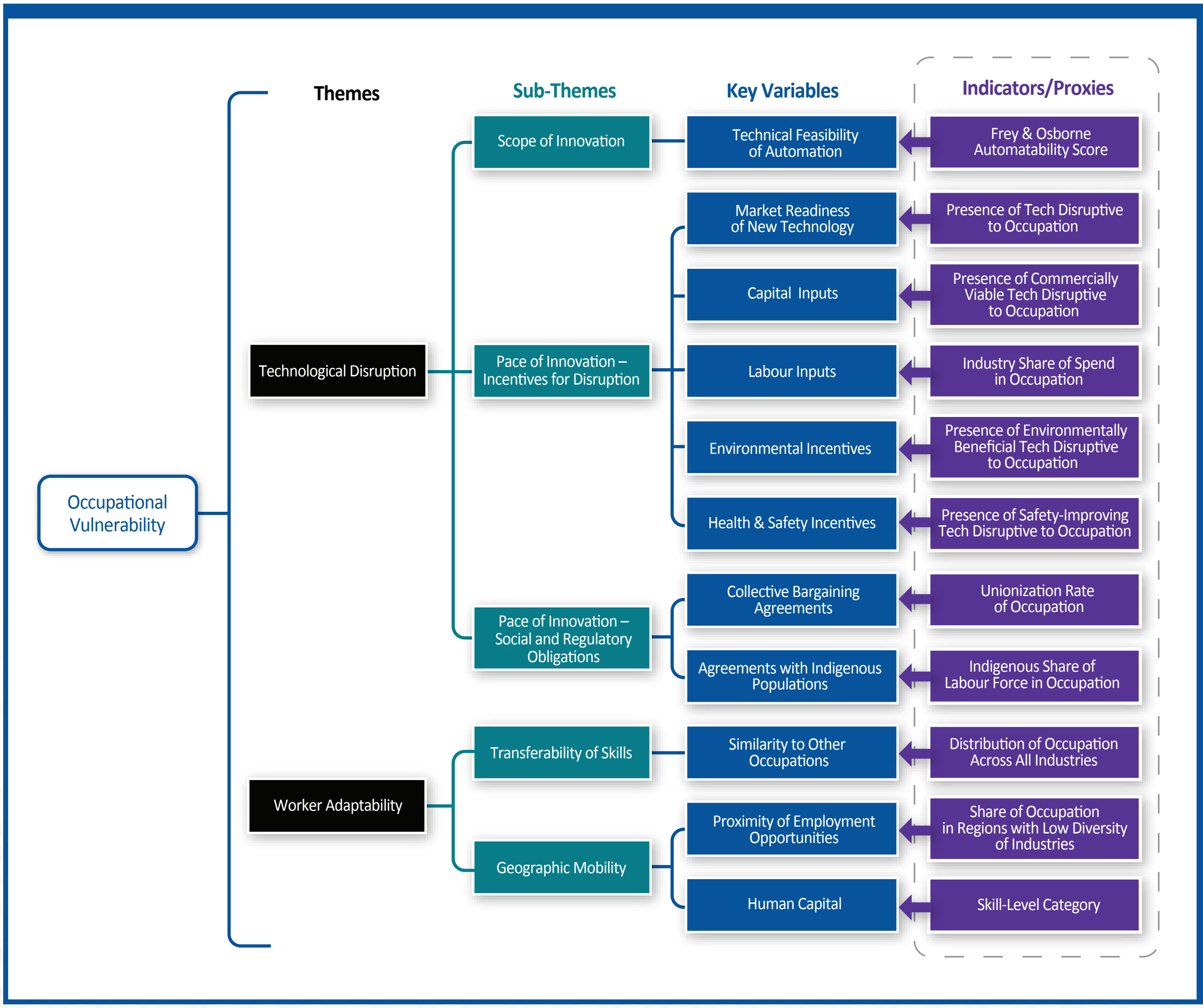
Precise estimates of the effect of new technology on labour demand are not feasible. The future of mining and the rollout of innovation are both highly contingent on exogenous factors such as commodity prices, the business cycle, and negotiations like Impact Benefit Agreements. Changes in the skillset required of workers as a result of innovations will very likely create occupations that do not yet exist and therefore projections of employment levels are impractical.

Consequently, the analysis does not offer an absolute measure of vulnerability, but rather a comparison between current occupations. Therefore, a MOVI score must be interpreted in relation to other occupations, to occupation groupings, or to the mining industry as a whole.

2.3.3.2 Data

MiHR has collected data in line with the theoretical framework in order to link each key variable to the best available indicator or proxy, thus providing a viable measure of the aspects of occupational vulnerability. The data listed below are organized according to Statistics Canada's NOC system for describing the labour market conditions of 120 mining occupations. A list of occupations and their corresponding NOC codes is provided in Appendix 2. Figure 2.2 shows how key variables are connected to indicators/proxies within the framework. A description of each individual indicator (and data source used) is also provided in Table 2.2.

FIGURE 2.2: MiHR's Occupational Vulnerability Index (MOVI)



Source: Mining Industry Human Resources Council, 2019

TABLE 2.2: Indicators/Proxies Used to Capture Key Variables

Key Variable	Indicators/proxies and data used to capture key variables
Technical Feasibility of Automation	**Frey & Osborne Automatability Scores** • These scores are obtained from a 2013 Oxford University study by Frey and Osborne. The authors estimate the probability that an occupation can be fully automated given cutting-edge technology, providing a score for 702 occupations. • MiHR uses these scores as a measure of technical feasibility of automation. An automatability score serves to approximate the maximum level of disruption that innovation could bring to a mining NOC. A higher score denotes higher potential for vulnerability.

Market Readiness of New Technology	**Presence of Technology Disruptive to Occupation**
	• MiHR assesses the availability of disruptive technologies through qualitative findings on innovation currently deployed in mining operations. New mining technologies are classified into three distinct categories:
	  • **Data Analytics:** The use of logistical data, often gathered through digital sensors, in order to optimize the processes of mining operations. This includes wireless connectivity, internet of things and smart sensors, artificial intelligence, real-time decision support, and preventive maintenance.
	  • **Machine Automation:** The intensified use of machinery along the mining value chain, performing tasks previously carried out by workers and displacing them from physically hazardous settings. This includes drones, line-of-sight control, remote control, and operational hardware automation.
	  • **Energy Alternatives:** The introduction of machines and processes utilizing energy sources other than fossil fuels, with the aim of reducing emissions and lowering costs. This includes electric vehicles, as well as renewable energy (wind, solar, bioenergy) in ongoing power needs such as ventilation, pumping, and water treatment.
	• The presence of new technologies on the ground can be taken as a sign of the accelerating pace of innovation in the industry. Therefore, we consider only those technologies presently for sale by manufacturers and in use by mining companies.
	• MiHR evaluates whether each of the three categories significantly disrupts the essential job duties of 120 mining occupations, granting a score of 1 if the occupation can be disrupted, and a score of 0 if not. This yields three binary indicators that gauge a NOC's exposure to currently disruptive technologies.

Capital Inputs	**Presence of Commercially Viable Technology Disruptive to Occupation** • The initial capital expense required to incorporate new technologies can provide another measure of an occupation's exposure to disruption. • If an occupation is only impacted by big-budget innovations, then there is a higher cost-benefit threshold for the occupation to be disrupted. • In the absence of detailed investment data, this makes the assumption that the commercial availability of new technology implies a clearing of the threshold.
Labour Inputs	**Industry Share of Spend in Occupation** • The 2016 Census provides data on the average wages of NOCs, as well as the employee headcount for each NOC in the mining industry. MiHR uses these figures to estimate how much the industry pays in wages to each occupation. • A higher amount means the occupation represents a higher share of operating expenses, suggesting that there is an economic incentive for firms to introduce labour-saving technologies, and making the occupation more vulnerable.
Environmental Incentives	**Presence of Environmentally Beneficial Technology Disruptive to Occupation** • As with the "Market Readiness" indicator, MiHR evaluates whether each of 120 mining occupations would be disrupted by environmentally friendly technologies, considering only technologies presently for sale by manufacturers and in use by mining companies. • A score of 1 is granted if the essential job duties of an occupation can be disrupted by technologies with environmental benefits, and a score of 0 if not. • The presence of environmentally beneficial technology provides an additional incentive for mining operations to accelerate the pace of innovation.

(CONTINUED...) TABLE 2.2: Indicators/Proxies Used to Capture Key Variables

Key Variable	Indicators/proxies and data used to capture key variables
Health & Safety Incentives	**Presence of Safety-Improving Technology Disruptive to Occupation** • As with the "Market Readiness" indicator, a panel of experts evaluates whether each of 120 mining NOCs would be disrupted by technologies that improve the health and safety of workers, considering only technologies that are presently for sale by manufacturers and in use by mining companies. • A score of 1 is granted if the essential job duties of a NOC can be disrupted by technologies with safety benefits, and a score of 0 if not. • The presence of technology beneficial to the health and safety of workers provides an additional incentive for mining operations to accelerate the pace of innovation.
Collective Bargaining Agreements	**Unionization Rate of Occupation** • The 2016 Census provides data on the unionization rate of major groups of occupations (at the 2-digit NOC level). • MiHR uses these numbers to approximate the percentage of each occupation that is represented by a labour union. A higher percentage denotes a higher likelihood that workers of a NOC are protected by collective bargaining agreements, signifying lower vulnerability.
Agreements with Indigenous Populations	**Indigenous Share of the Labour Force in Occupation** • The 2016 Census provides data on the number of workers of a particular occupation that identify as Indigenous. • The percentage of Indigenous workers employed in an occupation indicates the likelihood that firms must consider Impact Benefit Agreements (IBAs) with Indigenous organizations before restructuring the labour force. • A higher percentage denotes a higher likelihood that workers of an occupation are protected by an IBA, signifying lower vulnerability.
Similarity to Other Occupations	**Distribution of Occupation Across all Industries** • 2016 Census data are used to gauge how mining occupations are concentrated across 20 industry sectors in the Canadian economy. • Demand across industries points to a wider range of employment possibilities and competitiveness for workers of that occupation. • For each occupation, MiHR estimates the percentage of workers in each industry, then compares the distribution across industries. • A higher standard deviation statistic denotes unevenness in the distribution (higher vulnerability), while a lower number signifies a more equal representation across industries (lower vulnerability). • This report uses this as a proxy of transferability of skills across occupations. MiHR is developing a more definitive measure of occupational similarity for the mining industry, which once complete can be used in future iterations of this report.
Proximity of Employment Opportunities	**Share of Occupation in Non-Diversified Regions** • Using 2016 Census data, MiHR considers the distribution of 102 industry subsectors (by 3-digit NAICS code) in 154 Census Metropolitan Areas (CMAs) across Canada. This distribution provides a weighted measure of how industries are represented within each CMA, with a greater weight corresponding to lower industry diversification. • CMA weights are applied to the CMA's share of that occupation, then averaged to arrive at a comparative measure of occupational exposure to non-diversified CMAs. • An occupation is vulnerable to the extent that it has a large share of workers in CMAs that rely heavily on one or a few industries (in the event of industry collapse).

Human Capital	**Skill-Level Category**
	• Statistics Canada classifies occupations according to experience, education and training into the following skill-level categories:
	  • Skill Level A (Management): Management occupations usually requiring university education
	  • Skill Level A (Professionals): Professional occupations usually requiring university education
	  • Skill Level B: Occupations usually requiring college education or apprenticeship training
	  • Skill Level C: Occupations usually requiring secondary school and/or occupation-specific training
	  • Skill Level D: Occupations provided with on-the-job training
	• MiHR uses these categories as an indicator of labour mobility. An advanced skill level generally makes it easier for a worker to find desirable employment opportunities across different parts of Canada.

Source: Mining Industry Human Resources Council, 2019

2.3.3.3 Composite Score

As part of MiHR's analysis, the data are combined to produce a single unique score for each mining occupation, making it possible to quantify and compare the vulnerability of occupations in the labour market.

Advantages and Disadvantages of Composite Indicator

Merging all of this data into a one-dimensional indicator can have benefits as well as drawbacks. There is the risk that the composite design may be biased toward irrelevant factors leading to incorrect conclusions. Moreover, highlighting only a single indicator can make it prone to misinterpretations and overly simplistic conclusions. Therefore, caution should be exercised in the reading of the results.

On the other hand, a composite score that is carefully constructed can cut through the noise and facilitate straightforward insights. By summarizing a large amount of information into a more digestible format, a composite score can diagnose problems and highlight what is truly important to support better decision-making.

Weighting and Aggregation

To ensure the quality and integrity of results, the construction of MOVI followed best practices outlined in the OECD *Handbook on Constructing Composite Indicators* (2008). MiHR considered several established methodologies (Budget Allocation Process, Principal Components Analysis, Supervised Machine Learning) as options for the aggregation process. In this iteration of the MOVI, the composite is formulated using a *Budget Allocation Process (BAP)*.

A technical explanation of the weighting and aggregation methodology is detailed in Appendix 1.

By summarizing a large amount of information into a more digestible format, a composite score can diagnose problems and highlight what is truly important to support better decision-making.

2.3.4 Findings

Using the described framework, MiHR has generated MOVI scores for 120 mining occupations. This section presents an analysis of the findings from this output including:

1. Descriptive statistics on the MOVI across occupations
2. Comparisons between categories of occupations
3. An in-depth look at individual occupations of interest

2.3.4.1 Descriptive Statistics Across Occupations

A summary of MOVI results for 120 occupations is provided in Table 2.3 and visualized in Figures 2.3 and 2.4. Key highlights are as follows:

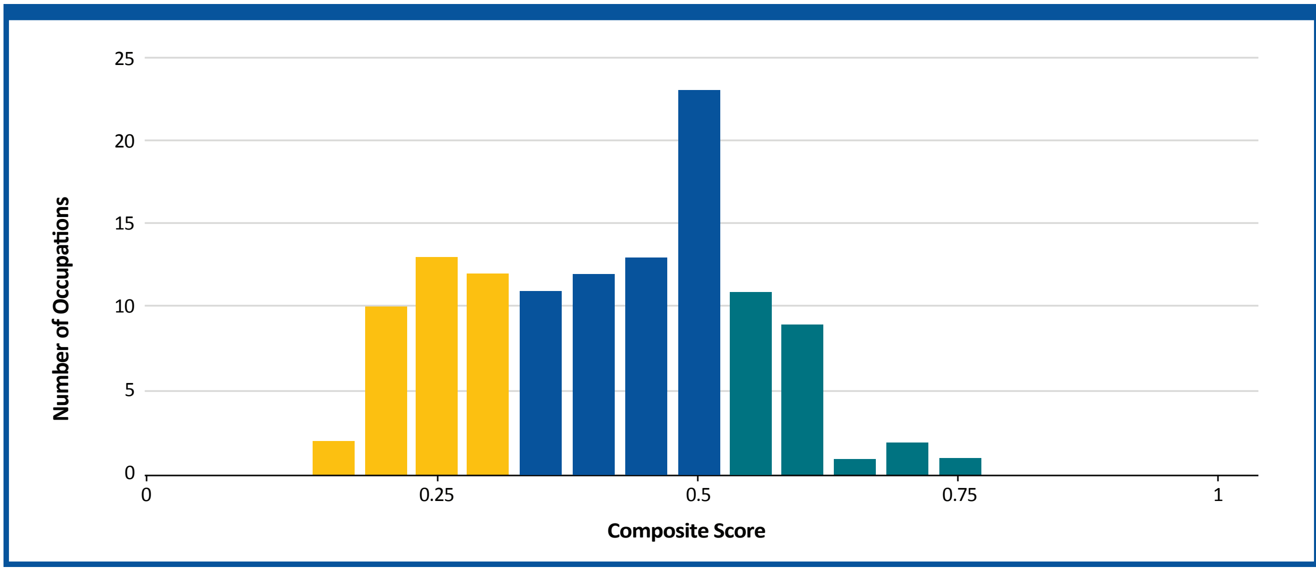
- The MOVI scores are fairly evenly distributed, with an average score of 0.44, and with 50% of scores lying between 0.32 and 0.54.
- Occupations in the top 25% have scores above 0.54 and can be considered relatively high in vulnerability.
- The distribution of all workers in the mining industry is somewhat skewed toward higher MOVI scores (Figure 2.4), underlining the fact that the greater part of the workforce is employed in occupations with higher vulnerability.
- While the typical mining occupation has a MOVI of 0.44, the typical worker has a MOVI of 0.57.

TABLE 2.3: Summary of MOVI Scores

Statistic	Value
Observations	120
Mean	0.44
Median	0.45
IQR	0.32 - 0.54
Max	0.75
Min	0.18
Average Mining Industry Score, Weighted by Headcount	0.57

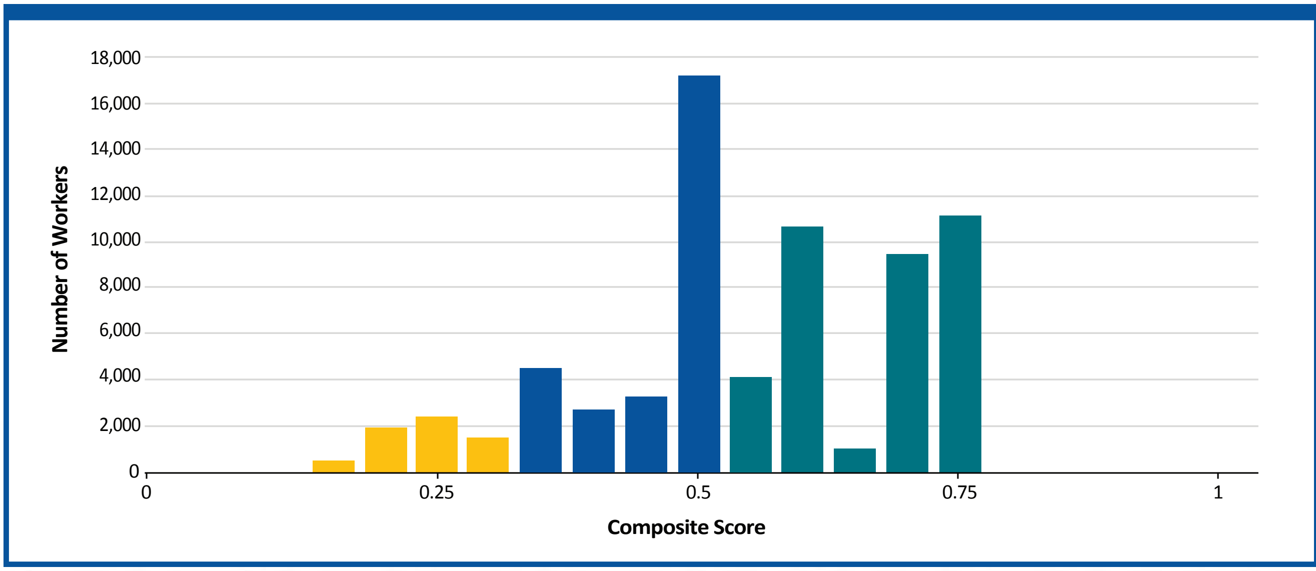
Source: Mining Industry Human Resources Council, 2019

FIGURE 2.3: Distribution of MOVI Across 120 Mining-Relevant Occupations



Source: Mining Industry Human Resources Council, 2019

FIGURE 2.4: Distribution of MOVI Across the Mining Labour Force



Source: Mining Industry Human Resources Council, 2019

Notable Studies That Informed MiHR's Analysis

The analysis in this report builds on a foundation of key studies on the impact of innovation on the labour market:

- **Frey, C. B. & Osborne, M. A. (2013).** ***The Future of Employment: How Susceptible Are Jobs to Computerisation.*** **Oxford Martin Programme on Technology and Employment.**

  The authors use machine learning methods to estimate the likelihood that a given occupation can be replaced by current technology. The paper concludes that 47% of total U.S. employment is at high risk of automation. Since publication, the paper has been among the most widely cited literature on the future of automation and employment. The output from this model, when mapped to mining industry data, can approximate the automation potential of mining-related occupations.

- **Manyika, J., Chui, M., Miremadi, M., George, K. and Willmott, P. (2017).** ***A Future That Works: Automation, Employment, and Productivity.*** **McKinsey Global Institute (MGI).**

  This research paper from MGI expands on the Frey and Osborne paper, focusing on the distinct tasks and activities performed by workers, rather than on occupations as a whole. MGI disaggregates occupations into 2,000+ constituent activities and calculates the probability of automation for each activity. Furthermore, MGI develops a more complete model for forecasting automation by including additional factors such as economic benefits, labour market dynamics, and regulatory and social factors.

- **Lamb, C. (2016).** ***The Talented Mr. Robot: The impact of automation on Canada's workforce.*** **Brookfield Institute for Innovation + Entrepreneurship (BI +E).**

  This study links Frey and Osborne's automatability scores and MGI's automation potential scores to Canadian data. The authors develop a crosswalk (i.e. a mapping) methodology to connect American Standard Occupational Classification (SOC) codes to Canadian NOC codes. MiHR has incorporated this translation of Frey and Osborne scores for 120 mining-related occupations.

- **World Economic Forum and Boston Consulting Group (2018).** ***Towards a Reskilling Revolution: A Future of Jobs for All.***

  This paper establishes a methodology for understanding skills transferability across occupations. WEF uses occupational task data from Occupational Information Network (O*Net) and job posting data from Burning Glass Technologies to generate a matrix of similarity scores for all occupations in the U.S. economy. This information is used to highlight realistic career transition paths for all workers in the economy. A measure of skills transferability is useful in assessing the versatility and career mobility of workers, and their susceptibility to unemployment.

- **EY (2019).** ***The Future of Work: The Changing Skills Landscape for Miners.*** **A report for the Minerals Council of Australia.**

  This paper uses Australian employment data, O*Net survey data, and automatability scores from the Frey and Osborne study (2013) to examine how a set of 52 work skills is distributed among the Australian labour force. The authors predict which skills are most likely to be in demand and which will be obsolete by 2030. Such a forecast of the skills landscape in the industry can be used to anticipate and prepare for changes in the labour market.

2.3.4.2 Analysis by Occupation

Figure 2.5 shows MOVI scores across 120 occupations and the corresponding headcounts. Occupations near the top right of the graph have high vulnerability and employ a large number of workers, making these workers ideal targets for any labour market strategies.

- The top five most vulnerable occupations are all *Production Occupations*, with the most vulnerable being *Underground Production and Development Miners* (Table 2.3).
- The majority of occupations have a relatively low headcount as shown in Figure 2.5.
- All of the occupations with a low MOVI score (lower than 0.32) also have a comparatively small headcount.

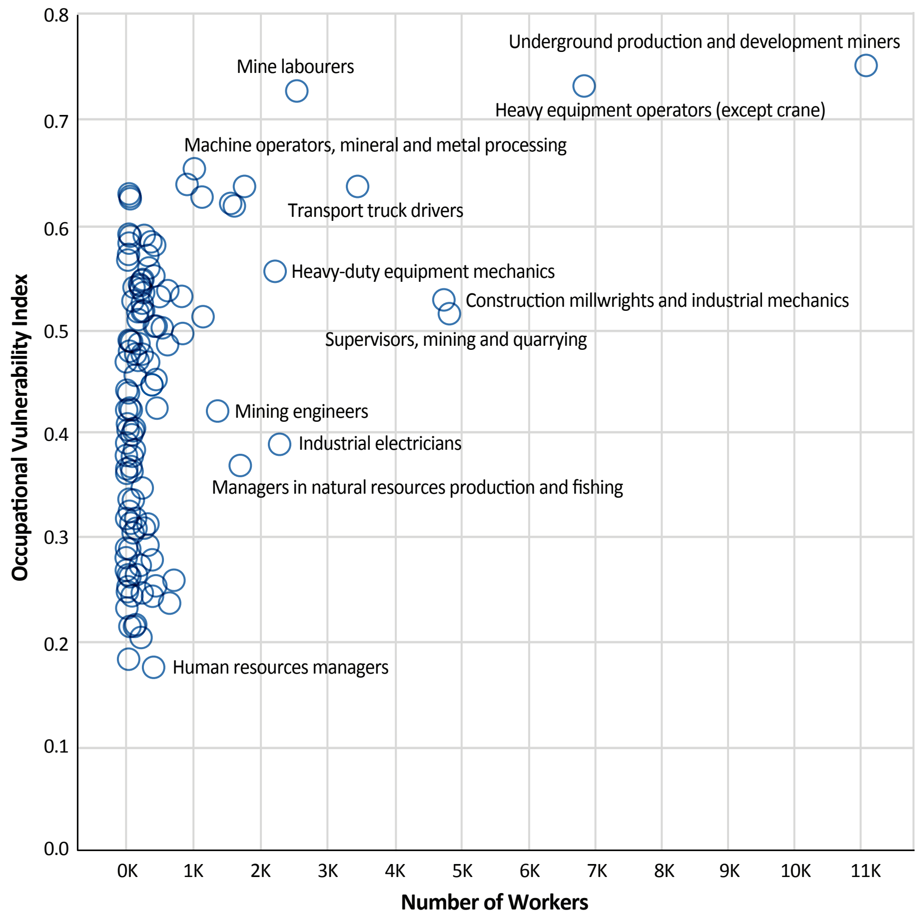
2.3.4.3 Analysis by Category

Skill Level Category

Figure 2.6 shows MOVI scores for skill level categories and the corresponding headcounts.

- Skill Levels C and D both have high vulnerability and are relatively close in score, possibly signifying that not having vocational training or post-secondary education significantly contributes to occupational vulnerability.[39]
- Skill Level B also appears to have a relatively high MOVI, though this result is skewed by the fact that Underground Production and Development Miners (the occupation with the highest MOVI and headcount) is classified under Skill Level B.[40]
- In general, it is evident that having a higher level of education and job experience substantially lowers occupational vulnerability.

FIGURE 2.5: MOVI and Headcount of 120 Mining-Relevant Occupations



Source: Mining Industry Human Resources Council, 2019

39 Skill Level C occupations usually require secondary school and/or occupation-specific training. Skill Level D occupations are usually provided with on-the-job training. See Statistics Canada's classification structure for the NOC skill levels at: https://www.statcan.gc.ca/eng/subjects/standard/noc/2016/introduction#a6.1

40 Skill Level B occupations usually require college education or apprenticeship training.

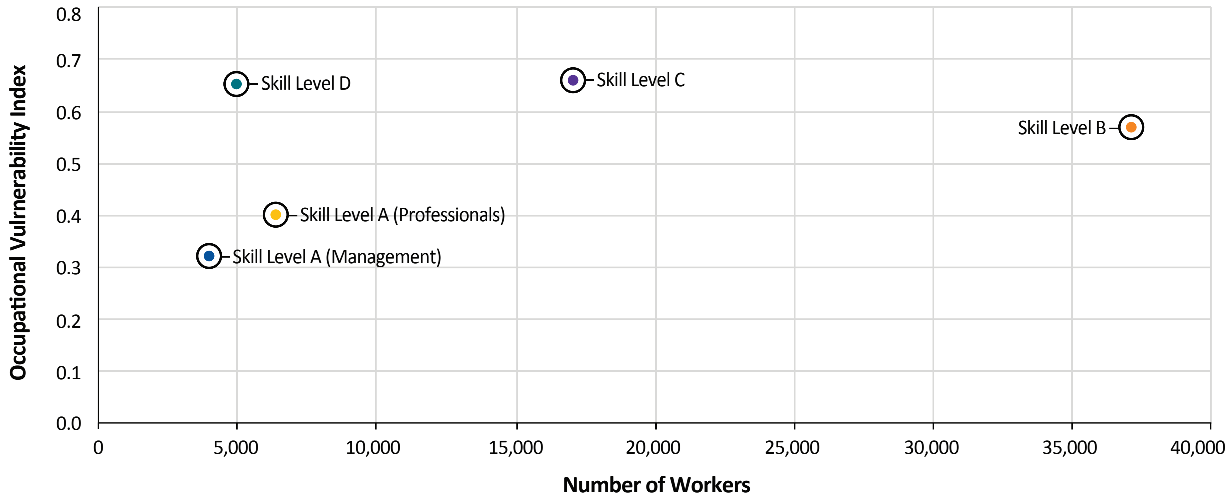
TABLE 2.4: Highest and Lowest MOVI Scores

Top 5	Workers	Share	MOVI	Category
Underground production and development miners	11,035	15.83%	0.75	Production Occupations
Heavy equipment operators (except crane)	6,830	9.79%	0.73	Production Occupations
Mine labourers	2,550	3.66%	0.73	Production Occupations
Machine operators, mineral and metal processing	1,020	1.46%	0.65	Production Occupations
Construction trades helpers and labourers	895	1.28%	0.64	Production Occupations

Bottom 5	Workers	Share	MOVI	Category
Human resource managers	400	0.57%	0.18	Human Resources and Financial Occupations
Social and community service workers	35	0.05%	0.18	Support Workers
Financial managers	220	0.32%	0.20	Human Resources and Financial Occupations
Engineering managers	125	0.18%	0.21	Supervisors, Coordinators, and Forepersons
Industrial engineering and manufacturing technologists and technicians	55	0.08%	0.21	Technical Occupations

Source: Mining Industry Human Resources Council, 2019

FIGURE 2.6: MOVI and Headcount by Skill Level Category



Skill Level Category	MOVI	Number of Workers
• Skill Level A (Management)	0.32	4,075
• Skill Level A (Professionals)	0.40	6,380
• Skill Level B	0.57	37,145
• Skill Level C	0.66	17,115
• Skill Level D	0.65	5,015

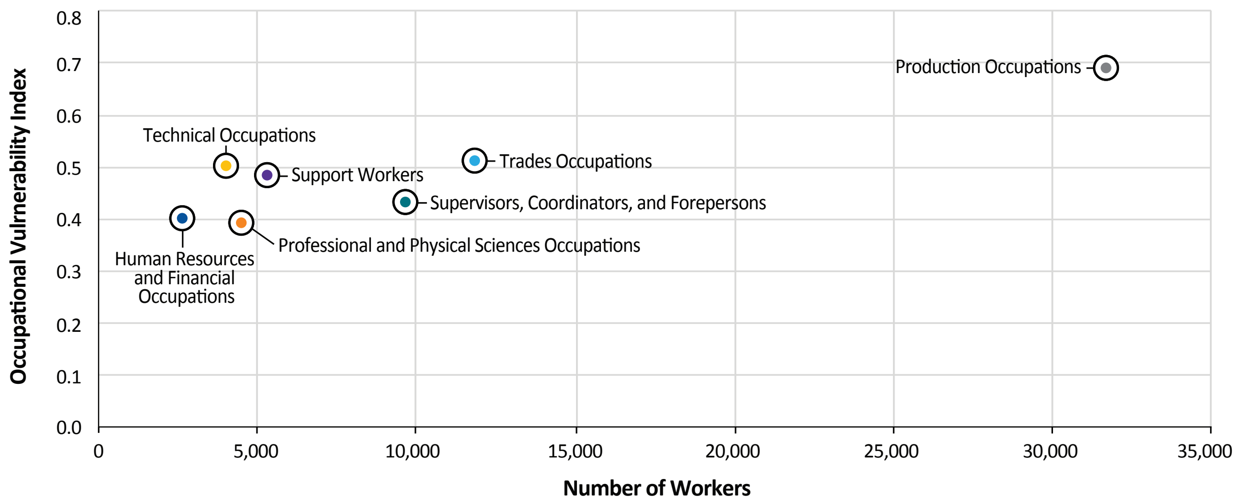
Source: Mining Industry Human Resources Council, 2019

Broad Occupational Category

Figure 2.7 shows MOVI scores for broad occupational categories and the corresponding headcounts.

- *Production Occupations* are by far the most populous occupational category and the most vulnerable to disruption.
- White collar, STEM (Science, Technology, Engineering and Math) and supervisory positions appear to be the least vulnerable.

FIGURE 2.7: MOVI and Headcount by Broad Occupational Category



Broad Occupational Category	MOVI	Number of Workers
• Professional and Physical Sciences Occupations	0.39	4,545
• Human Resources and Financial Occupations	0.40	2,675
• Supervisors, Coordinators, and Superintendent	0.43	9,635
• Support Workers	0.48	5,335
• Technical Occupations	0.50	4,035
• Trades Occupations	0.51	11,870
• Production Occupations	0.69	31,635

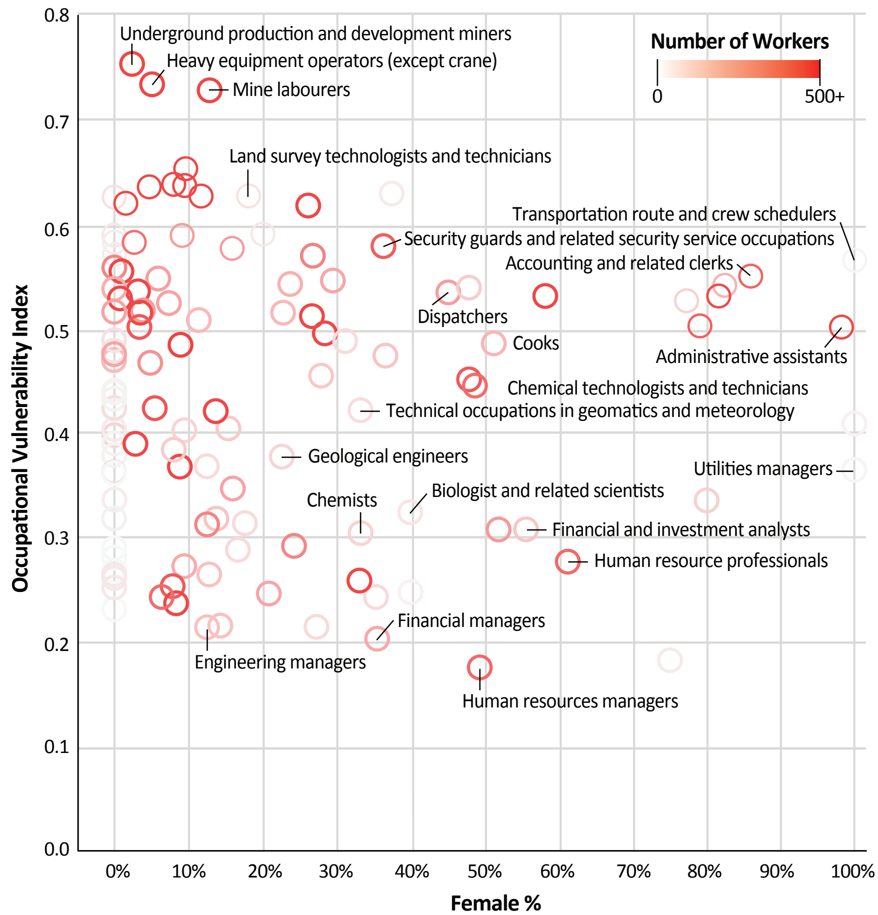
Source: Mining Industry Human Resources Council, 2019

Demographics

Figures 2.8 and 2.9 highlight MOVI scores for certain demographic and diversity profiles, along with the corresponding representation of the workforce. These figures also indicate the relative sample size to highlight data-integrity for each observation.

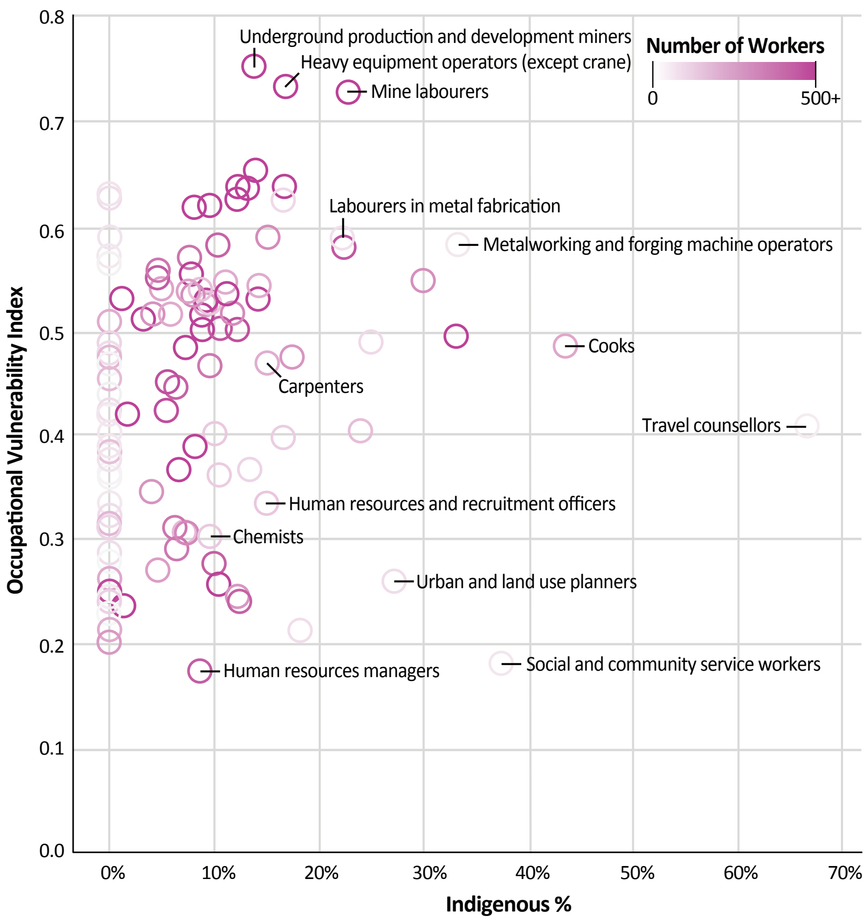
- Figure 2.8 shows several cases wherein the occupation has a large percentage of women and a relatively high MOVI, namely in administrative-type positions as shown at the right-hand side of the graph.
- Conversely, the lower bottom represents the greatest opportunities for women to expand their representation within the mining sector. These are occupations with both a low MOVI and a low percentage of women, such as professional, engineering and management positions.
- Overall, women's share of the workforce does not strongly correlate with occupational vulnerability.
- Figure 2.9 also highlights occupations wherein Indigenous workers are especially vulnerable (i.e. they have a large representation and a high MOVI). Notable occupations include several production occupations (*Underground Miners, Heavy Equipment Operators* and *Mine Labourers*) as shown moving to the upper-right in the graph.
- Although a higher share of Indigenous workers should, in theory, slow down the pace of disruption for an occupation, Figure 2.9 shows that there are a number of occupations with both a high percentage of Indigenous workers and a high MOVI score. This could be evidence of high exposure to disruption from all other key indicators, which should be concerning for these occupations.

FIGURE 2.8: MOVI vs. Female Share of Occupation



Source: Mining Industry Human Resources Council, 2019

FIGURE 2.9: MOVI vs. Indigenous Share of Occupation



Source: Mining Industry Human Resources Council, 2019

2.3.4.4 In-Depth Look at Selected Occupations

Though informative, the MOVI score alone could be misleading if taken out of context. For example, two occupations could have the same vulnerability score, but for fundamentally different reasons. It is therefore important when analyzing individual occupations to scrutinize the MOVI score and also to look at its constituent components.

To provide a comprehensive representation of occupational vulnerability, this report utilizes spider (or radar) charts to examine different occupations in a standardized format. These charts display the multiple aspects of occupational vulnerability in a two-dimensional picture to highlight those factors that most drive vulnerability.

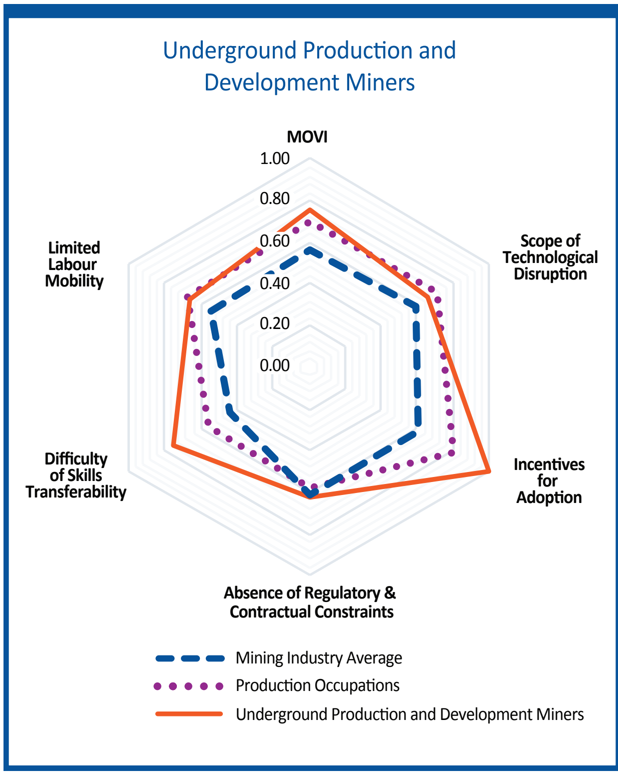
The spider charts depicted in this section of the report explore the vulnerability of four mining occupations of interest: (1) *Underground Production and Development Miners,* (2) *Industrial Engineering and Manufacturing Technologists and Technicians,* (3) *Heavy-duty Equipment Mechanics,* and (4) *Industrial Electricians.* Graphs for nine other occupations of interest can also be found in Appendix 3.

The spider chart axes display, in clockwise order, the MOVI score and the five sub-themes of vulnerability outlined in the theoretical framework (Figure 2.2):

- Scope of Innovation
- Pace of Innovation—Incentives for Disruption
- Pace of Innovation—Social and Regulatory Obligations
- Transferability of Skills
- Geographic Mobility

Because indicator scores must be interpreted in relation to those of other occupations, scores for the mining industry average and for the relevant occupational category are included for ease of comparison.

FIGURE 2.10: Aspects of Vulnerability for Underground Production and Development Miners

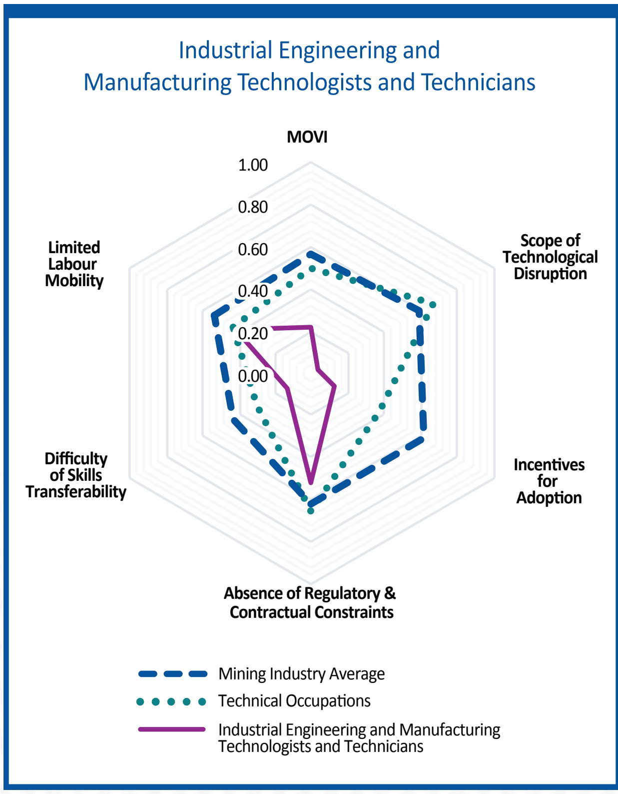


Source: Mining Industry Human Resources Council, 2019

Each sub-theme is an aggregate of its key variables and has been normalized to range from 0 to 1. The closer a point is to the edges, the higher the value, pointing to greater occupational vulnerability. A larger area denotes higher exposure to disruption.

- Figure 2.10 shows what the picture looks like for the occupation with the highest MOVI, *Underground Production and Development Miners*. This occupation has a wider area than both the mining industry average and the *Production Occupations* average in almost all aspects. Notably, there are very high incentives for bringing in technologies disruptive to this occupation, and workers in this occupation are likely to have a higher than average difficulty in transferring their skillset.
- Figure 2.11 shows a drastically different picture. The MOVI score for *Industrial Engineering and Manufacturing Technologists and Technicians* is one of the lowest, and it only appears to be somewhat vulnerable in its regulatory and contractual protections, and in its labour mobility. Still, it has below-average exposure in both of these aspects.
- Figure 2.12 shows that *Heavy-duty Equipment Mechanics* appears to be an occupation with a vulnerability that is average in almost every respect, except for a higher-than-average potential for automation.
- Figure 2.13 shows that *Industrial Electricians* are subject to high incentives for introducing disruptive technologies, however they remain low in vulnerability because their potential for automation is very limited.

FIGURE 2.11: Aspects of Vulnerability for Industrial Engineering and Manufacturing Technologists and Technicians



Source: Mining Industry Human Resources Council, 2019

FIGURE 2.12: Aspects of Vulnerability for Heavy-duty Equipment Mechanics

Source: Mining Industry Human Resources Council, 2019

FIGURE 2.13: Aspects of Vulnerability for Industrial Electricians

Source: Mining Industry Human Resources Council, 2019

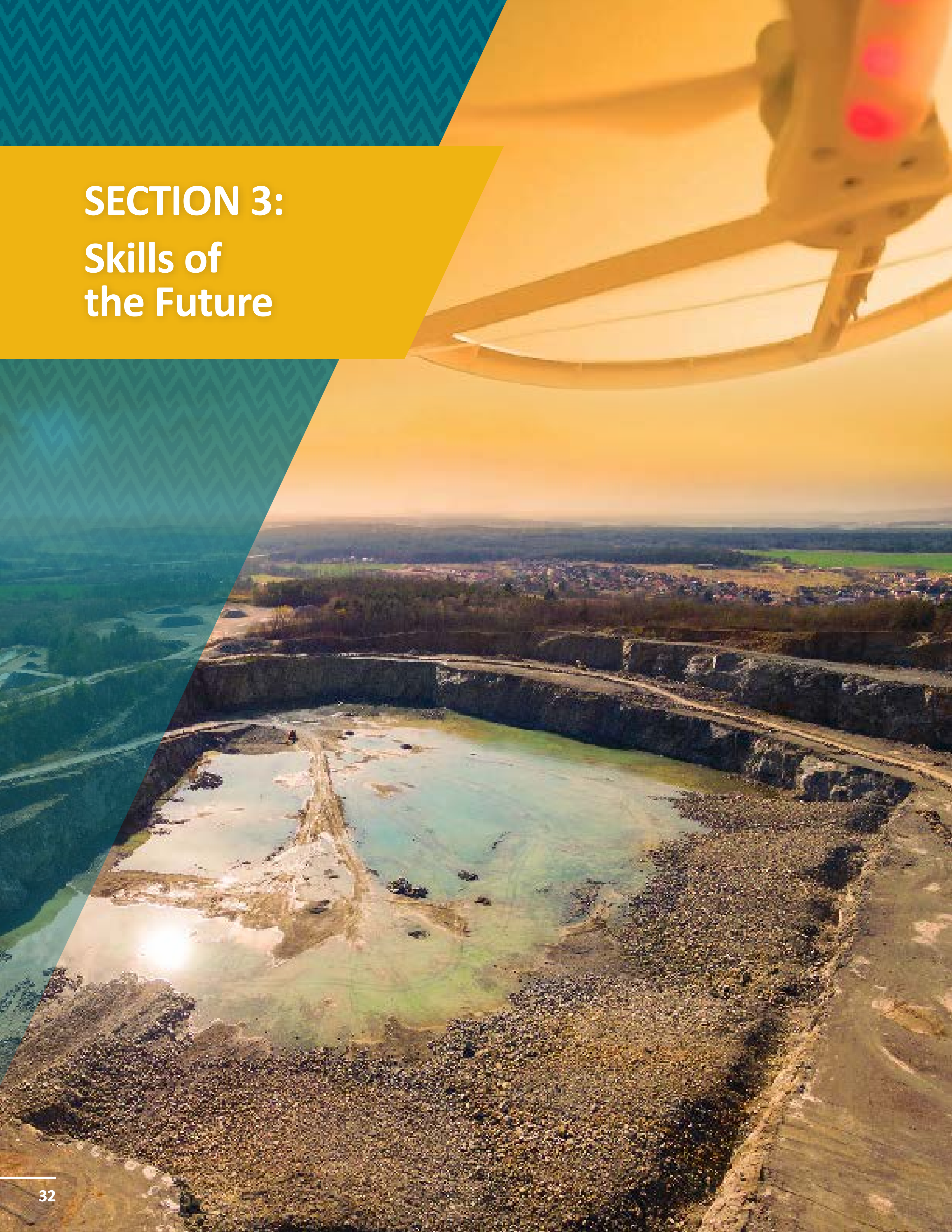
2.3.5 Conclusions

A quantitative measure of the mining labour force's susceptibility to technological disruption is invaluable for decision-makers to design intelligent strategies and avoid being caught off-guard by the incoming wave of innovation.

This section of the report introduced MOVI, a composite index that allows us to identify segments of the labour pool that would most benefit from resources. MOVI is built on a comprehensive framework that enables an examination of the individual factors that most affect these workers.

At first glance, findings make it evident that workers in *Production Occupations*, in particular, are highly exposed to technological disruption for multiple reasons. Many of their job duties are highly automatable, and furthermore their work experience and education levels may limit their ability to adapt to displacement.

SECTION 3:
Skills of the Future



INTRODUCTION

This section explores the changing skills requirements of the mining labour force as a result of digital innovations and new technologies. As background to the qualitative and quantitative studies, this section provides highlights from the literature review and three case studies featuring the digital innovations and related training programs at Agnico LaRonde, Anaconda and NORCAT.

3.1 BACKGROUND

As noted in Section 2, the adoption of new technologies can result in a shift in demand for workers. Occupations across industries are evolving in different ways in response to the increased uptake of new technologies and the skills required to use them effectively. Every occupation will be affected to some extent, some significantly more so than others, because occupations are defined by their tasks and activities, and each activity may have a different technical potential for automation.[41] The performance of a particular task or activity requires a specific skill or set of skills. Hence a key challenge for mining stakeholders is to determine the skills requirements of the future workforce, when occupations continue to be re-constituted or enhanced because of increased use of digital technologies.

Research suggests that routine, repetitious and physical activities are more susceptible to automation, and that this susceptibility is not directly related to whether the work is performed by a low-skilled or middle-skilled worker.[42, 43] A WTO study revealed that technological change had a negative effect on the employment of middle-skilled workers performing routine tasks which are easily automated, but had little direct effect on the employment of low-skilled workers performing non-routine manual tasks which are not easily automated nor require complementary skills in information and communications technology.[44]

Occupations that are considered to have a low risk of automation have a substantial number of activities that require abstract, complex decision-making skills, with a strong focus on creativity, critical thinking and interpersonal social skills.[45] Digital technologies will increase the demand for skilled workers in “abstract occupations” that entail these very skills.[46, 47, 48] Digital technologies will create new roles and hybrids from others, requiring workers with cross-functional skills to perform a greater variety of tasks.[49]

In Australia, where white-collar workers now represent the largest share of that country’s minerals workforce, the development of core/technical skills, coupled with cognitive or soft skills and interpersonal skills, are considered essential to building the mining workforce of the future.[50] A recent study for the Minerals Council of Australia identified the nine skills with the greatest growth in demand:[51]

- Systems Evaluation
- Systems Analysis
- Mathematics
- Data Analysis
- Data and Digital Literacy
- Writing
- Judgment and Decision Making
- Active Listening
- Active Learning

41 *A Future that Works*, McKinsey Global Institute (2017). The researchers developed a framework of 18 capabilities, estimated the level of performance required to successfully perform each work activity, and assessed the performance of existing technologies today against the same criteria.
42 S. Holcombe and D. Kemp, “Indigenous Employment Futures in an Automated Mining Industry: An Issues Paper and A Case for Research,” Centre for Social Responsibility in Mining, Sustainable Minerals Institute, The University of Queensland (2018): Brisbane. Retrieved from https://smi.uq.edu.au/files/26280/CSRM_IndigenousEmploymentFuturesInAnAutomatedMiningIndustry_Dec2018.pdf.pdf
43 Jobs involving physical activities were found to be more susceptible to automation when performed in predictable environments (81%) versus unpredictable settings (26%). See, *A Future that Works*. McKinsey Global Institute (2017).
44 World Trade Organization (2017).
45 M. Oschinski & R. Wyonch (March 2017), *Future Shock? The Impact of Automation on Canada’s Labour Market.* Commentary No. 472., C. D. Howe Institute.
46 European Parliamentary Research Service (2016).
47 World Economic Forum (2017).
48 World Trade Organization (2017).
49 Bellehumeur (2018).
50 Minerals Council of Australia (2018), Industry Education Summit, Melbourne, 17 May 2018.
51 For each skill (17 in total), EY identified the skills composition, skill type category, field of education, level of education, and the likely future demand (%) for the skill. EY also assessed the likely impact of technology on occupations, and categorized them into three occupation types (automated, redesigned, and enhanced). See EY (2019), *The Future of Work: The Changing Skills Landscape for Miners,* A Report for the Minerals Council of Australia. Retrieved from https://minerals.org.au/sites/default/files/190214%20The%20Future%20of%20Work%20the%20Changing%20Skills%20Landscape%20for%20Miners.pdf

3.2 CHANGING SKILLS REQUIREMENTS: QUALITATIVE FINDINGS

The stakeholders that participated in MiHR's qualitative study concurred that digital technologies are transforming the nature of mining work. The skills requirements of mining occupations are changing. There will be an increased need for "technologically savvy, data-driven individuals who can interpret and analyze data," and for "technical miners comfortable using software and computer systems, who can easily download and upload information."

The respondents also affirmed the need for "well-rounded" individuals who can think strategically, are adaptable lifelong learners, have leadership skills, work collaboratively on teams, think creatively, and have communication skills (Figure 3.1). The changing nature of mining will require workers to continuously gain new skills and knowledge. The industry will need "curious people, wanting to learn," who can quickly adapt to new technologies, and have a core understanding of the mining business and how to apply both their technical and analytical skills as needed. As an example, a manager using their skills in data analytics could gain a more global understanding of the operations.

The increased demand for higher skills and knowledge will raise the threshold for basic education and training. "Higher education and continuous training will become the norm" as workers will continue to expand their knowledge and expertise into other areas of mining.

3.2.1 Case Studies

In early 2019, MiHR visited two Canadian mine sites and one training facility – Agnico Eagle (LaRonde Zone 5), Anaconda, and NORCAT – to learn more about their digital innovations and related training programs. These three firms have very different corporate histories and experience in using digital technologies yet recognize the need for integrated human and technological capacity as the pathway to a sustainable mining future. Highlights include:

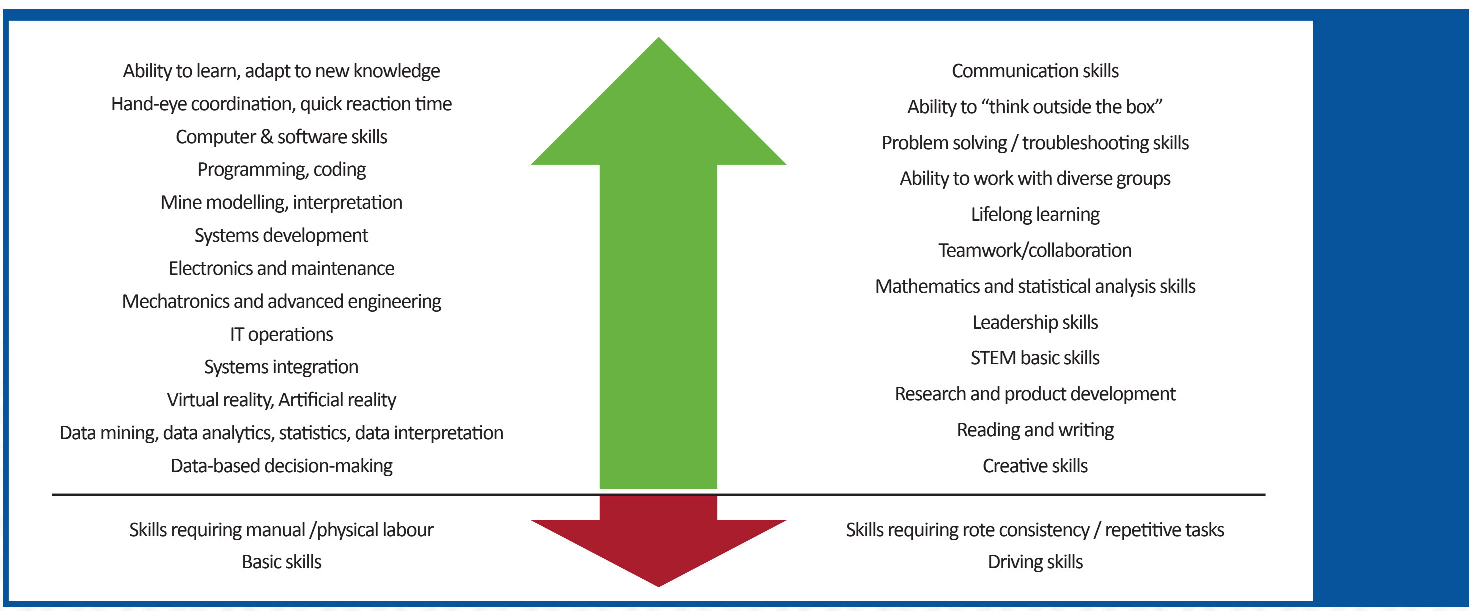
- Agnico Eagle's piloting of autonomous vehicles underground and related training for control room operators.
- Anaconda's implementation of Sustainable Mining by Drilling and development of the Anaconda University training platform.
- NORCAT's simulation training centre.

Case Study 1: Agnico Eagle – LaRonde Zone 5

Company Overview

Agnico Eagle is a senior Canadian gold mining company that has produced precious metals since 1957. Its mines are in Canada, Finland and Mexico, with exploration activities in each of these countries as well as in the United States and Sweden. The LaRonde Zone 5 (LZ5) mine is part of the LaRonde mining complex in the Abitibi-Témiscamingue region of Quebec. Previous owners operated the property as an open-pit gold mine.

FIGURE 3.1: Future Skills Demand in Mining, Summary of Participants' Responses



Source: Mining Industry Human Resources Council, 2019

Agnico Eagle extended the mine underground and it is presently being mined through underground ramp access. Under the current mine plan, 350,000 ounces of gold are expected to be mined until 2026.

Agnico Eagle was the first mining company in Canada to implement cellular technology underground that successfully integrates both voice and digital communications in the same network. The system has been in use at both LaRonde and LZ5 since 2017.

Sandvik's TH551i truck *Photo courtesy of Sandvik, 2019*

Autonomous Vehicles

> *"Autonomous trucks will complement the work being done by our employees, stabilizing production as we access deeper ore zones."*
>
> *— Keith Harris-Lowe, VP People, Agnico Eagle Mines*

Agnico Eagle is using the LaRonde Zone 5 mine as a test facility for new technologies. LZ5 is the first mine in the world to use autonomous vehicles on a production scale in an underground mining environment. The mine's automated scoop (LH517), truck (TH551i) and operator control room are part of Sandvik's AutoMine® technology system and are designed to integrate with the 4G LTE communication network on site. This autonomous system allows for auto-assisted loading in the open topping application and dumping to the dump truck, which autonomously hauls up the ramp to the surface.[52]

Previous studies on the introduction of autonomous vehicles have shown increased productivity, worker safety, and operation efficiency. Implementation of autonomous equipment in its mining operations could enable Agnico Eagle to access and add challenging, deeper mineralized zones to its production profile.

On-site testing of the system is in the preliminary phase. The autonomous equipment is used only during the shift change (when workers are not operating equipment underground) to increase productive time. Agnico Eagle is collecting real-time data to help them better understand if, and how, implementing this technology will impact the sustainability and life of the mine. Modifications are on-going to improve the system's efficiency and effectiveness.

52 Mining.com (June 20, 2018), "Sandvik books first-ever AutoMine order to run on an underground LTE network." Retrieved from: https://www.rocktechnology.sandvik/en/news-and-media/news-archive/2018/06/sandvik-books-first-ever-automine-order-to-run-on-an-underground-lte-network/

A scoop in operation, underground at Agnico Eagle's La Ronde Zone 5 mine

Training: Control Room Operators

The autonomous system at LZ5 is designed to increase production in underground situations where workers cannot operate, necessitating a new occupation: control-room operators who work above-ground to ensure that the increased productivity is not compromised by technical problems. These operators are required to monitor how effectively and efficiently the autonomous truck and scoop are working and ensure that each follows the planned route. If necessary, operators can take control of either piece of equipment remotely to fix any operating problems and re-program to correct any routing errors. Computer programming and increasing emphasis on technical skills are a large component of this new occupation.

At the time of MiHR's visit, LZ5 had only one control-room operator, but was planning to recruit five more internally. External Sandvik trainers were instructing the operator trainee, step-by-step, on the control (and re-programming) of the autonomous equipment. The goal is for the operator to gain the skills required to train other LZ5 employees coming onboard the automation team. The human resources and operational teams are developing a competency-based assessment tool to test the technical skills and aptitudes of candidates for this new role.

Operation center for autonomous equipment at La Ronde Zone 5

Anaconda's Pine Cove project, Baie Verte, Newfoundland

Photo courtesy of Anaconda Mining

Case Study 2: Anaconda Mining

Company Overview

Anaconda is a TSX-listed mining, exploration and development company with a focus on gold deposits in Newfoundland and Nova Scotia. The company operates the Point Rousse project in Baie Verte, Newfoundland, which consists of the Pine Cove open-pit mine, the fully permitted Pine Cove Mill and tailings facility, the Stog'er Tight and Argyle deposits, and approximately 11,181 hectares of prospective gold-bearing property.[53]

Anaconda is also developing the recently acquired Goldboro Project in Nova Scotia, a high-grade mineral resource with the potential to leverage existing infrastructure at the company's Point Rousse Project.

Sustainable Mining by Drilling (SMD)

A top-three finalist in the 2019 Disrupt Mining Innovation Challenge, Anaconda's Sustainable Mining by Drilling (SMD) project was developed in partnership with researchers from Memorial University of Newfoundland (MUN) and support from the College of the North Atlantic (CAN). The SMD project represents an important break-through for the company. When fully developed, the technology can unlock the value of potentially thousands of ounces of gold currently stranded in narrow veins. Such deposits were thought to be uneconomic to mine using traditional underground or surface mining methods. The developed SMD technology has the potential to be commercialized and introduced into the mining marketplace for purchase or lease by other mining companies and contractors.

Site-level workers provided input to the development of the SMD project, to ensure that the technology met Anaconda's operational needs. The technology uses a two-pass drilling system that allows the ore to be delineated, measured, developed and extracted

53 Anaconda Mining, "Anaconda Mining Reports First Quarter 2019 Results," Press Release (May 2, 2019). Retrieved at https://www.anacondamining.com/2019-05-02-Anaconda-Mining-Reports-First-Quarter-2019-Results-Generates-4-1-Million-of-Cash-Flow-from-Operating-Activities

The team at Memorial University showcasing some of the drilling components for the SMD technology

simultaneously. In the first pass, a pilot hole is drilled halfway between the hanging wall and the footwall using directional drilling technology steered by sub-surface imaging. In the second pass, hole-opening technology is used, which follows the original pilot hole and opens up the vein all the way from the hanging wall to the footwall.[54]

Economic and Environmental Benefits

Anaconda's SMD technology offers economic, safety, and environmental benefits including:

- Access to areas that are closed to conventional mining technologies.
- Reduced ore extraction costs by 50% over conventional underground narrow mining techniques.
- Placing the operator in a safe location on the surface.
- Enabling a smaller environmental footprint that can easily be reclaimed.[55]

Anaconda is developing and/or utilizing other innovations to help optimize their operations, including:

- Blast movement monitoring to reduce dilution and increase ore recovery in narrow gold-bearing quartz veins.
- Facilitated an arrangement to supply 3.5 million tonnes of waste rock aggregate to a construction project on the eastern seaboard of the United States.
- A partnership with CNA (College of The North Atlantic) & Memorial University (Grenfell Campus) to explore the feasibility of repurposing Anaconda's fine-grained processed material for agricultural use.

Training Platform: Anaconda University

Anaconda University is an innovative corporate training platform designed to support innovation and the development of new ideas, motivate the workforce, and attract and retain high quality talent.

Anaconda retained the services of Training Works[56] to help align the training platform with the needs of learners and any changes in the operational environment. Training Works conducted a comprehensive needs assessment of all Anaconda employees, which yielded useful information about employees' learning styles and training preferences:

- Employees with limited computer skills expressed concerns about having to use the online and blended learning modules; 60% indicated they did not want to use a computer for training.
- They stated that they would prefer to work on the training modules together as a group, with an operations leader in the room to walk them through the training.
- Many of the employees reported that they understand their role but do not necessarily understand how their job fits into the entire Anaconda operation.

54 Jackey Lock (March 29, 2019), "'Mining' our business: Engineering team developing world-leading sustainable drilling methods," *Memorial University Gazette.* Retrieved from https://gazette.mun.ca/research/mining-our-business/
55 Ore is retrieved as drill cuttings, reducing both the amount of ore dilution and the need for primary crushing, and eliminating the need for blasting. The technology can operate using electrically powered equipment, resulting in significantly lower emissions compared to currently available conventional mining technologies.
56 Training Works (2019), Corporate website. Retrieved from https://training-works.ca/

- They also reported that they found it challenging to locate information on company policies and standard operating procedures (e.g. emergency response).

In response, Anaconda has indicated that it plans to distribute tablets to all employees for use on site or setup more computer kiosks. All relevant policies and standard operating procedures (e.g. emergency response) are now posted on Anaconda University's internal website, which is accessible to all employees. Anaconda has created a training module (webinar) on Anaconda's entire mining operation value chain to help employees better understand the company's business model.

Case Study 3: NORCAT

Company Overview

NORCAT, known formerly as the Northern Centre for Advanced Technology, is a not-for-profit technology and innovation centre headquartered in Greater Sudbury, Ontario. NORCAT was founded in 1995 to support the development of local entrepreneurs, technology innovators and skilled labour workers in Northern Ontario. It has since evolved into a multi-national, global company offering programs, resources and services to provide clients with the skills and competencies to enable sustainable economic and social prosperity.

NORCAT's services encompass five distinct areas:

1. **Training:** build and deploy proprietary skilled labour training and development programs for the global mining, forestry and construction industries.
2. **Innovation:** support early stage technology start-ups and their founders.
3. **Underground Centre:** deliver training and develop, test and demonstrate new technologies in an underground operating mine.
4. **Studio:** develop and deliver meaningful training experiences in a safe, hands-on, interactive environment (includes VR / AR and avatar-based learning).
5. **Advisory:** advise on strategic and tactical projects with an emphasis on risk management, talent and human capital development, innovation strategy and policy development.

NORCAT Simulation Training Centre

> *"While it is a fully operational mine, it is more like a lab with all the technology we have underground. Our underground mine fosters a mining tech ecosystem like no other in the world."*
>
> *— Don Duval, CEO, NORCAT*

NORCAT simulator

Photo courtesy of NORCAT

The Simulation Training Centre features a user-friendly simulated cab with all the instruments and controls that would be available on actual mining equipment. Operators can gain hands-on experience working in a non-destructive environment. The simulator can train workers on the operation of eight different pieces of equipment including the Sandvik LH 514 Loader, the CAT R1700 Loader, the Atlas Copco Rocket Boomer 281, and the Maclean Bolter 928.

The simulator cab is mounted on a motion platform and surrounded by a 360-degree panoramic, high-resolution projection display with surround-sound audio. The operations of the engines, braking systems, drilling heads and hydraulics are mathematically modelled to the manufacturers' specifications, providing accurate feedback to both the trainer and user. Situational analysis, operator vigilance and procedural knowledge are tested throughout the training process to ensure that operators that successfully complete the training are skilled, safe and productive.

Clients have the option of centralized and/or remote simulation training (although it is sometimes more economical to bring the simulator and trainer to the customer). The training period typically runs for one week, with 35 hours of simulation training and four hours of classroom training. Simulation training teaches both the theoretical and practical aspects of an economical and productive operation. The two simulation trainers at NORCAT were both lifelong miners before they moved into their current roles. With a combined 104 years of mining experience, they are well versed in all aspects of operating equipment in mining environments (both open pit and underground).

A trainer is present to answer questions and address learners' specific training needs. The training targets the required skills and allows for real-time monitoring of the operator's adherence to safety and operating procedures. Operators receive training in emergency situations that would not be possible to replicate using the real equipment. The simulation training is designed to ensure that operators instinctually make the correct response if the unexpected occurs. All operators' movements are digitally logged, enabling trainers to offer individual feedback on performance, and providing a digital record of operators' skills development and knowledge over time.

A Cost-Effective Approach

> *"Operators who have been through the Sandvik training system have a proven record in achieving higher production rates."*
>
> *— Tom White, simulation trainer at NORCAT*

NORCAT's simulation training offers a cost-effective approach to developing the skills of heavy equipment operators, with wide-reaching benefits including:

- Reduced on-site training: 80% of training occurs during simulation training; the remaining 20% occurs in an underground environment and requires sign-off by the mine's training department.
- Reduced wear-and-tear on vehicles used by inexperienced operators.
- Increased production rates: Operators who complete the simulation training have higher production rates than operators who train through conventional methods.
- Reduced downtime: There is no need to take equipment out of production.

3.3 PROFILING FUTURE WORKFORCE SKILLS: QUANTITATIVE ANALYSIS

Introduction

This section of the report presents MiHR's approach to mapping skills-to-occupations. The purpose of this analysis is to profile the skills and competencies of the workforce that are prevalent today and then to anticipate how emerging technologies will change the skills that will be required from the workforce of the future. The intent is to identify circumstances in which there is a significant gap (or disparity) between the current and future skills landscapes – an indication of the need for training, upskilling and the re-prioritization of skills.

Background

Workforce skills represent a unique modelling challenge. There are several competing classifications and interpretations for "skills" from various literature and resources. Skills may have a wide range of meanings and definitions – from specific workplace aptitudes (e.g. writing) to workplace functions or tasks (e.g. producing documents). Existing classifications can range in the level of specificity, the relative weight/importance of each skill, and how they are grouped (e.g. baseline, fundamental, specialized, computer).

In general, skills are difficult to quantify given the ambiguity of their application across different roles in the economy. For example, "mathematics" has a different significance for an engineer compared to an accountant, though they both may require a use of mathematics in their roles. As a result, present-day skills measurements struggle to capture the nuance and complexity of skills in the context of various roles.

Contemporary analyses of skills typically leverage occupations and occupation-based data as a means of describing skills in the workplace, principally because it is intuitive to think about skills through an occupational lens, but also since the available resources for occupations (i.e. data, definitions and general awareness/familiarity) make this a practical approach.[57] Given a particular occupation, a catalogue (or ranking) of the necessary skills will vary depending on the method used to determine whether a skill is important to an occupation. In recent contributions on the topic, the method for determining skill importance has varied – from an appraisal of occupational skills (conducted by people with expertise) to the use of job posting data to identify the skills that are frequently cited by employers.[58]

3.3.1 Scope and Limitations

MiHR acknowledges certain limitations regarding the prediction and analysis of future workforce skills. A strong understanding of the scope and limitations of the analysis in this section will ensure the analysis is interpreted appropriately.

This analysis only considers occupations that exist today. This study does not predict newly created occupations that will exist in the future. Since this analysis of skills necessarily leverages occupational data, it is ultimately limited to occupations that are currently observable. It is very likely that a number of unprecedented occupations will emerge[59] as a result of technological advancements, representing an inherent blind spot of the analysis presented in this section.

This analysis does not predict the future production mix. It is important to note that given the unprecedented nature of new technologies, the analysis in this section does not predict how new capital and labour will combine in future operational processes. As a result, it is difficult to measure how new technologies that are not yet mainstream, will affect labour productivity and the demand for specific occupations.

MiHR's conventional forecast of mining employment primarily focuses on the effects of broader macroeconomic factors (i.e. movement in prices, gross domestic product (GDP), interest rates, among others), but necessarily assumes the production mix will continue to align with the prevailing observations of capital and labour. The analysis in this section does not aim to predict the future production mix, though the findings evaluate whether a skill is expected to be particularly sensitive to changing production processes resulting from new technologies.

In the future, consideration will be given to reconcile MiHR's conventional 10-Year Outlook with the findings of this report.

This analysis does not rank skills by importance or frequency of use. Given their ambiguities, workplace skills are very difficult to measure consistently across varying roles in the economy. Therefore, this analysis does not rank skills by their relative importance to a specific occupation, nor does it compare skills by their frequency of use in the workplace. Rather, this analysis simply determines whether an occupation uses a specific skill or not, arriving at a binary outcome of "yes" or "no."

3.3.2 Retrospective Analysis

To better comprehend how the mining workforce may progress moving forward, it is appropriate first to observe how the mining workforce has progressed to its present-day form. This sub-section provides a retrospective analysis of the mining workforce, focusing on two key areas: capital intensification and shifts in labour composition by education.

3.3.2.1 Mining Has Become More Capital Intensive

The mining industry typically uses significant capital inputs in its operations; these investments are usually large in scale and involve considerable equipment and/or technology. There are signs that the industry has become progressively more capital intensive. Statistics Canada data on the inputs of production[60] reveal that the ratio of *capital input* to *labour input* has consistently been on the rise, indicating a shift in the production mix and a trend of capital intensification in mineral extraction over the last four decades (Figure 3.2). Even as labour input has also increased (aside from a recent drop in 2014), capital input is shown to have outpaced it over the same period.

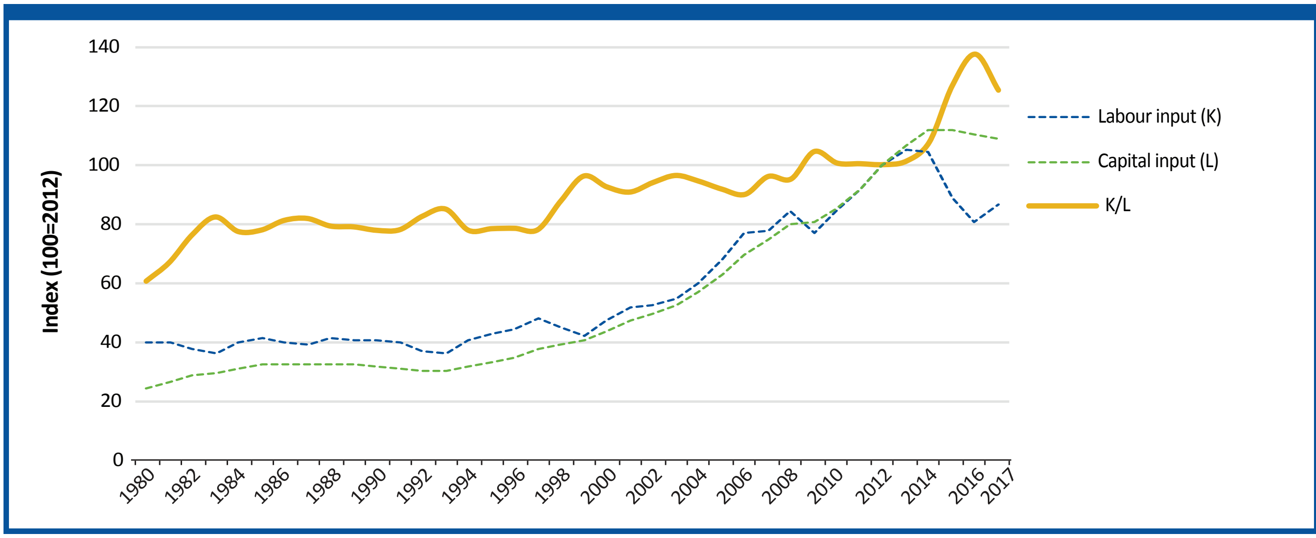
57 Also, any present-day primary data collection of workforce skills – that is, physically measuring the aptitudes of people in a standardized way – would be a massive and impractical effort.

58 Note that job-posting data do not rank or even reveal the skills that are essential for employment in a certain occupation. Rather, the data on skills are purely a reflection of what employers are requesting in the job-search context. For example, an employer may assume that a particular set of skills is understood to be a given (e.g., math skills for an engineer) and thus understates the skills; in another instance, an employer may ask for skills that are not necessary or essential for the job, but which will differentiate candidates.

59 *Data Scientist* is an example of an occupation that has recently emerged since the beginning of this century. The analysis in this report does not predict similar occupations that have yet to emerge, though these will indeed influence the future skills landscape. Furthermore, occupational data in this report are aligned with the NOC codes, which are not updated in real time as new occupation roles are continually evolving.

60 Production inputs are defined by Statistics Canada for estimating productivity measures as follows: "Labour input is obtained by chained-Fisher aggregation of hours worked of all workers, classified by education, work experience, and class of workers (paid workers versus self-employed and unpaid family workers) using hourly compensation as weights." https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610020801

FIGURE 3.2: Indices of Capital Inputs vs. Labour Inputs: Mining, Quarrying and Oil & Gas Extraction (NAICS 21), (1980–2017)



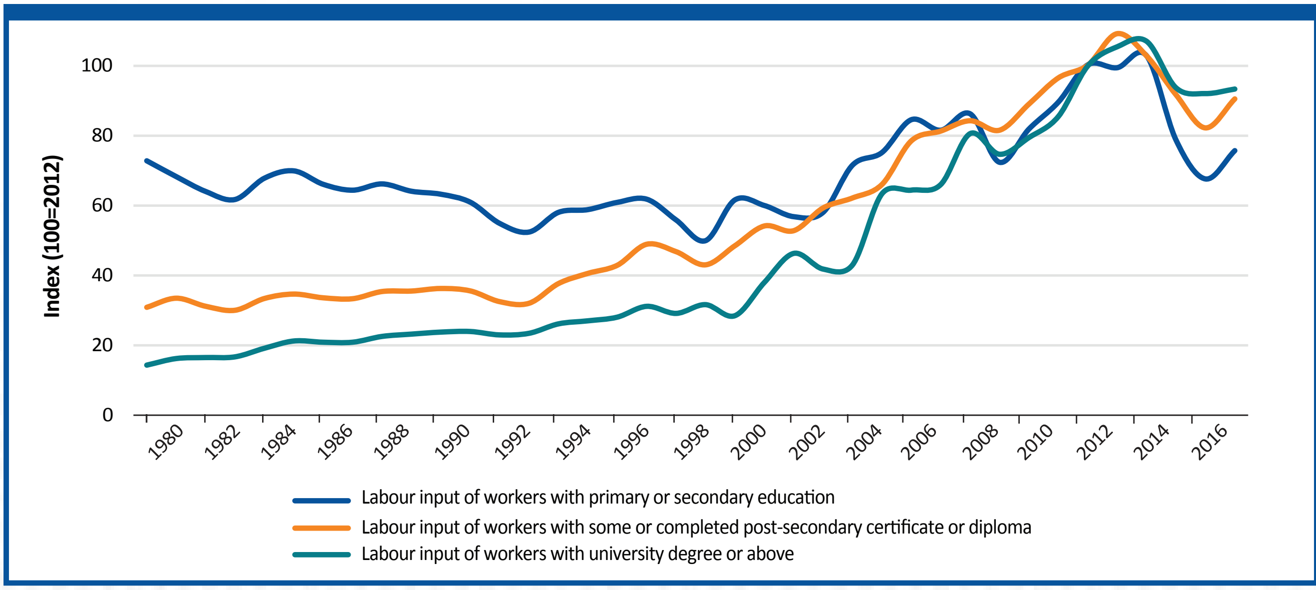
Source: Mining Industry Human Resources Council; Statistics Canada (Table 36-10-0208-01 Multifactor productivity, value-added, capital input and labour input in the aggregate business sector and major sub-sectors, by industry), 2019

3.3.2.2 Labour Composition (by Education) Has Shifted

With the rise in capital intensity, the mining workforce has also evolved to keep up with modern-day production processes and technologies. For instance, with larger-scale and more technologically sophisticated equipment, companies may require workers who possess higher-level skills, education and experience. Statistics Canada data on labour inputs (by educational attainment) reveal that, just as the industry has become more capital intensive, the mineral extraction sector's labour inputs have shifted, emphasizing a growth in workers with a post-secondary certificate/diploma or a university degree (Figure 3.3).

The changes in the production mix and workforce composition indicate that the average worker's interaction with capital has evolved over time, though it has taken several decades for the changes to be considerable. These trends offer a historical benchmark for the pace of change and provide insights into how the production mix and workforce composition might evolve in the future.

FIGURE 3.3: Indices of Labour Inputs by Educational Attainment: Mining, Quarrying and Oil & Gas Extraction (NAICS 21), (1980–2017)



Source: Mining Industry Human Resources Council; Statistics Canada (Table 36-10-0208-01 Multifactor productivity, value-added, capital input and labour input in the aggregate business sector and major sub-sectors, by industry), 2019

"Capital input measures the services derived from the stock of fixed reproducible business assets (equipment and structures), inventories, and land. It is obtained by chained-Fisher aggregation of capital stocks using the cost of capital to determine weights." https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610020801

3.3.3 MiHR's Approach to Skills Analysis

MiHR offers a straightforward analysis that aims to quantify the prevalence to which certain skills are used by Canada's mining workforce and (in the next sub-section) investigates how each skill is sensitive to incoming technologies.

Note: This analysis does not explicitly predict whether a skill will be required in the future; rather, the intent is to gauge the expected response (both in direction and scope) to new technologies should they arrive.

MiHR considers "skills" as the competencies required to perform job-related tasks. Ten different skills have been selected for analysis based on their relevance to the mining industry and on MiHR's qualitative research findings collected from interviews, case studies, surveys and focus groups with industry stakeholders. These skills are defined by the O*Net Online database[61] and are listed as follows:

- *Active Learning*
  Understanding the implications of new information for both current and future problem-solving and decision-making.
- *Complex Problem Solving*
  Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.
- *Critical Thinking*
  Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.
- *Judgment and Decision Making*
  Considering the relative costs and benefits of potential actions to choose the most appropriate one.
- *Operation and Control*
  Controlling operations of equipment or systems.
- *Operation Monitoring*
  Watching gauges, dials, or other indicators to make sure a machine is working properly.
- *Programming*
  Writing computer programs for various purposes.
- *Reading Comprehension*
  Understanding written sentences and paragraphs in work related documents.
- *Troubleshooting*
  Determining causes of operating errors and deciding what to do about it.
- *Writing*
  Communicating effectively in writing as appropriate for the needs of the audience.

Central Themes of How Innovation Will Shape Future Skills Demand

- New tools and processes will result in a change in the day-to-day duties of workers.
- As new technology is deployed, the mining labour pool will require updated skills and expertise to achieve a satisfactory level of operational integration.
- Having an idea of future skills demand and how it compares with the current skills landscape can help the industry anticipate future needs.
  - — For employers, a sufficiently skilled labour force is key to remaining competitive and making the most of capital investments.
  - — For employees and career seekers, identifying which skills will be in demand can help them follow a stable and positive career trajectory.

MiHR's analysis of skills follows a two-step approach. The goal is to quantify and observe existing skills in the mining workforce, such that each skill's relative weight can be compared and analyzed. For a particular skill of interest, MiHR's analysis centres on:

1. Mapping skills-to-occupations
2. Adding up workers in occupations using a particular skill

STEP ONE: Mapping Skills-to-Occupations

Mapping skills-to-occupations forms the foundation for this analysis. The first objective was to derive a list of occupations that use a particular skill. This list was developed for 10 skills of interest, using the O*Net Online database and MiHR's curated list of 120 mining-related occupations. The O*Net database provides an established resource that delineates occupations in terms of skills, knowledge, abilities and experience (among other criteria).[62]

61 O*Net Online: https://www.onetonline.org/find/descriptor/browse/Skills/
62 As O*Net is based in the United Sates, the list of Standard Occupational Classification (SOC) codes were converted to a corresponding NOC code using a crosswalk developed by the Brookfield Institute for Innovation + Entrepreneurship (see https://github.com/BrookfieldIIE/NOC_ONet_Crosswalk)

Selected skills are attributed to occupations by applying numerical thresholds[63] on O*Net data for "importance" and "level".[64] As stated, this mapping simply decides whether an occupation uses a specific skill or not, arriving at a binary outcome of "yes" or "no." The assumed thresholds mark the critical point at which the skill is determined to be significant enough to the occupation. As a result, this selection criterion necessarily discounts, from certain occupations, skills that are otherwise considered to be universally used (e.g. writing). The complete skills-to-occupations map is provided in Appendix 4.

A count (out of 120 occupations) reveals how often a particular skill is used across occupations in the mining industry. A greater number implies a skill is generally in use, while a lesser number suggests a skill is comparatively specialized. Note: This measure does not capture the relative importance of a skill, but a simple observation of how commonly the skill is being utilized across occupational roles.

STEP TWO: Adding Up Workers in Occupations Using a Particular Skill

A subsequent measure considers the share of the mining workforce that uses a particular skill. This measure is estimated by tallying the workers in the occupations that use the skill (with the occupational mapping described above) and then dividing by the total workforce. Statistics Canada data (2011 and 2016 censuses) were used to determine the number of workers in 120 mining-related occupations, focusing on *NAICS 212 mining and quarrying*.

This metric shows the rate at which a skill is used among the workers, but not necessarily among occupations. In other words, a skill could be specialized (relevant to few occupations) but used by a large contingent of the overall workforce, or vice versa.

In the event that a particular skill becomes requisite, obsolete or is merely altered by technology, this metric signifies the blast-radius (the workforce's potential level of exposure to the change) as it shows the extent of workers that will potentially need to adjust their skills to remain competitive in the labour market.

The Mining Toolbox Analogy

A useful analogy for describing how skills are framed in this report is to think of an individual occupation as a toolbox, and the skills as the specific tools inside (e.g. hammer, screwdriver). The objectives are to:

- Identify the main tools (i.e. skills) that are most likely found in each toolbox (i.e. occupation).
- Evaluate how widespread a particular tool is used across the range of toolboxes.
- Count the percentage of people using the tool (regardless of the toolbox).
- Reveal how sensitive each tool is to new technology.
  - — Will the effects of new technology add or remove the tool from numerous toolboxes?
  - — Will the effects of new technology implicate a significant number of people currently using the tool (or who do not currently use the tool)?

Together, these questions identify which tools are comparatively sensitive to changes in technology – whether this means the tool is at risk of becoming obsolete or is emerging as requisite to the workforce.

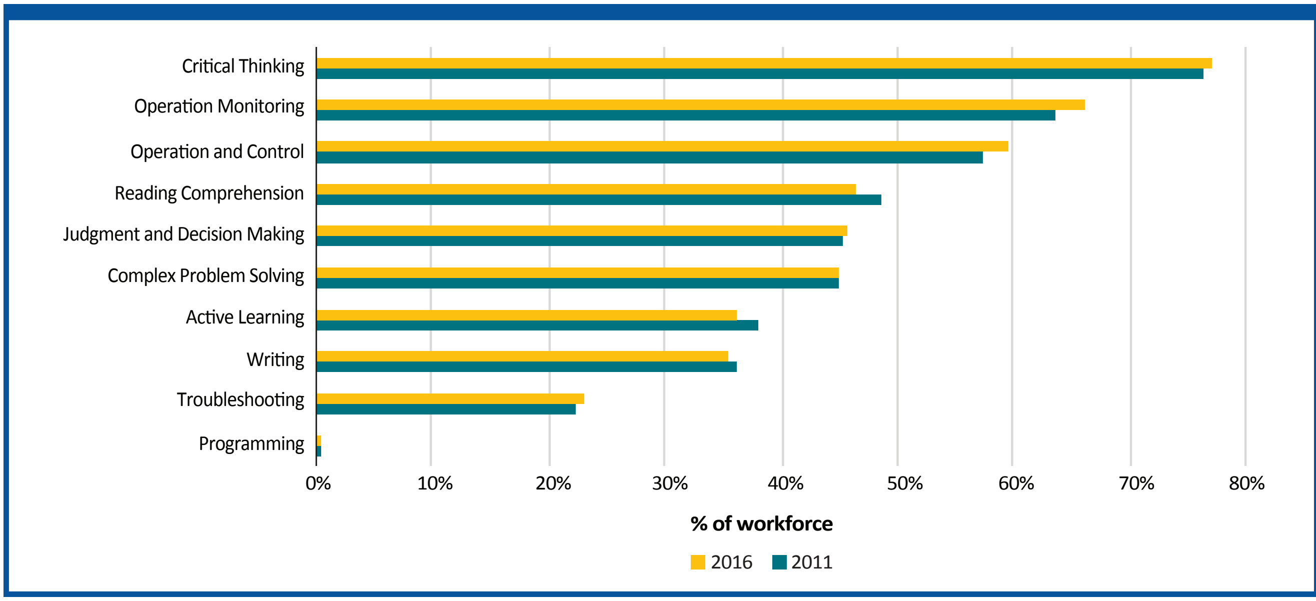
63 MiHR assumes threshold levels of 3.0 and greater for both importance and level.

64 O*Net defines "importance" and "level" as follows: "Importance: This rating indicates the degree of importance a particular descriptor is to the occupation. The possible ratings range from "Not Important" (1) to "Extremely Important"(5)." "Level: This rating indicates the degree, or point along a continuum, to which a particular descriptor is required or needed to perform the occupation." For a detailed description, see the O*Net Online website (https://www.onetonline.org/help/online/scales#foot3).

3.3.3.1 Observing Current Industry Skills

The results of this two-step approach show *Critical Thinking, Operation Monitoring,* and *Operation Control* among the most widely used skills by share of workforce (Figure 3.4). Conversely *Programming* is used by a relatively smaller, specialized portion of the mining workforce. Interestingly *Writing* is used by only 35% of the workforce, but 65% of occupations (Table 3.1). These findings serve as a reference point for how skills distribute among the present-day mining workforce. The next step is to evaluate how this picture may change with incoming innovation and technologies.

FIGURE 3.4: Share of Workforce Using Skills of Interest: Mining and Quarrying (NAICS 212), (2011 and 2016)



Source: Mining Industry Human Resources Council; Statistics Canada (Census 2011, 2016); O*Net Online database, 2019

TABLE 3.1: Share of Occupations Using Skills of Interest (Present Day)

Skill of Interest	Number of Occupations Using Skill	Percentage of Occupations Using Skill
Critical Thinking	103	86%
Reading Comprehension	92	77%
Judgment and Decision Making	82	68%
Complex Problem Solving	79	66%
Writing	78	65%
Active Learning	72	60%
Operation Monitoring	49	41%
Operation and Control	31	26%
Troubleshooting	19	16%
Programming	3	3%

Source: Mining Industry Human Resources Council; Statistics Canada (Census 2011, 2016); O*Net Online database, 2019

3.3.3.2 Forward-Looking Analysis

This section builds on the skills analysis presented above and develops two scenarios (Table 3.2) depicting the future skills landscape. Each revised scenario must determine how both inputs – the skills-to-occupation mapping and occupational demand – might change in the future.

Baseline scenario: The first “baseline” scenario assumes the status quo as the mining industry continues to implement present-day capital, technology and operational processes. The skills-to-occupation mapping is assumed to be static.

This scenario uses MiHR’s updated employment forecast for *NAICS 212 (mining and quarrying)* to the year 2030; an underlying econometric model accounts for ongoing variations in employment, prices and various other macroeconomic variables, but does not predict the arrival of unprecedented technologies that would permanently change the production mix, labour productivity and occupational demand.

Innovation scenario: A second “innovation” scenario introduces the potential influence of new technologies by revisiting both the skills-to-occupation mapping and the occupational demand.

The skills-to-occupation mapping has been modified to align with MiHR’s qualitative findings on future skill needs. Specifically, the intelligence gained from primary research – including an understanding of the specific new technologies on the horizon – was used to override the existing skills map (based on the O*Net database). This modified mapping can be found in Appendix 4.

The scenario then considers how occupational demand (by headcount) might change by applying the applicable Frey and Osborne (2013) score to each occupational employment forecast. Thus, Frey and Osborne scores are taken as the probability that an occupation will be completely replaced in the future, and the resulting modified forecast represents an expected value of future occupational employment.

Therefore, the objective of this analysis is to point to the direction (and relative scope) of the potential change, rather than predict a specific future outcome.

Comparing scenarios: These scenarios represent two extremes – in the former case, the production mix does not change, which is unlikely given the observations previously explored in this report. In the latter case, the change to the production mix (and occupational demand) is merely directional as the modified forecasted employment represents an expected value (i.e. not an exact outcome).

Together, these contrasting scenarios reveal the potential (directional) effect of emerging technologies on prevailing workforce skills (Figure 3.5). The total effect contains both the result of skills changing within each occupation and the result of shifting occupational demand. For example, automated heavy equipment may introduce the need for *operation monitoring* among *heavy equipment operators* but also reduce the overall demand for this occupation; both effects determine the occurrence of operation monitoring used in the workforce.

TABLE 3.2: Effects of Emerging Technologies on Prevailing Workforce Skills, Baseline Vs. Innovation Scenarios (Forecast to 2030)

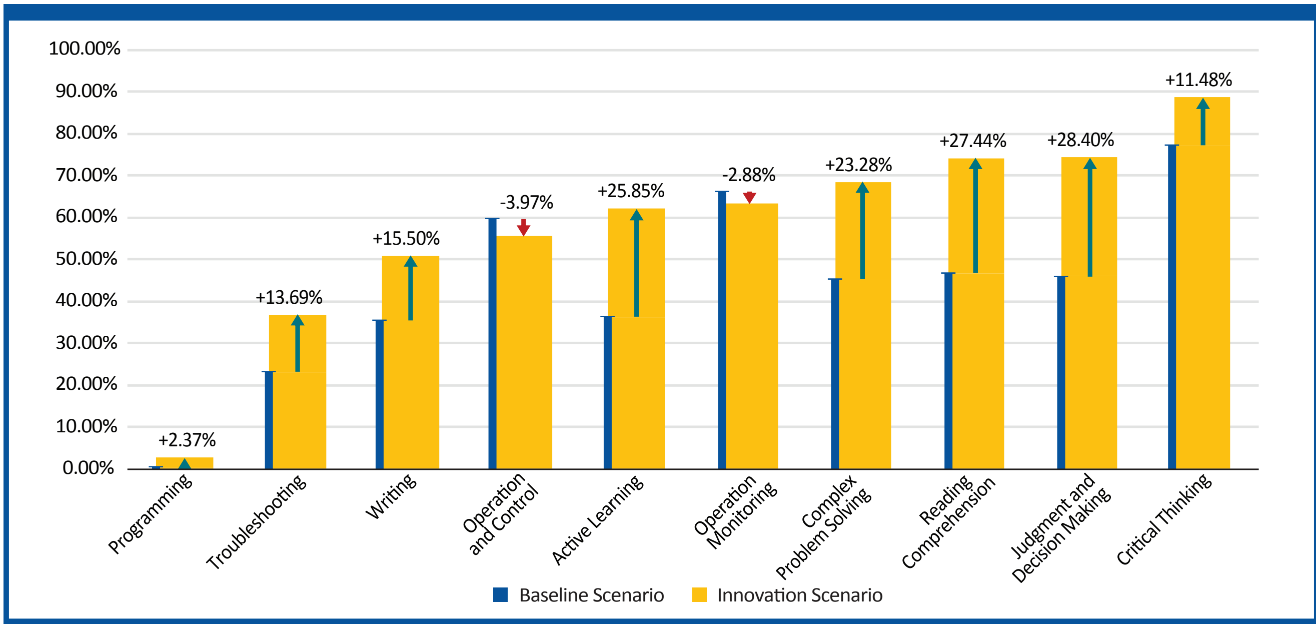
	Baseline Scenario	Innovation Scenario
Types of Occupations	• Same 120 mining-related occupations as in 2016	• Same 120 mining-related occupations as in 2016
Macroeconomic Factors	• Increased workforce demand for NAICS 212 as a whole • Scenario uses MiHR’s employment forecast to 2030	• Increased workforce demand for NAICS 212 as a whole • Scenario uses MiHR’s employment forecast to 2030
Skills-to-Occupations Mapping	• No assumed change from 2016	• Incoming technology requires occupations to possess a different set of skills • Appraisal of incoming technologies and 120 occupations to override O*Net based skills-to-occupations mapping
Production/ Occupational Mix	• Same production mix as in 2016 • Same occupational mix as in 2016	• Incoming technology changes the capital/labour mix • Occupational demand grows unevenly, changing the occupational mix • Scenario applies Frey and Osborne scores to estimate the effect of technology on the demand for each occupation

Source: Mining Industry Human Resources Council, 2019

Key Findings

- The majority of the selected skills are anticipated to increase under the innovation scenario, notably *Judgement and Decision Making, Reading Comprehension, Complex Problem Solving* and *Active Learning.*
- *Critical Thinking* continues to be the most widely used skill with close to 90% of the mining workforce requiring this skill in their skillset.
- These results are consistent with other relevant literature, such as the World Economic Forum's *The Future of Jobs Report* and *The Future of Jobs Survey*.[65] Survey findings state that "a wide range of occupations will require a higher degree of cognitive abilities—such as creativity, logical reasoning and problem sensitivity—as part of their core skill set."
- The exceptions include *Operation and Control* and *Operation Monitoring*, which are expected to decrease, yet are expected to remain prevalent in close to 60% of the workforce.[66]
- *Programming* remains the least commonly used skill among the workforce, even as it is expected to be used in a slightly larger number of occupations.

FIGURE 3.5: Projected Share of Workforce Using Skills of Interest, Baseline and Innovation Scenarios: Mining and Quarrying (NAICS 212), (Forecast to 2030)



Source: Mining Industry Human Resources Council; Statistics Canada, Census (2011; 2016); O*Net Online database, 2019

TABLE 3.3: Share of Occupations Using Skills of Interest, Baseline and Innovation Scenario (Present Day and Future)

Skill of Interest	Baseline Scenario: Percentage of Occupations Using Skill in 2030	Innovation Scenario: Percentage of Occupations Using Skill in 2030	Change
Critical Thinking	86%	88%	+2%
Reading Comprehension	77%	81%	+4%
Judgment and Decision Making	68%	78%	+10%
Complex Problem Solving	66%	70%	+4%
Writing	65%	68%	+3%
Active Learning	60%	68%	+8%
Operation Monitoring	41%	46%	+5%
Operation and Control	26%	42%	+16%
Troubleshooting	16%	28%	+12%
Programming	3%	7%	+4%

Source: Mining Industry Human Resources Council; Statistics Canada (Census 2011, 2016); O*Net Online database, 2019

65 See the World Economic Forum, *The Future of Jobs Report (Skills Stability)*. Retrieved at http://reports.weforum.org/future-of-jobs-2016/skills-stability/
66 Note: The share of occupations that use these skills is estimated to increase, implying that they will be needed in more occupational roles but by fewer people overall.

3.3.4 Conclusions

More than ever, contemporary labour market information is shifting attention towards workplace skills—beyond the conventional occupation/education-based information. This trend is, in part, because skills have become more commonly studied; several datasets, taxonomies, analysis and resources have emerged, providing insight on which skills are most likely needed to be competitive and foster preparedness among labour market participants.

In this report, MiHR offers a simple approach to quantifying the skills that are being used within Canada's mining workforce, and though this analysis acknowledges certain limitations, it provides an initial reference for comparing how various skills are represented and how they may evolve as new technologies are introduced. It is recommended that mining stakeholders (i.e. career seekers, employers, educators, governments) and workforce planners use this information to make better decisions, anticipate technological changes, and align the labour supply skillsets with those predicted to be in greatest demand.

Based on this preliminary analysis of 10 selected skills, *Critical Thinking* is emphasized as the most prominent, whereas *Programming* is observed to be relatively specialized. Future scenarios to 2030 then reveal an emphasis on *Active Learning, Reading Comprehension, Judgement and Decision Making* and *Complex Problem Solving,* while *Operation and Control* and *Operation Monitoring* are both projected to decline modestly.

As noted earlier in the report, future considerations will be given to reconcile MiHR's conventional 10-Year Outlook with the findings of this report.

3.4 THE IMPERATIVE FOR LITERACY AND ESSENTIAL SKILLS IN MINING

Introduction

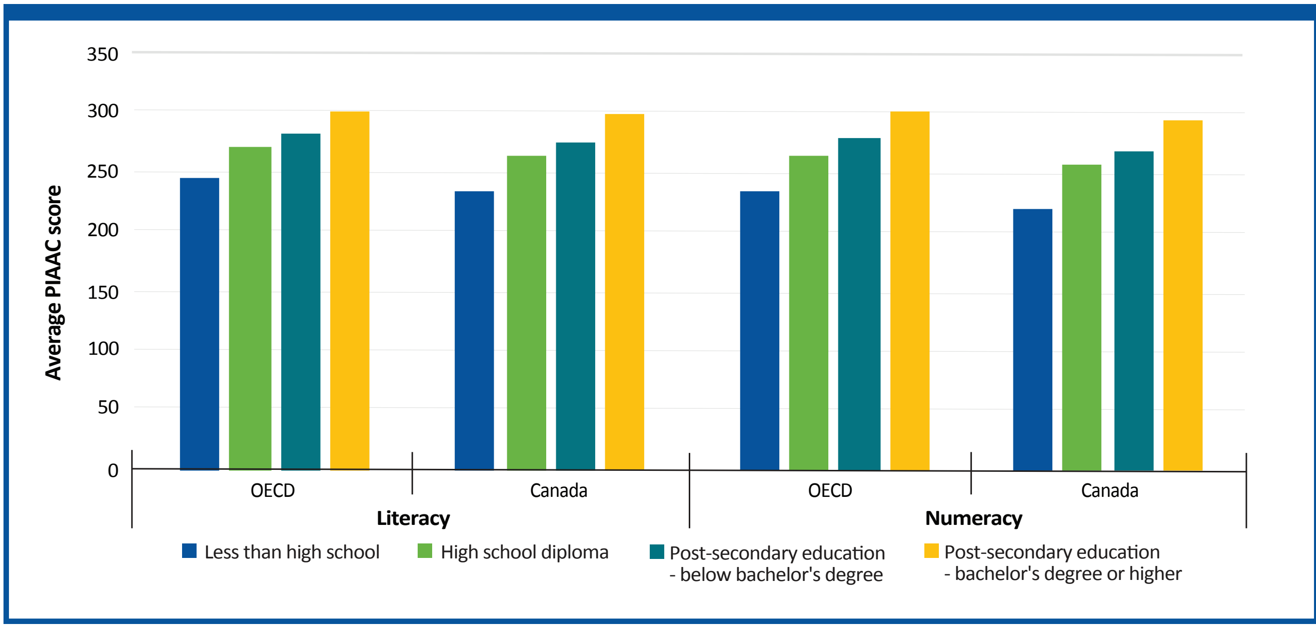
This section focuses on an area rarely addressed in the discourse on skills requirements in the mining labour force – literacy and essential skills. These skills are foundational to learning all other skills, including those required to succeed in an increasingly digitalized work environment. Literacy and essential skills include reading comprehension, writing, and critical thinking,[67] and are among the 10 skills of interest investigated in this report's quantitative analysis. Essential skills enable individuals to access and use information effectively, and solve problems in a complex, ever changing and knowledge-intensive society.[68] Individuals with inadequate literacy skills are more likely to have worse health outcomes, lower earning potential, and fewer opportunities.[69] In particular, low literacy skills of the mining labour market was identified as a key challenge for employers.

3.4.1 Literacy and Education Level

The Survey of Adult Skills, part of the Programme for the International Assessment of Adult Competencies (PIAAC), measures three skills essential to processing information – literacy, numeracy, and problem-solving skills in technology-rich environments. PIAAC's most recent results for Canada (2013) showed that less than half (48%) of Canadians ages 16 to 65 have adequate literacy skills (Figure 3.6).

67 Other essential skills are oral communication, numeracy, document use, computer use/digital skills, teamwork, and continuous learning. See Economic and Social Development Canada (2019).
68 TOWES (Test of Workplace Essential Skills) (2019), Literacy and Essential Skills. Retrieved from http://www.towes.com/en/literacy-and-essential-skills/overview
69 ABC Life Literacy Canada (2017), Up skills for work: Workplace literacy. Retrieved from https://upskillsforwork.ca/2017/07/21/workplace-literacy/

FIGURE 3.6: PIAAC Literacy and Numeracy Scores by Level of Education

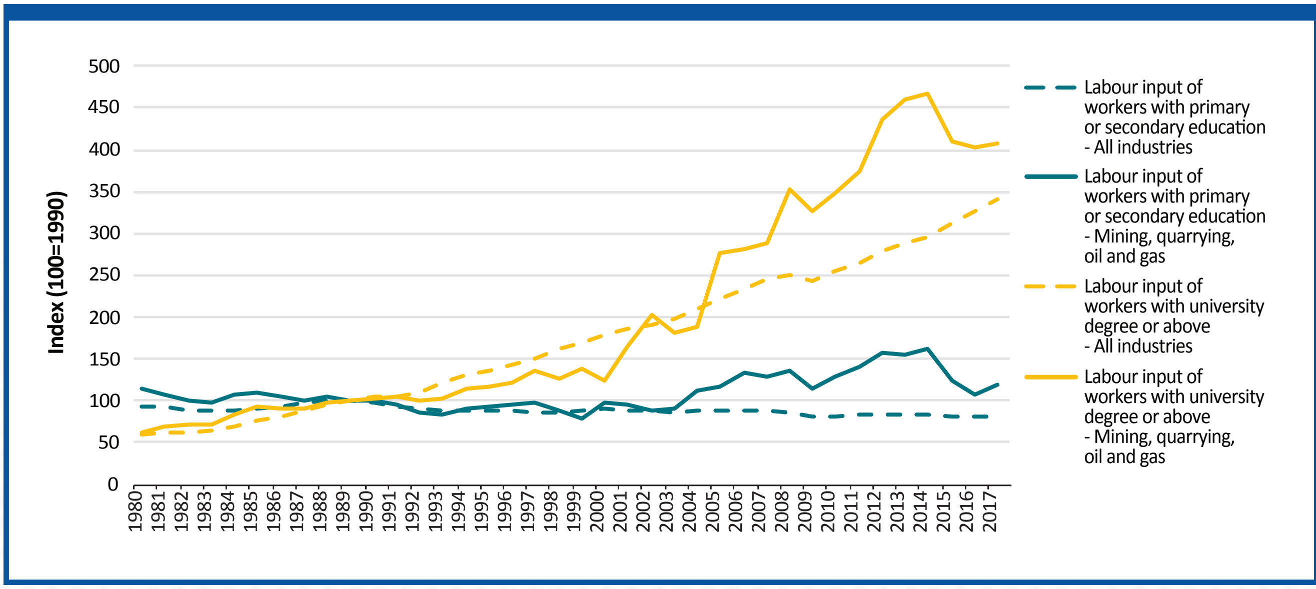


Source: Statistics Canada, Employment and Social Development Canada, and the Council of Ministers of Education, Canada (2013), Skills in Canada – First Results from the Programme for the International Assessment of Adult Competencies (PIAAC)

Higher levels of educational attainment are becoming increasingly important for all workers. Of particular interest is the labour input of highly educated workers in *mining, quarrying, oil and gas extraction (NAICS 21)* – it has been growing at a much higher rate than the all-industry average over the past 15 years (Figure 3.7).

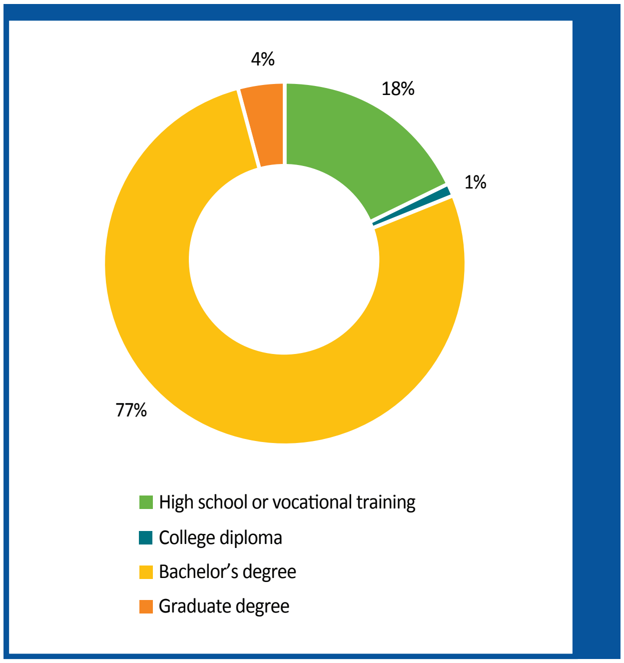
Mining employers are demanding workers with higher levels of education, while decreasing their reliance on less-educated workers (Figure 3.8).

FIGURE 3.7: Labour Input of Workers in Mining, Quarrying and Oil & Gas Extraction (NAICS 21) by Education Level (1980–2017)



Source: Mining Industry Human Resources Council, Statistics Canada (Productivity Measures and Related Variables, 2018

FIGURE 3.8: Online Job Postings in Mining and Quarrying (NAICS 212) by Educational Requirement (2013–2018)



Source: Mining Industry Human Resources Council, Burning Glass Technologies, http://www.burning-glass.com, 2019

3.4.2 Literacy and the Workplace

The term *workplace literacy* refers to the fundamental skills that employees need to do their jobs and includes both essential skills and employability skills.[70] Workplace literacy forms the foundation for productive workers who can adapt to technological and workforce changes by developing or transitioning throughout all phases of their career. Increased workplace literacy and essential skills training can result in considerable improvements in workers' skills and job performance.[71]

As technology and innovation continue to change the way that we work, continuous education and skills development become increasingly important for individuals. Remarkably, one-third of managers across Canadian industries have reported that low levels of literacy among their employees have contributed to challenges in new technology implementation, product quality, and productivity.[72]

3.4.3 Increasing Demand for Digital Literacy

There appears to be no singular definition of digital literacy and no definitive list of skills that comprise it. However, most observers view digital literacy as the capacity to navigate and adapt to a changing digital environment.[73]

The demand for generic information and communications technology (ICT) skills (e.g. word processing and accessing websites) has increased in a large majority of OECD-member countries, with Canada ranking fourth after the Netherlands, United Kingdom, and Australia.[74] (About 84% of jobs in Canada currently require use of a computer and basic technical competencies.[75]) However, in OECD-member countries, a large share of workers who use ICTs regularly have inadequate generic ICT skills: on average, over 40% of workers who use office software daily do not have the skills required to use the software effectively.[76]

Digital literacy provides individuals with skills to adapt to and benefit from a digital economy.[77] A study for the Minerals Council of Australia identified digital literacy as one of the 10 key skills required for the mining industry of the future.[78]

3.4.4 Preparing Mining Workers for the Future

The quantitative analysis in this report affirmed that automation and digital technologies will disproportionately impact low-skilled workers who perform manual and repetitive tasks. These workers need opportunities to gain literacy and essential skills so that they can pursue further learning and acquire the skills to work in digital environments. Mining companies have an opportunity to position literacy and essential skills development as the cornerstone for a digitally literate and sustainable mining workforce.

70 Employability skills include motivation, attitude, accountability, presentation, teamwork, time management, adaptability, stress management, and confidence. See ABC Life Literacy Canada (2017).
71 Social Research and Demonstration Corporation, 2016. UPSKILL Health – Technical Report on worker and business outcomes. Retrieved from http://www.srdc.org/media/199892/upskill-health-worker-and-business-outcomes.pdf
72 Centre for Educational Research and Innovation (1992), *Adult literacy and economic performance.*
73 Tea Hadziristic (April 2017), The State of Digital Literacy in Canada. A Literature Review. Brookfield Institute. Retrieved from https://brookfieldinstitute.ca/wp-content/uploads/BrookfieldInstitute_State-of-Digital-Literacy-in-Canada_Literature_WorkingPaper.pdf
74 Organisation for Economic Co-operation and Development (OECD, 2016), Skills for a Digital World, Background Paper for Ministerial Panel 4.2. DSTI/ICCP/IIS(2015)10/FINAL
75 ICTC (2016), "Innovation Agent Project (SEED)." Retrieved from http://www.ictc-ctic.ca/wpcontent/uploads/2016/12/ICTC_Innovation-Agent-Report.pdf
76 OECD (2016).
77 Media Smarts (2014), "Digital Literacy in Canada: From Inclusion to Transformation" Retrieved from https://mediasmarts.ca/sites/default/files/pdfs/publication-report/full/digitalliteracypaper.pdf
78 EY (2019), *The Future of Work.*

SECTION 4:
Preparing for the Future

4.1 SUMMARY / CONCLUSIONS

The digital transformation of the mining sector is highly fluid and non-linear. The adoption of new technologies will impact workers across the mining cycle at different times and to different degrees. At times, innovations will introduce new job responsibilities; at other times they will modify or take over a task previously performed by a human. There will be increased demand for the labour of certain workers and decreased demand for others. Depending on the occupation, the adoption of new technologies will enhance, re-design, or completely automate workers' jobs.

Future mining work will require a fundamentally different skillset from the historical one; an individual worker may acquire multiple roles and job activities as equipment, technologies, and processes evolve. As new technology is deployed, the mining labour pool will require updated skills and expertise to achieve a satisfactory level of operational integration. New employees will need to meet higher requirements for basic training, post-secondary education, and continuous learning.

Having an idea of how the demand for skills might compare with the current skills landscape can help the industry anticipate future needs. For these reasons, it is important to ascertain which workers will face the biggest challenges and which workers are most likely to be impacted first.

4.2 RECOMMENDATIONS

4.2.1 Use Innovation-Focused Labour Market Information to Make Decisions

In this report, MiHR offers a simple approach to quantifying the skills being used within Canada's mining workforce, providing an initial reference for comparing how various skills are represented and how they may evolve as new technologies are introduced. It is recommended that mining stakeholders use this information to prepare for a disruptive future and make better decisions to minimize negative outcomes. Data-driven strategies can improve job stability for workers and establish a competitive labour pool that mining operations can effectively draw upon.

4.2.2 Focus on Comprehensive Skills Development

MOVI results revealed that the greater part of the mining workforce is employed in occupations with higher vulnerability to new technologies. Workers in *Production Occupations* are particularly vulnerable. Skills development is especially critical for workers in this occupational group and should include literacy and other essential skills as they are foundational for further learning and skills.

Assessment of the full scope of potential skills gaps relative to operational needs would help to ensure effective, targeted training. Comprehensive assessments can identify whether a worker may have in-demand transferable skills that may not be visible because the worker's current role does not require their use. Alternately, a worker may not have a particular skill, such as reading comprehension, but that gap in essential skills goes unnoticed because the worker's current role does not require them to use it.

4.2.3 Shift the Discourse from Crisis to Opportunity

Throughout mining history, miners have demonstrated adaptability, resilience and flexibility in the face of technological change. The digital transformation of mining is necessary and unstoppable – a stage in a long evolution, rather than an isolated crisis. Workers' anxieties about potential job losses need to be acknowledged. However, there is room for shifting the discourse from crisis/vulnerability to opportunity/adaptability.

The industry also needs to be forthright about the labour market disruption that lies ahead. Mining workers need a clear understanding of who is vulnerable and why – and this should originate from innovation-focused LMI that allows for systematic monitoring and reporting of changes. With timely and accurate information, workers and workforce planners can make informed decisions about training and foster resiliency in the face of change.

4.2.4 Diversify the Mining Labour Force

The mining industry needs to attract more women, immigrants, Indigenous people, and labour from other industries, to help fill the gap in supply and meet the changing skills requirements brought on by innovations in mining.

- Despite their strong presence in the overall labour force, women are underrepresented in *mining and quarrying*. MiHR's occupational analysis indicates that the greatest opportunities for women to expand their representation in the mining sector are in professional, engineering and management positions – occupations with both a low MOVI and a low percentage of women.
- Indigenous people are one of the most important labour supply groups for the mining industry because mining operations are often located near Indigenous communities. Canada's mining workforce has the highest representation of Indigenous workers (7%) compared to other Canadian industries.
- Immigrants represented 13% of the mining industry workforce in 2016 compared to 23% of Canada's workforce. Statistics Canada projects that the immigrant share of Canada's population could reach between 25% and 30% by 2036.[79] New Canadians are often highly educated and have transferable skills that are beneficial to mining employers.

79 Statistics Canada, "Immigration and ethnocultural diversity: Key results from the 2016 Census," *The Daily* (Oct. 25, 2017). Retrieved from https://www150.statcan.gc.ca/n1/daily-quotidien/171025/dq171025b-eng.htm

4.2.5 Strengthen Collaboration with Academic Institutions

Many colleges and universities offer mining-related programs. However, a commonly expressed concern from industry is that academic programming needs to better reflect the industry's skills requirements and prepare graduates for the challenges that lie ahead.

As well, existing workers need more flexible program pathways in the quest for relevant credentials. Mining companies and academic institutions need to find common ground on what mining education should look like. Academic institutions need to understand industry expectations about what it means to be "job ready" out of school. A stronger presence of mining representatives on academic advisory committees and co-development of training programs would help to strengthen collaboration.

A key challenge for both groups is the rapid rollout of new technologies. Industry experts and technology firms are well-positioned to provide specialized training in the use of new technologies. Academic institutions could focus more on curricula that foster skills in critical thinking, judgment and decision making, teamwork and other competencies that will become increasingly important for future mining workers.

4.2.6 Collaborate and Share Information Across the Industry

The introduction of new technologies comes with benefits, but also with risks. The willingness of companies to collaborate and share information about the risks and rewards they have experienced will ultimately strengthen both individual companies and the industry as a sector.

Mining companies, educational institutions, other industries, suppliers, technology firms, mining associations, and government all have a role to play. Similarly, the mining industry could be more open to learning from other industries, especially regarding their workforce development. Workers from other sectors (such as processing industries) have relevant expertise that could be passed on to the mining sector, including an understanding of specific technologies to ensure that training and skills development planning is fit-to-purpose.

A stronger presence of mining representatives on academic advisory committees and co-development of training programs would help to strengthen collaboration.

Training for Jobs in Mining Automation

"This is not only about retraining existing workers to transition to new jobs, it is also about building on the skills of the people that power Western Australia's diverse industries and developing talent pipelines to ensure the state's workforce is prepared for the changes and opportunities that will emerge."

— Chris Salisbury, Chief Executive, Iron Ore, Rio Tinto

In June 2019, Rio Tinto introduced Australia's first nationally recognized qualifications in automation. Accredited by the Training Accreditation Council (West Australia), the new modular courses offer a pathway to emerging jobs in automation. They are designed to up-skill workers in analytics, robotics and IT — key areas needed to succeed in an increasingly STEM-based industry (science, technology, engineering and math). Rio Tinto is contributing up to A$2 million to the development of the curriculum.

The Vocational Educational Training (VET) curriculum is the result of an historic collaboration between the Western Australian Government, South Metropolitan TAFE,[80] and industry (Rio Tinto, FMG, BHP and Komatsu).[81] The curriculum provides a pathway after high school, complements Rio Tinto's apprenticeship initiative, and is applicable to other industries. Certificate I and II can be used for part of the traineeship and apprenticeship programs, and as a pathway to a university degree.[82]

Automation courses are being introduced at Western Australian TAFE colleges and high schools. A group of Rio Tinto iron ore workers and students (Year 11 and 12) in selected high schools across the state will pilot the Certificate II in Autonomous Workplace Operations. A micro-credential course, Working Effectively in an Automated Workplace, will also be available for trade-qualified, apprentices and technicians. A Certificate IV in Remote Centre Operations is in development.

Rio Tinto, Pilbara, Western Australia

80 South Metropolitan TAFE (formerly known as Challenger Institute of Technology or Challenger TAFE) is a Technical and Further Education (TAFE) institution based in Fremantle, Western Australia.

81 Cecilia Jamasmie (June 13, 2019), "Rio Tinto, Western Australia bring automation to the classroom," Mining.com. Retrieved from https://www.mining.com/rio-tinto-western-australia-bring-automation-to-the-classroom/

82 Many of Australia's TAFE institutes have partnerships with universities that allow students to use their Certificate IV, Diploma or Advanced Diploma qualifications to enter a Bachelor degree program. See TAFEcourses.com.au, TAFE in Australia. Retrieved from https://www.tafecourses.com.au/resources/tafe-in-australia/

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Appendices

APPENDIX 1: WEIGHTING AND AGGREGATION FOR MIHR'S OCCUPATIONAL VULNERABILITY INDEX (MOVI)

The MOVI is constructed using several indicators related to occupational vulnerability. To produce a single composite score that incorporates all indicators, MiHR has chosen to follow the Budget Allocation Process (BAP) methodology detailed in the OECD *Handbook on Constructing Composite Indicators* (2008).

Under this approach, the first step is to gather the data that best describes the key variables. Primary data sources include the 2016 Canadian Census, the Frey & Osborne study, and qualitative research sources. Data is then transformed (for monotonicity of the vulnerability function) and normalized (scaled from 0 to 1) in order to render dimensions comparable.

In accordance with MiHR's theoretical framework, a panel of experts evaluates each key variable for importance. Each expert grants percentage weight values to all 13 indicators. Panel results are averaged to arrive at a final percentage weight for each variable. Indicators are multiplied by their respective weights, then added to arrive at a final composite value: the MOVI.

Themes	Visualization Category (Sub-Themes)	Indicator/Proxy	Data Source
Technological Disruption	Scope of Innovation	Frey & Osborne Automatability Score	2013 Oxford University Study
	Incentives for Adoption	Presence of Technology Disruptive to Occupation: *Analytics*	Qualitative Research
		Presence of Technology Disruptive to Occupation: *Machine Automation*	Qualitative Research
		Presence of Technology Disruptive to Occupation: *Energy Alternatives*	Qualitative Research
		Industry Share of Spend in Occupation	2016 Census
		Presence of Environmentally Beneficial Technology Disruptive to Occupation	Qualitative Research
		Presence of Safety-Improving Technology Disruptive to *Underground Occupations*	Qualitative Research
		Presence of Safety-Improving Technology Disruptive to *Occupation using Heavy Equipment*	Qualitative Research
	Social & Regulatory Obligations	Indigenous Share of Labour Force	2016 Census
		Unionization Rate	2016 Census
Worker Adaptability	Skills Transferability	Distribution of Occupation across all industries	2016 Census
	Labour Mobility	Skill Level Category	2016 Census
		Share of Occupation in Non-Diversified Regions	2016 Census

APPENDIX 2: MOVI COMPOSITE SCORES

The tables below list the 120 NOC codes that MiHR uses to define the occupations considered to be important to the mining industry in Canada, as well as composite MOVI scores and indexed scores for the five sub-themes of MOVI delineated in the theoretical framework.

Broad Occupational Category	MOVI	Scope of Technological Disruption	Incentives for Adoption	Absence of Regulatory & Contractual Constraints	Difficulty of Skills Transferability	Limited Labour Mobility	2016 Census Headcount, NAICS 212
Professional and Physical Sciences Occupations	0.39	0.25	0.37	0.79	0.44	0.37	4,545
Human Resources and Financial Occupations	0.40	0.57	0.17	0.77	0.23	0.34	2,675
Supervisors, Coordinators, and Forepersons	0.43	0.25	0.47	0.72	0.53	0.43	9,635
Support Workers	0.48	0.74	0.18	0.56	0.21	0.56	5,335
Technical Occupations	0.50	0.67	0.37	0.66	0.30	0.44	4,035
Trades Occupations	0.51	0.58	0.68	0.54	0.20	0.40	11,870
Production Occupations	0.69	0.72	0.81	0.58	0.56	0.67	31,635
Mining Industry Average	0.57	0.59	0.61	0.62	0.43	0.54	69,730

NOC Code	NOC Title	Broad Occupational Category	MOVI	Scope of Technological Disruption	Incentives for Adoption	Absence of Regulatory & Contractual Constraints	Difficulty of Skills Transferability	Limited Labour Mobility	2016 Census Headcount, NAICS 212
0013	Senior managers- financial, communications and other business services	Human Resources and Financial Occupations	0.23	0.09	0.00	0.94	0.55	0.15	0
0016	Senior managers - construction, transportation, production and utilities	Supervisors, Coordinators, and Forepersons	0.24	0.09	0.26	0.93	0.14	0.11	640
0111	Financial managers	Human Resources and Financial Occupations	0.20	0.07	0.15	0.87	0.11	0.14	220
0112	Human resources managers	Human Resources and Financial Occupations	0.18	0.01	0.17	0.79	0.05	0.15	400
0113	Purchasing managers	Supervisors, Coordinators, and Forepersons	0.22	0.03	0.28	0.87	0.01	0.16	140
0211	Engineering managers	Supervisors, Coordinators, and Forepersons	0.21	0.02	0.15	0.87	0.32	0.16	125
0711	Construction managers	Supervisors, Coordinators, and Forepersons	0.27	0.07	0.28	0.86	0.51	0.11	210
0714	Facility operation and maintenance managers	Supervisors, Coordinators, and Forepersons	0.48	0.81	0.47	0.84	0.12	0.12	610
0811	Managers in natural resources production and fishing	Supervisors, Coordinators, and Forepersons	0.37	0.36	0.38	0.85	0.29	0.18	1,700
0911	Manufacturing managers	Supervisors, Coordinators, and Forepersons	0.25	0.03	0.40	0.91	0.16	0.07	20
0912	Utilities managers	Supervisors, Coordinators, and Forepersons	0.36	0.31	0.39	0.91	0.49	0.08	10
1111	Financial auditors and accountants	Human Resources and Financial Occupations	0.53	0.94	0.21	0.82	0.41	0.30	820
1112	Financial and investment analysts	Human Resources and Financial Occupations	0.31	0.23	0.13	0.76	0.32	0.37	135
1121	Human resource professionals	Human Resources and Financial Occupations	0.28	0.20	0.16	0.73	0.14	0.34	395
1215	Supervisors, supply chain, tracking and scheduling coordination	Supervisors, Coordinators, and Forepersons	0.25	0.01	0.28	0.59	0.03	0.43	230
1221	Administrative officers	Support Workers	0.50	0.96	0.15	0.61	0.11	0.47	420
1223	Human resources and recruitment officers	Human Resources and Financial Occupations	0.34	0.31	0.12	0.56	0.28	0.50	105
1225	Purchasing agents and officers	Support Workers	0.45	0.77	0.15	0.66	0.03	0.48	445
1241	Administrative assistants	Support Workers	0.50	0.96	0.14	0.62	0.14	0.45	545
1311	Accounting technicians and bookkeepers	Human Resources and Financial Occupations	0.54	0.98	0.12	0.82	0.30	0.43	190
1411	General office support workers	Support Workers	0.53	0.96	0.14	0.59	0.08	0.61	485
1431	Accounting and related clerks	Human Resources and Financial Occupations	0.55	0.98	0.14	0.69	0.13	0.60	410
1452	Correspondence, publication and regulatory clerks	Support Workers	0.53	0.87	0.12	0.64	0.15	0.66	105
1521	Shippers and receivers	Support Workers	0.55	0.98	0.27	0.53	0.03	0.57	225
1523	Production logistics coordinators	Support Workers	0.57	0.88	0.43	0.56	0.00	0.61	325
1524	Purchasing and inventory control workers	Support Workers	0.47	0.77	0.13	0.64	0.04	0.61	140

NOC Code	NOC Title	Broad Occupational Category	MOVI	Scope of Technological Disruption	Incentives for Adoption	Absence of Regulatory & Contractual Constraints	Difficulty of Skills Transferability	Limited Labour Mobility	2016 Census Headcount, NAICS 212
1525	Dispatchers	Support Workers	0.53	0.96	0.14	0.56	0.22	0.58	250
1526	Transportation route and crew schedulers	Support Workers	0.56	0.96	0.25	0.64	0.12	0.59	15
2112	Chemists	Professional and Physical Sciences Occupations	0.30	0.10	0.27	0.74	0.38	0.34	100
2113	Geoscientists and oceanographers	Professional and Physical Sciences Occupations	0.51	0.63	0.45	0.80	0.44	0.33	1,140
2115	Other professional occupations in physical sciences	Professional and Physical Sciences Occupations	0.45	0.43	0.47	0.83	0.33	0.35	130
2121	Biologist and related scientists	Professional and Physical Sciences Occupations	0.32	0.16	0.26	0.83	0.39	0.32	50
2131	Civil engineers	Professional and Physical Sciences Occupations	0.35	0.02	0.48	0.79	0.54	0.29	235
2132	Mechanical engineers	Professional and Physical Sciences Occupations	0.25	0.01	0.17	0.83	0.36	0.30	440
2133	Electrical and electronics engineers	Professional and Physical Sciences Occupations	0.31	0.06	0.29	0.77	0.40	0.37	320
2134	Chemical engineers	Professional and Physical Sciences Occupations	0.24	0.02	0.12	0.83	0.33	0.31	80
2141	Industrial and manufacturing engineers	Professional and Physical Sciences Occupations	0.26	0.03	0.26	0.83	0.22	0.29	40
2142	Metallurgical and materials engineers	Professional and Physical Sciences Occupations	0.32	0.02	0.48	0.83	0.35	0.25	140
2143	Mining engineers	Professional and Physical Sciences Occupations	0.42	0.14	0.49	0.81	0.49	0.46	1,360
2144	Geological engineers	Professional and Physical Sciences Occupations	0.38	0.14	0.33	0.83	0.83	0.28	95
2145	Petroleum engineers	Professional and Physical Sciences Occupations	0.32	0.16	0.12	0.83	0.52	0.37	10
2147	Computer engineers (except software engineers and designers)	Professional and Physical Sciences Occupations	0.34	0.22	0.12	0.83	0.41	0.42	30
2148	Other professional engineers, n.e.c.	Professional and Physical Sciences Occupations	0.27	0.11	0.12	0.83	0.34	0.31	0
2152	Landscape architects	Professional and Physical Sciences Occupations	0.29	0.05	0.12	0.83	0.73	0.29	0
2153	Urban and land use planners	Professional and Physical Sciences Occupations	0.26	0.13	0.12	0.56	0.48	0.32	55
2154	Land surveyors	Technical Occupations	0.51	0.38	0.61	0.83	0.71	0.30	170
2171	Information systems analysts and consultants	Technical Occupations	0.29	0.11	0.15	0.77	0.41	0.37	315
2173	Software engineers and designers	Professional and Physical Sciences Occupations	0.32	0.09	0.12	0.83	0.55	0.44	0
2174	Computer programmers and interactive media developers	Professional and Physical Sciences Occupations	0.29	0.05	0.12	0.83	0.52	0.37	55
2211	Chemical technologists and technicians	Technical Occupations	0.45	0.57	0.29	0.64	0.27	0.46	385
2212	Geological and mineral technologists and technicians	Technical Occupations	0.62	0.91	0.58	0.62	0.30	0.46	1,620
2221	Biological technologists and technicians	Technical Occupations	0.36	0.30	0.25	0.70	0.29	0.41	0
2223	Forestry technologists and technicians	Technical Occupations	0.39	0.42	0.25	0.70	0.33	0.37	0
2231	Civil engineering technologists and technicians	Technical Occupations	0.51	0.75	0.33	0.64	0.43	0.41	175
2232	Mechanical engineering technologists and technicians	Technical Occupations	0.38	0.38	0.27	0.70	0.24	0.42	120
2233	Industrial engineering and manufacturing technologists and technicians	Technical Occupations	0.21	0.03	0.12	0.52	0.14	0.42	55
2234	Construction estimators	Support Workers	0.47	0.57	0.32	0.70	0.43	0.41	10
2241	Electrical and electronics engineering technologists and technicians	Technical Occupations	0.47	0.84	0.14	0.61	0.16	0.44	315
2243	Industrial instrument technicians and mechanics	Technical Occupations	0.42	0.67	0.16	0.65	0.14	0.43	455
2253	Drafting technologists and technicians	Technical Occupations	0.49	0.67	0.27	0.70	0.49	0.40	75
2254	Land survey technologists and technicians	Technical Occupations	0.63	0.96	0.40	0.70	0.72	0.38	55
2255	Technical occupations in geomatics and meteorology	Technical Occupations	0.42	0.42	0.27	0.70	0.37	0.48	70
2261	Non-destructive testers and inspection technicians	Support Workers	0.57	0.80	0.46	0.70	0.48	0.40	30
2262	Engineering inspectors and regulatory officers	Support Workers	0.42	0.61	0.12	0.70	0.22	0.48	10
2263	Inspectors in public and environmental health and occupational health and safety	Support Workers	0.26	0.08	0.18	0.60	0.13	0.45	710
2264	Construction inspectors	Supervisors, Coordinators, and Forepersons	0.48	0.63	0.32	0.70	0.34	0.42	55
2271	Air pilots, flight engineers and flying instructors	Professional and Physical Sciences Occupations	0.44	0.18	0.40	0.70	0.90	0.44	0
2274	Engineer officers, water transport	Professional and Physical Sciences Occupations	0.28	0.01	0.25	0.70	0.44	0.35	0
2281	Computer network technicians	Technical Occupations	0.26	0.03	0.13	0.70	0.23	0.49	150
4161	Natural and applied science policy researchers, consultants and program officers	Professional and Physical Sciences Occupations	0.31	0.33	0.03	0.50	0.36	0.45	265
4212	Social and community service workers	Support Workers	0.18	0.01	0.00	0.31	0.39	0.41	35
6221	Technical sales specialists- wholesale trade	Technical Occupations	0.31	0.25	0.01	0.93	0.22	0.45	75
6322	Cooks	Support Workers	0.48	0.83	0.01	0.43	0.85	0.42	185

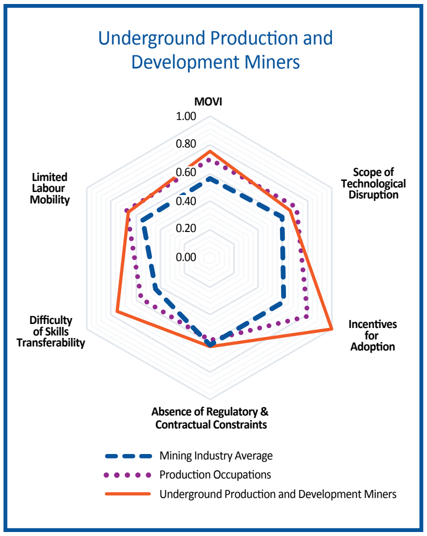
NOC Code	NOC Title	Broad Occupational Category	MOVI	Scope of Technological Disruption	Incentives for Adoption	Absence of Regulatory & Contractual Constraints	Difficulty of Skills Transferability	Limited Labour Mobility	2016 Census Headcount, NAICS 212
6521	Travel counsellors	Support Workers	0.41	0.10	0.40	0.15	1.00	0.62	20
6541	Security guards and related security service occupations	Support Workers	0.58	0.84	0.14	0.59	0.70	0.65	425
6733	Janitors, caretakers and building superintendents	Support Workers	0.49	0.66	0.19	0.41	0.28	0.76	840
7201	Contractors and supervisors, machining, metal forming, shaping and erecting trades and related occupations	Supervisors, Coordinators, and Forepersons	0.37	0.17	0.61	0.44	0.27	0.36	75
7203	Contractors and supervisors, pipefitting trades	Supervisors, Coordinators, and Forepersons	0.40	0.17	0.46	0.58	0.69	0.40	35
7204	Contractors and supervisors, carpentry trades	Supervisors, Coordinators, and Forepersons	0.38	0.17	0.34	0.58	0.68	0.42	10
7205	Contractors and supervisors, other construction trades, installers, repairers and servicers	Supervisors, Coordinators, and Forepersons	0.40	0.17	0.47	0.41	0.74	0.43	90
7231	Machinists and machining and tool inspectors	Trades Occupations	0.47	0.65	0.41	0.42	0.38	0.38	165
7235	Structural metal and platework fabricators and fitters	Trades Occupations	0.44	0.41	0.54	0.58	0.40	0.32	30
7236	Ironworkers	Trades Occupations	0.49	0.87	0.29	0.33	0.44	0.35	60
7237	Welders and related machine operators	Trades Occupations	0.62	0.94	0.75	0.48	0.25	0.35	1,560
7241	Electricians	Trades Occupations	0.42	0.15	0.46	0.58	0.92	0.39	55
7242	Industrial electricians	Trades Occupations	0.39	0.15	0.69	0.49	0.20	0.40	2,295
7251	Plumbers	Trades Occupations	0.36	0.35	0.01	0.47	0.96	0.40	95
7252	Steamfitter, pipefitter and sprinkler system installer	Trades Occupations	0.40	0.35	0.46	0.48	0.47	0.33	100
7271	Carpenters	Trades Occupations	0.47	0.72	0.22	0.40	0.64	0.40	230
7301	Contractors and supervisors, mechanic trades	Supervisors, Coordinators, and Forepersons	0.52	0.68	0.49	0.63	0.26	0.42	240
7302	Contractors and supervisors, heavy equipment operator crews	Supervisors, Coordinators, and Forepersons	0.54	0.72	0.48	0.59	0.40	0.42	200
7311	Construction millwrights and industrial mechanics	Trades Occupations	0.53	0.63	0.72	0.58	0.09	0.40	4,745
7312	Heavy-duty equipment mechanics	Trades Occupations	0.55	0.67	0.68	0.59	0.20	0.44	2,215
7321	Automotive service technicians, truck and bus mechanics and mechanical repairers	Trades Occupations	0.56	0.59	0.63	0.62	0.54	0.42	320
7371	Crane operators	Production Occupations	0.52	0.90	0.31	0.55	0.31	0.37	255
7372	Drillers and blasters- surface mining, quarrying and construction	Production Occupations	0.58	0.67	0.77	0.56	0.41	0.38	380
7452	Material handlers	Production Occupations	0.62	0.85	0.67	0.61	0.08	0.58	1,125
7511	Transport truck drivers	Production Occupations	0.64	0.79	0.63	0.51	0.56	0.56	3,455
7521	Heavy equipment operators (except crane)	Production Occupations	0.73	0.89	0.86	0.51	0.33	0.71	6,830
7611	Construction trades helpers and labourers	Production Occupations	0.64	0.88	0.36	0.54	0.49	0.74	895
7612	Other trades helpers and labourers	Production Occupations	0.59	0.88	0.33	0.52	0.21	0.73	255
8221	Supervisors, mining and quarrying	Supervisors, Coordinators, and Forepersons	0.51	0.17	0.58	0.67	0.80	0.64	4,815
8231	Underground production and development miners	Production Occupations	0.75	0.67	1.00	0.62	0.76	0.66	11,035
8411	Underground mine service and support workers	Production Occupations	0.63	0.37	0.74	0.79	0.57	0.79	1,760
8614	Mine labourers	Production Occupations	0.73	0.37	0.89	0.62	0.77	1.00	2,550
9211	Supervisors, mineral and metal processing	Supervisors, Coordinators, and Forepersons	0.24	0.02	0.15	0.57	0.43	0.36	390
9212	Supervisors, petroleum, gas and chemical processing and utilities	Supervisors, Coordinators, and Forepersons	0.25	0.02	0.12	0.69	0.30	0.43	40
9231	Central control and process operators, mineral and metal processing	Production Occupations	0.50	0.62	0.44	0.57	0.47	0.40	445
9241	Power engineers and power systems operators	Production Occupations	0.54	0.90	0.32	0.58	0.25	0.45	620
9243	Water and waste treatment plant operators	Production Occupations	0.40	0.61	0.13	0.45	0.45	0.40	125
9411	Machine operators, mineral and metal processing	Production Occupations	0.65	0.88	0.62	0.50	0.54	0.55	1,020
9412	Foundry workers	Production Occupations	0.59	0.67	0.46	0.64	0.71	0.54	40
9415	Inspectors and testers, mineral and metal processing	Support workers	0.54	0.98	0.12	0.55	0.32	0.54	115
9416	Metalworking and forging machine operators	Production Occupations	0.58	0.86	0.54	0.30	0.36	0.54	30
9417	Machining tool operators	Production Occupations	0.63	0.88	0.54	0.64	0.37	0.54	35
9418	Other metal products machine operators	Production Occupations	0.62	0.89	0.54	0.47	0.42	0.56	60
9423	Rubber processing machine operators and related workers	Production Occupations	0.55	0.85	0.28	0.34	0.64	0.52	245
9611	Labourers in mineral and metal processing	Production Occupations	0.52	0.66	0.27	0.56	0.38	0.68	235
9612	Labourers in metal fabrication	Production Occupations	0.59	0.66	0.54	0.43	0.42	0.70	45
9619	Other labourers in processing, manufacturing and utilities	Production Occupations	0.54	0.66	0.41	0.51	0.15	0.75	195

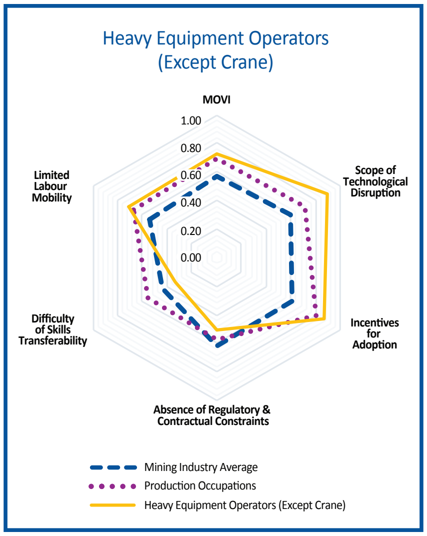
APPENDIX 3: MOVI SPIDER CHARTS FOR INDIVIDUAL OCCUPATIONS

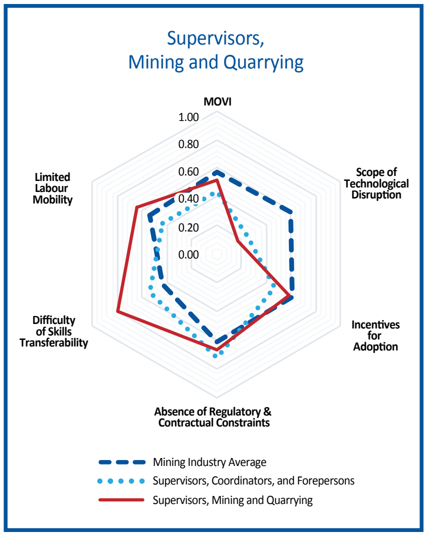
Below are a series of spider (or radar) charts presenting a holistic picture of occupational vulnerability as detailed in MiHR's theoretical framework (see Figure 2.2). Each chart represents one of 13 occupations of interest to this study.

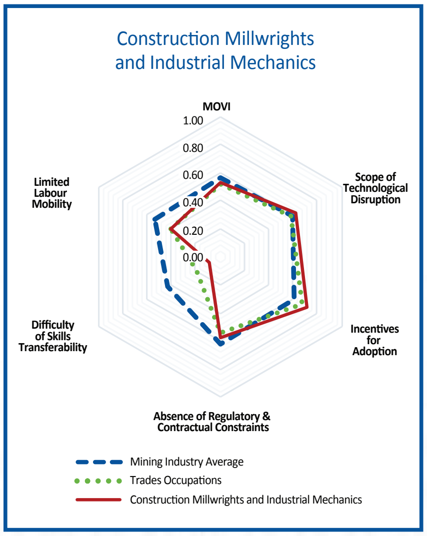
At the top of the wheel is the estimated MOVI score for the occupation; the other axes correspond to the five sub-themes of occupational vulnerability. Data has been normalized (to range from 0 to 1) and transformed (to ensure monotonicity): a score closer to 1 indicates greater vulnerability compared to other occupations.

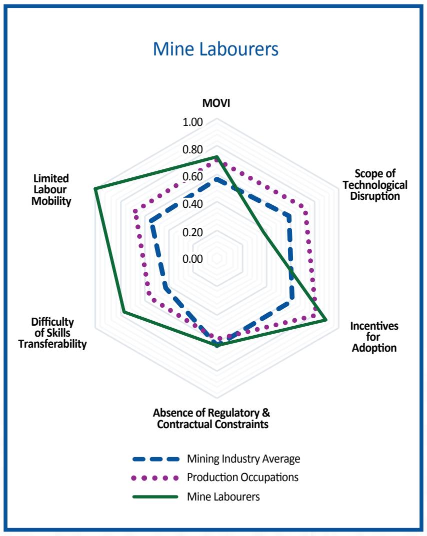
A larger area denotes higher exposure and greater vulnerability across more factors – meaning the workers in the occupation are comparatively susceptible to the negative aspects of technological change. Each occupational score is benchmarked against its broad occupational category and against the mining industry *(NAICS 212 Mining and quarrying)* as a whole.

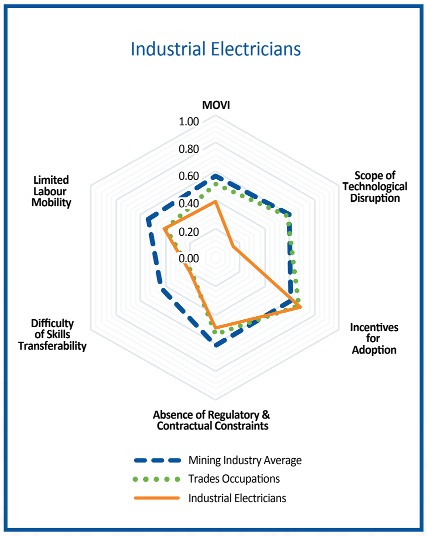




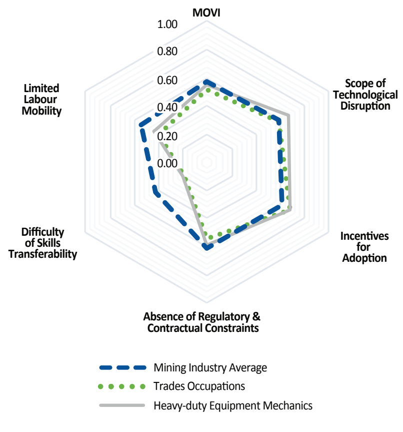




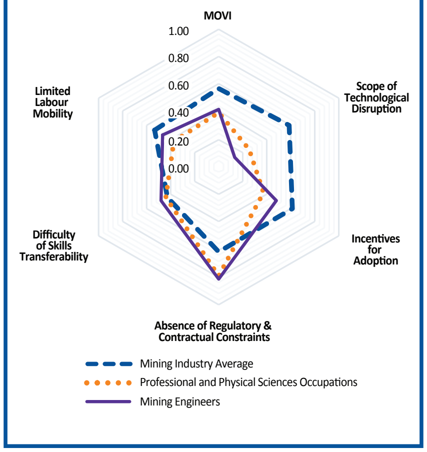




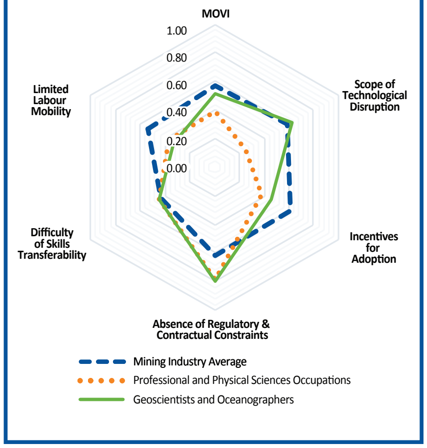
Heavy-duty Equipment Mechanics



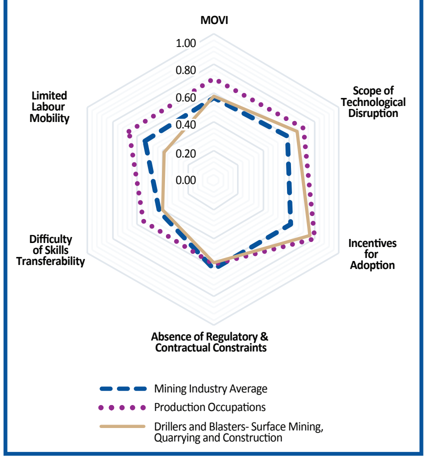
Mining Engineers



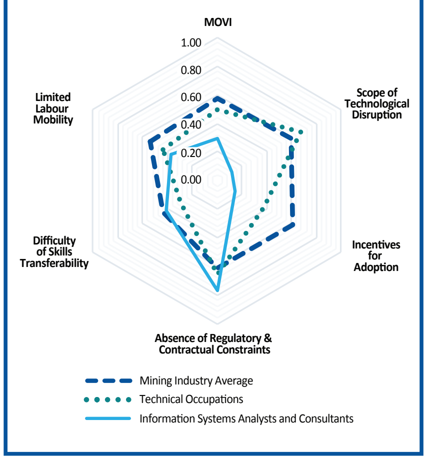
Geoscientists and Oceanographers



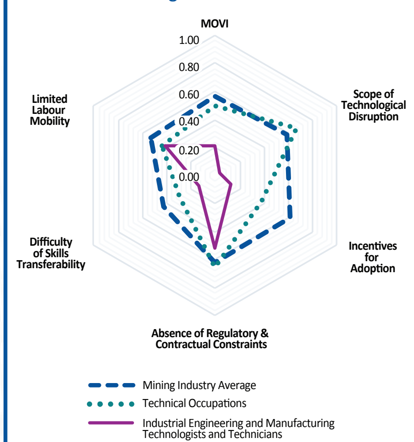
Drillers and Blasters - Surface Mining, Quarrying and Construction



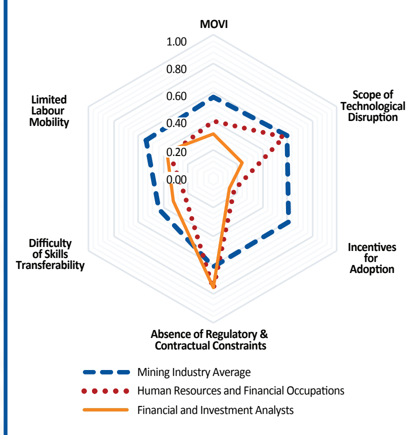
Information Systems Analysts and Consultants



Industrial Engineering and Manufacturing Technologists and Technicians



Financial and Investment Analysts



APPENDIX 4: SKILLS-TO-OCCUPATIONS MAPPING

A detailed skills-to-occupation mapping is provided in the following table. A total of 120 mining-related occupations of interest are mapped to the 10 skills selected for this analysis. These skills are exactly defined according to the O*Net Online database. For each of the 120 occupations, the table reports: (1) O*Net scores for "importance" and "level," (2) how they translate to binary scores in the "baseline" scenario, and (3) how the baseline binary score has been modified in the "innovation" scenario to align with MiHR's qualitative findings on future skill needs.

		Programming			Troubleshooting			Writing			Operation and Control			Active Learning		
NOC Code	NOC Title	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario
0013	Senior managers- financial, communications and other business services	1.58, 0.71	0	0	1.37, 0.50	0	0	3.71, 4.21	1	1	1.79, 1.50	0	0	3.67, 4.04	1	1
0016	Senior managers - construction, transportation, production and utilities	1.58, 0.71	0	0	1.37, 0.50	0	1	3.71, 4.21	1	1	1.79, 1.50	0	0	3.67, 4.04	1	1
0111	Financial managers	1.67, 0.92	0	0	1.08, 0.13	0	0	3.79, 4.04	1	1	1.25, 0.33	0	0	3.75, 4.04	1	1
0112	Human resources managers	1.75, 1.38	0	0	1.00, 0.00	0	0	3.88, 4.00	1	1	1.25, 0.25	0	0	3.75, 4.00	1	1
0113	Purchasing managers	1.75, 1.00	0	0	1.62, 0.88	0	0	3.82, 4.00	1	1	1.00, 0.00	0	0	3.57, 3.82	1	1
0211	Engineering managers	2.00, 1.38	0	0	1.88, 1.88	0	0	3.62, 4.12	1	1	1.88, 1.50	0	1	3.50, 4.25	1	1
0711	Construction managers	1.50, 0.62	0	0	2.00, 2.25	0	0	3.38, 4.00	1	1	2.12, 2.12	0	0	3.62, 3.88	1	1
0714	Facility operation and maintenance managers	1.50, 0.50	0	0	1.62, 0.75	0	1	3.50, 3.88	1	1	1.50, 0.62	0	1	3.00, 3.38	1	1
0811	Managers in natural resources production and fishing	1.62, 0.83	0	0	2.04, 1.79	0	0	3.37, 3.92	1	1	2.17, 2.25	0	0	3.58, 4.00	1	1
0911	Manufacturing managers	1.69, 0.94	0	0	2.07, 1.56	0	0	3.37, 3.88	1	1	2.19, 2.31	0	0	3.56, 4.06	1	1
0912	Utilities managers	2.00, 1.40	0	0	2.63, 2.67	0	1	3.50, 3.75	1	1	2.80, 2.95	0	0	3.35, 3.47	1	1
1111	Financial auditors and accountants	1.63, 1.00	0	0	1.13, 0.19	0	0	3.75, 3.63	1	1	1.00, 0.00	0	0	3.31, 3.50	1	1
1112	Financial and investment analysts	1.88, 1.12	0	0	1.38, 0.38	0	0	3.75, 4.12	1	1	1.12, 0.25	0	0	3.50, 3.88	1	1
1121	Human resource professionals	1.60, 0.90	0	0	1.00, 0.00	0	0	3.83, 4.15	1	1	1.17, 0.22	0	0	3.50, 3.73	1	1
1215	Supervisors, supply chain, tracking and scheduling coordination	1.62, 0.75	0	0	1.88, 1.12	0	1	3.62, 3.88	1	1	2.00, 1.62	0	0	3.62, 4.12	1	1
1221	Administrative officers	1.62, 0.75	0	0	1.00, 0.00	0	0	3.75, 3.50	1	1	1.25, 0.25	0	0	2.88, 3.00	0	0
1223	Human resources and recruitment officers	1.62, 0.62	0	0	1.00, 0.00	0	0	3.88, 4.00	1	1	1.12, 0.12	0	0	3.25, 3.38	1	1
1225	Purchasing agents and officers	1.25, 0.38	0	0	1.62, 0.75	0	0	3.75, 3.75	1	1	1.00, 0.00	0	1	3.75, 3.88	1	1
1241	Administrative assistants	1.62, 0.75	0	0	1.00, 0.00	0	0	3.75, 3.50	1	1	1.25, 0.25	0	0	2.88, 3.00	0	0
1311	Accounting technicians and bookkeepers	1.38, 0.38	0	0	1.00, 0.00	0	0	3.12, 3.12	1	1	1.12, 0.12	0	0	2.75, 3.12	0	0
1411	General office support workers	1.25, 0.38	0	0	1.50, 0.50	0	0	3.12, 3.12	1	1	1.38, 0.38	0	0	2.75, 2.75	0	0
1431	Accounting and related clerks	1.38, 0.38	0	0	1.00, 0.00	0	0	3.12, 3.12	1	1	1.12, 0.12	0	0	2.75, 3.12	0	0
1452	Correspondence, publication and regulatory clerks	1.50, 0.50	0	0	1.00, 0.00	0	0	4.00, 4.00	1	1	1.25, 0.25	0	0	2.62, 2.75	0	1
1521	Shippers and receivers	1.62, 0.62	0	0	2.00, 1.25	0	0	2.62, 2.75	0	0	2.00, 2.00	0	0	2.38, 2.12	0	0
1523	Production logistics coordinators	1.62, 0.62	0	0	1.88, 0.88	0	0	3.38, 3.12	1	1	1.75, 1.00	0	1	2.62, 2.88	0	1
1524	Purchasing and inventory control workers	1.38, 0.50	0	0	1.12, 0.25	0	0	3.75, 3.25	1	1	1.12, 0.25	0	0	3.25, 3.50	1	1
1525	Dispatchers	1.50, 0.63	0	0	2.00, 1.54	0	0	3.25, 3.21	1	1	1.58, 0.67	0	0	3.00, 2.92	0	0
1526	Transportation route and crew schedulers	1.25, 0.25	0	0	1.88, 1.00	0	0	3.25, 3.00	1	1	1.00, 0.00	0	1	3.00, 3.00	1	1
2112	Chemists	2.12, 1.75	0	0	2.75, 2.62	0	0	3.62, 4.75	1	1	2.38, 2.50	0	1	3.38, 4.12	1	1
2113	Geoscientists and oceanographers	2.38, 1.88	0	0	1.75, 1.12	0	0	3.75, 4.50	1	1	2.00, 2.12	0	0	3.25, 3.62	1	1
2115	Other professional occupations in physical sciences	2.12, 1.88	0	0	2.00, 2.00	0	0	3.75, 4.38	1	1	2.12, 2.00	0	0	3.25, 4.50	1	1
2121	Biologist and related scientists	1.98, 1.90	0	0	1.72, 1.30	0	0	3.90, 4.38	1	1	2.05, 1.93	0	0	3.63, 3.90	1	1
2131	Civil engineers	2.06, 2.25	0	0	1.69, 1.31	0	0	3.44, 3.94	1	1	1.63, 0.75	0	1	3.38, 4.25	1	1
2132	Mechanical engineers	2.62, 2.82	0	0	2.75, 3.16	0	0	3.56, 3.91	1	1	2.57, 2.79	0	1	3.44, 4.35	1	1
2133	Electrical and electronics engineers	2.31, 2.19	0	0	3.00, 3.06	1	1	3.82, 3.94	1	1	2.00, 1.62	0	1	3.44, 3.57	1	1
2134	Chemical engineers	2.17, 2.21	0	0	2.67, 2.87	0	0	3.58, 4.04	1	1	2.42, 2.29	0	0	3.63, 4.12	1	1
2141	Industrial and manufacturing engineers	1.85, 1.66	0	0	2.75, 2.72	0	0	3.72, 4.10	1	1	2.19, 2.13	0	0	3.53, 3.88	1	1
2142	Metallurgical and materials engineers	2.12, 1.88	0	0	2.00, 2.00	0	0	3.75, 4.38	1	1	2.12, 2.00	0	0	3.25, 4.50	1	1
2143	Mining engineers	2.62, 3.00	0	0	1.88, 1.88	0	0	4.00, 4.25	1	1	2.00, 2.00	0	0	3.50, 4.12	1	1
2144	Geological engineers	2.62, 3.00	0	0	1.88, 1.88	0	0	4.00, 4.25	1	1	2.00, 2.00	0	0	3.50, 4.12	1	1
2145	Petroleum engineers	1.75, 1.38	0	0	2.00, 2.12	0	0	3.88, 4.12	1	1	2.12, 2.25	0	0	3.50, 3.75	1	1
2147	Computer engineers (except software engineers and designers)	2.94, 3.31	0	1	2.56, 2.81	0	1	3.75, 4.06	1	1	1.50, 0.69	0	1	3.69, 3.94	1	1
2148	Other professional engineers, n.e.c.	2.22, 1.99	0	0	2.49, 2.61	0	0	3.76, 4.20	1	1	2.22, 2.12	0	0	3.51, 4.20	1	1
2152	Landscape architects	1.38, 0.50	0	0	2.00, 1.12	0	0	3.62, 3.75	1	1	2.00, 1.62	0	0	3.50, 3.75	1	1
2153	Urban and land use planners	1.69, 1.06	0	0	1.00, 0.00	0	0	3.50, 3.81	1	1	1.50, 0.87	0	0	3.25, 3.56	1	1
2154	Land surveyors	2.13, 2.25	0	0	2.06, 1.75	0	0	3.44, 3.94	1	1	2.82, 2.69	0	0	3.25, 3.63	1	1
2171	Information systems analysts and consultants	2.92, 3.00	0	1	2.01, 1.95	0	0	3.66, 3.95	1	1	1.63, 1.00	0	1	3.55, 4.02	1	1
2173	Software engineers and designers	3.19, 3.25	1	1	2.07, 2.32	0	1	3.00, 3.31	1	1	1.63, 1.32	0	1	2.94, 3.31	0	1
2174	Computer programmers and interactive media developers	4.75, 4.88	1	1	2.25, 1.62	0	1	3.25, 3.25	1	1	1.12, 0.25	0	1	3.12, 3.25	1	1
2211	Chemical technologists and technicians	1.50, 0.62	0	0	2.88, 2.75	0	0	3.62, 3.75	1	1	2.88, 2.75	0	0	3.00, 3.12	1	1
2212	Geological and mineral technologists and technicians	1.75, 1.06	0	0	2.44, 2.32	0	0	3.25, 3.38	1	1	2.69, 2.82	0	0	2.81, 2.87	0	1
2221	Biological technologists and technicians	1.88, 1.75	0	0	2.62, 2.62	0	0	3.38, 3.75	1	1	2.62, 2.75	0	0	3.50, 3.88	1	1
2223	Forestry technologists and technicians	1.67, 1.00	0	0	2.09, 2.04	0	0	3.12, 3.54	1	1	2.83, 2.92	0	0	3.38, 3.50	1	1
2231	Civil engineering technologists and technicians	1.88, 1.00	0	0	1.75, 0.88	0	0	3.25, 3.50	1	1	2.12, 2.00	0	0	2.88, 3.00	0	1
2232	Mechanical engineering technologists and technicians	2.00, 1.50	0	0	3.13, 3.31	1	1	3.44, 3.50	1	1	3.25, 3.25	1	1	3.25, 3.25	1	1
2233	Industrial engineering and manufacturing technologists and technicians	2.06, 1.81	0	0	2.60, 2.84	0	0	3.12, 3.50	1	1	2.63, 2.50	0	0	3.13, 3.50	1	1
2234	Construction estimators	1.88, 1.62	0	0	1.00, 0.00	0	0	3.50, 3.75	1	1	1.12, 0.12	0	1	3.25, 3.88	1	1

		Programming			Troubleshooting			Writing			Operation and Control			Active Learning		
NOC Code	NOC Title	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario
2241	Electrical and electronics engineering technologists and technicians	2.25, 1.98	0	1	3.25, 3.50	1	1	3.12, 3.37	1	1	2.72, 2.80	0	0	3.17, 3.48	1	1
2243	Industrial instrument technicians and mechanics	2.00, 1.75	0	0	3.88, 3.88	1	1	2.75, 2.88	0	0	3.62, 3.62	1	1	2.88, 3.00	0	1
2253	Drafting technologists and technicians	1.97, 1.42	0	0	1.65, 0.85	0	0	3.12, 3.30	1	1	1.50, 0.62	0	0	3.03, 3.23	1	0
2254	Land survey technologists and technicians	1.38, 0.50	0	0	2.62, 2.25	0	0	3.12, 3.12	1	1	3.00, 3.00	1	1	2.88, 2.88	0	0
2255	Technical occupations in geomatics and meteorology	2.72, 3.00	0	1	1.72, 1.22	0	0	3.34, 3.78	1	1	1.85, 1.50	0	0	3.31, 3.47	1	1
2261	Non-destructive testers and inspection technicians	1.63, 0.81	0	0	2.44, 2.32	0	1	3.07, 3.00	1	1	2.81, 2.75	0	0	3.00, 2.88	0	0
2262	Engineering inspectors and regulatory officers	1.50, 0.50	0	0	1.88, 1.75	0	0	2.88, 2.88	0	1	2.62, 2.50	0	0	2.38, 2.25	0	1
2263	Inspectors in public and environmental health and occupational health and safety	1.88, 1.62	0	0	2.12, 2.12	0	0	3.62, 4.12	1	1	2.50, 2.62	0	0	3.62, 4.12	1	1
2264	Construction inspectors	1.50, 0.50	0	0	2.12, 2.00	0	0	3.38, 3.38	1	1	2.25, 2.25	0	0	3.12, 3.25	1	1
2271	Air pilots, flight engineers and flying instructors	1.88, 1.12	0	0	3.12, 3.25	1	1	3.12, 3.38	1	1	4.88, 5.62	1	1	3.75, 4.00	1	1
2274	Engineer officers, water transport	1.75, 0.75	0	0	3.75, 3.75	1	1	3.12, 2.88	0	0	3.88, 3.62	1	1	3.00, 3.12	1	1
2281	Computer network technicians	3.37, 3.38	1	1	3.13, 3.50	1	1	3.19, 3.57	1	1	2.38, 2.37	0	1	3.12, 3.75	1	1
4161	Natural and applied science policy researchers, consultants and program officers	2.04, 1.81	0	0	1.81, 1.50	0	0	3.75, 4.13	1	1	1.60, 0.91	0	0	3.35, 3.66	1	1
4212	Social and community service workers	1.50, 0.58	0	0	1.42, 0.50	0	0	3.50, 3.71	1	1	1.58, 0.87	0	0	3.25, 3.58	1	1
6221	Technical sales specialists- wholesale trade	1.81, 0.88	0	0	1.31, 0.56	0	0	3.32, 3.50	1	1	1.88, 1.38	0	0	3.31, 3.57	1	1
6322	Cooks	1.00, 0.00	0	0	2.00, 1.12	0	0	2.75, 2.62	0	0	2.88, 2.00	0	0	2.88, 2.88	0	0
6521	Travel counsellors	1.75, 0.75	0	0	1.00, 0.00	0	0	3.12, 3.00	1	0	1.62, 0.62	0	0	3.12, 3.12	1	0
6541	Security guards and related security service occupations	1.47, 0.72	0	0	1.91, 1.34	0	0	3.06, 3.07	1	1	1.84, 1.50	0	0	3.10, 2.81	0	0
6733	Janitors, caretakers and building superintendents	1.00, 0.00	0	0	2.00, 1.62	0	0	2.00, 1.50	0	0	2.00, 1.38	0	0	2.50, 2.00	0	0
7201	Contractors and supervisors, machining, metal forming, shaping and erecting trades and related occupations	1.25, 0.25	0	0	2.38, 2.38	0	0	3.00, 3.00	1	1	2.88, 3.00	0	0	3.12, 3.00	1	1
7203	Contractors and supervisors, pipefitting trades	1.25, 0.25	0	0	2.38, 2.38	0	0	3.00, 3.00	1	1	2.88, 3.00	0	0	3.12, 3.00	1	1
7204	Contractors and supervisors, carpentry trades	1.25, 0.25	0	0	2.38, 2.38	0	0	3.00, 3.00	1	1	2.88, 3.00	0	0	3.12, 3.00	1	1
7205	Contractors and supervisors, other construction trades, installers, repairers and servicers	1.50, 0.63	0	0	2.50, 2.57	0	0	3.19, 3.19	1	1	2.75, 2.81	0	0	3.19, 3.13	1	1
7231	Machinists and machining and tool inspectors	1.62, 1.12	0	0	2.75, 2.75	0	1	2.75, 2.75	0	1	3.12, 3.25	1	1	2.75, 2.88	0	1
7235	Structural metal and platework fabricators and fitters	1.00, 0.00	0	0	2.25, 2.00	0	0	2.00, 2.00	0	0	2.50, 2.38	0	0	2.25, 1.62	0	0
7236	Ironworkers	1.00, 0.00	0	0	2.25, 1.82	0	0	2.07, 2.00	0	0	3.25, 2.94	0	0	2.69, 2.44	0	0
7237	Welders and related machine operators	1.16, 0.21	0	0	2.29, 2.17	0	0	2.12, 1.83	0	0	2.83, 2.71	0	1	2.29, 2.13	0	0
7241	Electricians	1.00, 0.00	0	0	3.62, 4.00	1	1	2.88, 3.00	0	0	3.00, 3.00	1	1	3.12, 3.25	1	1
7242	Industrial electricians	1.38, 0.38	0	0	3.94, 4.00	1	1	2.82, 2.94	0	0	3.19, 3.06	1	1	3.06, 3.07	1	1
7251	Plumbers	1.00, 0.00	0	0	3.12, 3.00	1	1	2.62, 2.75	0	0	3.00, 3.00	1	1	3.00, 3.00	1	1
7252	Steamfitter, pipefitter and sprinkler system installer	1.12, 0.25	0	0	2.75, 2.75	0	0	2.38, 2.75	0	0	2.75, 2.50	0	0	3.00, 3.00	1	1
7271	Carpenters	1.62, 0.75	0	0	3.00, 2.88	0	0	2.38, 2.38	0	0	3.12, 2.88	0	0	2.75, 2.75	0	0
7301	Contractors and supervisors, mechanic trades	1.57, 0.69	0	0	3.13, 3.19	1	1	2.94, 2.88	0	1	3.32, 3.31	1	1	3.06, 3.00	1	1
7302	Contractors and supervisors, heavy equipment operator crews	1.25, 0.25	0	0	2.38, 2.38	0	1	3.00, 3.00	1	1	2.88, 3.00	0	1	3.12, 3.00	1	1
7311	Construction millwrights and industrial mechanics	1.81, 1.19	0	0	3.75, 3.88	1	1	2.75, 2.88	0	0	3.50, 3.56	1	1	2.88, 3.06	0	0
7312	Heavy-duty equipment mechanics	1.62, 0.62	0	0	4.12, 4.00	1	1	3.00, 2.88	0	0	3.62, 3.38	1	1	3.00, 3.00	1	1
7321	Automotive service technicians, truck and bus mechanics and mechanical repairers	1.83, 1.17	0	0	3.54, 3.54	1	1	2.96, 2.83	0	0	3.38, 3.21	1	1	3.00, 3.04	1	1
7371	Crane operators	1.00, 0.00	0	0	2.83, 2.87	0	1	2.46, 2.34	0	0	3.71, 3.37	1	1	2.79, 2.55	0	0
7372	Drillers and blasters- surface mining, quarrying and construction	1.00, 0.00	0	0	3.00, 3.00	1	1	2.38, 2.38	0	0	3.88, 4.00	1	1	2.75, 2.25	0	0
7452	Material handlers	1.08, 0.08	0	0	2.63, 2.63	0	0	2.67, 2.54	0	0	3.46, 3.25	1	1	2.66, 2.58	0	0
7511	Transport truck drivers	1.12, 0.12	0	0	3.00, 2.75	0	0	2.75, 2.50	0	0	3.88, 3.50	1	1	2.75, 2.25	0	0
7521	Heavy equipment operators (except crane)	1.08, 0.08	0	0	2.98, 2.85	0	1	2.15, 1.98	0	0	3.87, 3.47	1	1	2.58, 2.37	0	0
7611	Construction trades helpers and labourers	1.04, 0.04	0	0	2.67, 2.67	0	0	2.17, 2.08	0	0	3.25, 3.00	1	1	2.38, 2.08	0	0
7612	Other trades helpers and labourers	1.38, 0.62	0	0	3.12, 2.88	0	0	2.12, 1.75	0	0	3.00, 3.12	1	1	2.88, 2.62	0	0
8221	Supervisors, mining and quarrying	1.25, 0.25	0	0	2.38, 2.38	0	0	3.00, 3.00	1	1	2.88, 3.00	0	0	3.12, 3.00	1	1
8231	Underground production and development miners	1.09, 0.11	0	0	3.05, 2.94	0	0	2.45, 2.42	0	0	3.61, 3.45	1	1	2.77, 2.59	0	0
8411	Underground mine service and support workers	1.00, 0.00	0	0	3.38, 3.00	1	1	2.38, 2.25	0	0	3.50, 3.00	1	1	2.88, 2.62	0	0
8614	Mine labourers	1.00, 0.00	0	0	3.38, 3.00	1	1	2.38, 2.25	0	0	3.50, 3.00	1	1	2.88, 2.62	0	0
9211	Supervisors, mineral and metal processing	1.12, 0.25	0	0	2.38, 2.50	0	0	3.25, 3.75	1	1	2.50, 2.62	0	0	3.12, 3.25	1	1
9212	Supervisors, petroleum, gas and chemical processing and utilities	1.12, 0.25	0	0	2.38, 2.50	0	0	3.25, 3.75	1	1	2.50, 2.62	0	0	3.12, 3.25	1	1
9231	Central control and process operators, mineral and metal processing	1.00, 0.00	0	1	2.88, 2.75	0	1	2.75, 2.75	0	0	3.75, 3.75	1	1	2.88, 2.12	0	1
9241	Power engineers and power systems operators	1.59, 0.64	0	0	3.00, 3.03	0	1	2.88, 2.70	0	1	3.74, 3.61	1	1	2.86, 2.81	0	1
9243	Water and waste treatment plant operators	1.62, 0.62	0	0	3.25, 3.25	1	1	2.88, 2.88	0	0	3.75, 3.25	1	1	2.88, 3.12	0	0
9411	Machine operators, mineral and metal processing	1.00, 0.00	0	0	2.88, 2.75	0	0	2.75, 2.75	0	0	3.75, 3.75	1	1	2.88, 2.12	0	0
9412	Foundry workers	1.00, 0.00	0	0	2.57, 2.44	0	0	2.19, 1.87	0	0	2.75, 2.57	0	1	2.57, 2.13	0	0
9415	Inspectors and testers, mineral and metal processing	1.50, 0.50	0	0	1.88, 1.75	0	1	2.88, 2.88	0	1	2.62, 2.50	0	0	2.38, 2.25	0	0
9416	Metalworking and forging machine operators	1.51, 0.62	0	0	2.91, 2.75	0	0	2.57, 2.46	0	0	3.34, 3.37	1	1	2.59, 2.36	0	0
9417	Machining tool operators	1.63, 0.63	0	0	2.88, 2.82	0	0	2.50, 2.25	0	0	3.50, 3.44	1	1	2.69, 2.56	0	1
9418	Other metal products machine operators	1.62, 0.62	0	0	3.00, 3.00	1	1	2.75, 2.25	0	0	3.88, 3.75	1	1	2.62, 2.38	0	0
9423	Rubber processing machine operators and related workers	1.25, 0.31	0	0	2.75, 2.63	0	0	2.56, 2.28	0	0	3.50, 3.38	1	1	2.63, 2.35	0	0
9611	Labourers in mineral and metal processing	1.25, 0.25	0	0	2.12, 1.88	0	0	1.88, 1.62	0	0	2.62, 2.50	0	0	2.00, 1.88	0	0
9612	Labourers in metal fabrication	1.25, 0.25	0	0	2.12, 1.88	0	0	1.88, 1.62	0	0	2.62, 2.50	0	0	2.00, 1.88	0	1
9619	Other labourers in processing, manufacturing and utilities	1.13, 0.13	0	0	2.12, 1.82	0	0	2.19, 2.06	0	0	2.81, 2.69	0	1	2.50, 2.32	0	0

		Operation Monitoring			Complex Problem Solving			Reading Comprehension			Judgment and Decision Making			Critical Thinking		
NOC Code	NOC Title	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario
0013	Senior managers- financial, communications and other business services	2.29, 2.12	0	0	3.96, 4.33	1	1	4.00, 4.33	1	1	3.92, 4.42	1	1	4.09, 4.29	1	1
0016	Senior managers - construction, transportation, production and utilities	2.29, 2.12	0	0	3.96, 4.33	1	1	4.00, 4.33	1	1	3.92, 4.42	1	1	4.09, 4.29	1	1
0111	Financial managers	1.75, 1.12	0	0	3.67, 3.71	1	1	4.00, 4.12	1	1	3.83, 4.13	1	1	4.04, 4.25	1	1
0112	Human resources managers	1.75, 0.75	0	0	3.88, 3.75	1	1	4.00, 4.12	1	1	4.00, 4.00	1	1	3.75, 4.12	1	1
0113	Purchasing managers	2.13, 1.88	0	0	3.57, 3.63	1	1	3.88, 3.88	1	1	3.88, 3.88	1	1	3.88, 4.00	1	1
0211	Engineering managers	2.50, 2.62	0	0	3.75, 4.12	1	1	4.12, 4.38	1	1	3.75, 4.25	1	1	4.00, 4.25	1	1
0711	Construction managers	2.75, 3.00	0	0	3.75, 3.88	1	1	3.75, 4.00	1	1	3.50, 4.00	1	1	3.88, 4.00	1	1
0714	Facility operation and maintenance managers	1.75, 1.00	0	0	3.00, 3.12	1	1	3.75, 4.00	1	1	3.25, 3.50	1	1	3.50, 4.00	1	1
0811	Managers in natural resources production and fishing	2.71, 3.08	0	0	3.67, 3.84	1	1	3.83, 4.08	1	1	3.67, 4.13	1	1	3.92, 4.12	1	1
0911	Manufacturing managers	2.69, 3.13	0	0	3.63, 3.82	1	1	3.88, 4.13	1	1	3.75, 4.19	1	1	3.94, 4.19	1	1
0912	Utilities managers	3.15, 3.48	1	1	3.52, 3.67	1	1	3.83, 4.20	1	1	3.63, 3.75	1	1	3.93, 3.93	1	1
1111	Financial auditors and accountants	1.94, 1.50	0	0	3.44, 3.56	1	1	3.94, 4.07	1	1	3.50, 3.75	1	1	3.88, 3.88	1	1
1112	Financial and investment analysts	1.62, 0.75	0	0	3.50, 3.62	1	1	4.00, 4.12	1	1	3.62, 3.75	1	1	4.12, 4.12	1	1
1121	Human resource professionals	1.73, 1.05	0	0	3.45, 3.45	1	1	4.05, 4.25	1	1	3.55, 3.75	1	1	3.90, 4.10	1	1
1215	Supervisors, supply chain, tracking and scheduling coordination	2.50, 2.75	0	0	3.75, 3.88	1	1	4.00, 4.00	1	1	3.75, 3.88	1	1	3.88, 4.25	1	1
1221	Administrative officers	1.88, 1.00	0	0	2.88, 2.62	0	0	3.88, 3.88	1	1	3.00, 2.62	0	0	3.00, 3.62	1	1
1223	Human resources and recruitment officers	1.50, 0.50	0	0	3.12, 3.12	1	1	4.00, 4.00	1	1	3.25, 3.50	1	1	3.88, 4.00	1	1
1225	Purchasing agents and officers	1.50, 0.75	0	0	3.88, 3.88	1	1	4.00, 4.00	1	1	3.75, 3.88	1	1	3.75, 3.88	1	1
1241	Administrative assistants	1.88, 1.00	0	0	2.88, 2.62	0	0	3.88, 3.88	1	1	3.00, 2.62	0	0	3.00, 3.62	1	1
1311	Accounting technicians and bookkeepers	1.62, 0.62	0	0	2.88, 2.88	0	0	3.25, 3.75	1	1	2.75, 2.88	0	0	3.25, 3.25	1	1
1411	General office support workers	2.12, 2.00	0	0	2.62, 2.25	0	0	3.75, 3.50	1	1	2.75, 2.25	0	0	3.00, 3.00	1	1
1431	Accounting and related clerks	1.62, 0.62	0	0	2.88, 2.88	0	0	3.25, 3.75	1	1	2.75, 2.88	0	0	3.25, 3.25	1	1
1452	Correspondence, publication and regulatory clerks	1.50, 0.50	0	0	3.00, 2.88	0	1	3.88, 3.88	1	1	3.50, 3.00	1	1	3.75, 3.75	1	1
1521	Shippers and receivers	2.25, 2.12	0	0	2.88, 2.25	0	0	3.12, 3.12	1	1	2.88, 2.75	0	0	3.00, 3.00	1	1
1523	Production logistics coordinators	2.25, 1.75	0	0	3.00, 3.00	1	1	3.88, 4.00	1	1	3.12, 3.00	1	1	3.38, 3.88	1	1
1524	Purchasing and inventory control workers	1.38, 0.50	0	0	3.62, 3.00	1	1	4.00, 3.88	1	1	3.50, 3.25	1	1	3.62, 3.62	1	1
1525	Dispatchers	2.62, 2.25	0	0	3.04, 3.00	1	1	3.62, 3.46	1	1	3.12, 3.00	1	1	3.37, 3.67	1	1
1526	Transportation route and crew schedulers	2.25, 2.00	0	0	3.00, 3.00	1	1	3.75, 3.25	1	1	3.00, 3.00	1	1	3.12, 3.88	1	1
2112	Chemists	3.00, 3.12	1	1	3.75, 4.00	1	1	4.00, 5.00	1	1	3.12, 3.38	1	1	4.00, 4.12	1	1
2113	Geoscientists and oceanographers	2.50, 2.50	0	0	3.88, 4.12	1	1	4.12, 4.88	1	1	3.75, 3.75	1	1	4.12, 4.12	1	1
2115	Other professional occupations in physical sciences	2.88, 3.00	0	0	3.62, 4.00	1	1	4.00, 4.50	1	1	3.25, 4.00	1	1	4.00, 4.38	1	1
2121	Biologist and related scientists	2.45, 2.38	0	0	3.50, 3.77	1	1	4.02, 4.75	1	1	3.63, 3.90	1	1	3.95, 4.20	1	1
2131	Civil engineers	2.19, 2.12	0	1	3.94, 4.12	1	1	4.00, 4.57	1	1	3.63, 4.12	1	1	3.94, 4.31	1	1
2132	Mechanical engineers	3.16, 3.56	1	1	3.84, 4.34	1	1	3.79, 4.63	1	1	3.85, 4.16	1	1	3.88, 4.37	1	1
2133	Electrical and electronics engineers	3.07, 3.25	1	1	3.94, 3.94	1	1	3.94, 4.19	1	1	3.31, 3.38	1	1	3.94, 4.00	1	1
2134	Chemical engineers	3.12, 3.33	1	1	3.79, 3.96	1	1	3.88, 4.63	1	1	3.75, 4.13	1	1	3.88, 4.37	1	1
2141	Industrial and manufacturing engineers	2.94, 3.13	0	0	3.75, 3.94	1	1	3.97, 4.41	1	1	3.66, 4.00	1	1	3.91, 4.09	1	1
2142	Metallurgical and materials engineers	2.88, 3.00	0	0	3.62, 4.00	1	1	4.00, 4.50	1	1	3.25, 4.00	1	1	4.00, 4.38	1	1
2143	Mining engineers	3.00, 3.38	1	1	4.12, 4.38	1	1	4.00, 4.75	1	1	4.00, 4.62	1	1	4.00, 4.50	1	1
2144	Geological engineers	3.00, 3.38	1	1	4.12, 4.38	1	1	4.00, 4.75	1	1	4.00, 4.62	1	1	4.00, 4.50	1	1
2145	Petroleum engineers	3.00, 3.50	1	1	3.88, 4.12	1	1	4.12, 4.62	1	1	3.62, 4.00	1	1	3.88, 4.25	1	1
2147	Computer engineers (except software engineers and designers)	2.88, 2.94	0	0	3.69, 4.13	1	1	4.06, 4.32	1	1	3.38, 3.81	1	1	4.06, 3.94	1	1
2148	Other professional engineers, n.e.c.	2.96, 3.21	0	0	3.77, 4.13	1	1	3.99, 4.72	1	1	3.70, 3.98	1	1	3.99, 4.35	1	1
2152	Landscape architects	2.38, 2.12	0	0	3.62, 3.75	1	1	4.00, 4.00	1	1	3.62, 3.62	1	1	3.62, 3.75	1	1
2153	Urban and land use planners	1.94, 1.50	0	0	3.32, 3.56	1	1	3.94, 4.07	1	1	3.69, 3.75	1	1	3.69, 3.88	1	1
2154	Land surveyors	2.94, 2.75	0	1	3.38, 3.57	1	1	3.94, 4.19	1	1	3.38, 3.44	1	1	3.94, 4.00	1	1
2171	Information systems analysts and consultants	2.48, 2.41	0	0	3.67, 3.94	1	1	3.94, 4.35	1	1	3.64, 3.87	1	1	3.91, 4.20	1	1
2173	Software engineers and designers	2.13, 1.87	0	0	3.44, 3.75	1	1	3.50, 3.94	1	1	3.44, 3.62	1	1	3.62, 3.88	1	1
2174	Computer programmers and interactive media developers	2.25, 2.12	0	0	3.75, 3.88	1	1	3.38, 3.50	1	1	3.25, 3.25	1	1	3.75, 3.88	1	1
2211	Chemical technologists and technicians	3.12, 3.12	1	1	3.12, 3.12	1	1	3.88, 4.00	1	1	3.25, 3.25	1	1	3.88, 4.00	1	1
2212	Geological and mineral technologists and technicians	2.81, 3.12	0	1	2.94, 3.00	0	1	3.62, 4.00	1	1	3.00, 2.94	0	1	3.63, 3.38	1	1
2221	Biological technologists and technicians	3.00, 3.00	1	1	3.25, 3.50	1	1	4.00, 4.62	1	1	3.12, 3.50	1	1	3.88, 4.00	1	1
2223	Forestry technologists and technicians	2.88, 2.79	0	0	3.46, 3.71	1	1	3.54, 3.92	1	1	3.67, 3.71	1	1	3.88, 3.75	1	1
2231	Civil engineering technologists and technicians	2.38, 2.38	0	0	3.12, 3.25	1	1	3.75, 4.12	1	1	3.12, 3.12	1	1	3.88, 3.62	1	1
2232	Mechanical engineering technologists and technicians	3.69, 3.50	1	1	3.44, 3.19	1	1	3.69, 3.94	1	1	3.32, 3.19	1	1	3.62, 3.63	1	1
2233	Industrial engineering and manufacturing technologists and technicians	3.28, 3.47	1	1	3.53, 3.66	1	1	3.72, 3.94	1	1	3.34, 3.75	1	1	3.85, 3.78	1	1
2234	Construction estimators	1.75, 1.38	0	0	3.25, 3.62	1	1	3.88, 4.12	1	1	3.75, 3.75	1	1	3.88, 4.25	1	1
2241	Electrical and electronics engineering technologists and technicians	3.17, 3.30	1	1	3.48, 3.50	1	1	3.57, 4.05	1	1	3.12, 3.35	1	1	3.68, 3.80	1	1
2243	Industrial instrument technicians and mechanics	4.00, 4.00	1	1	3.12, 3.00	1	1	2.88, 3.12	0	1	3.12, 3.00	1	1	3.50, 3.50	1	1
2253	Drafting technologists and technicians	1.95, 1.80	0	0	3.05, 3.17	1	0	3.50, 3.80	1	1	3.05, 3.10	1	0	3.40, 3.53	1	1
2254	Land survey technologists and technicians	3.12, 3.00	1	1	3.00, 3.00	1	1	3.25, 3.50	1	1	3.12, 2.88	0	1	3.62, 3.12	1	1
2255	Technical occupations in geomatics and meteorology	2.37, 2.31	0	0	3.38, 3.44	1	1	3.72, 4.16	1	1	3.31, 3.35	1	1	3.66, 3.72	1	1

		Operation Monitoring			Complex Problem Solving			Reading Comprehension			Judgment and Decision Making			Critical Thinking		
NOC Code	NOC Title	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario	O*Net Importance & Level	Baseline Scenario	Innovation Scenario
2261	Non-destructive testers and inspection technicians	3.06, 3.12	1	1	3.00, 2.87	0	0	3.37, 3.44	1	1	3.13, 3.13	1	1	3.37, 3.44	1	1
2262	Engineering inspectors and regulatory officers	3.00, 3.12	1	1	2.75, 2.62	0	1	3.12, 3.12	1	1	3.00, 2.88	0	1	3.12, 3.38	1	1
2263	Inspectors in public and environmental health and occupational health and safety	3.38, 3.12	1	1	3.62, 4.00	1	1	4.00, 4.62	1	1	3.38, 3.75	1	1	4.00, 4.25	1	1
2264	Construction inspectors	2.88, 2.50	0	0	3.50, 3.25	1	1	3.88, 4.00	1	1	3.38, 3.38	1	1	3.75, 4.00	1	1
2271	Air pilots, flight engineers and flying instructors	4.75, 4.88	1	1	3.88, 3.88	1	1	3.88, 4.00	1	1	3.88, 4.25	1	1	4.00, 4.12	1	1
2274	Engineer officers, water transport	3.88, 3.75	1	1	3.50, 3.38	1	1	3.25, 3.38	1	1	3.12, 3.25	1	1	3.88, 3.75	1	1
2281	Computer network technicians	2.88, 3.00	0	1	3.75, 3.94	1	1	3.88, 4.06	1	1	3.63, 3.63	1	1	3.94, 4.00	1	1
4161	Natural and applied science policy researchers, consultants and program officers	2.28, 2.13	0	0	3.66, 3.78	1	1	4.00, 4.41	1	1	3.72, 4.00	1	1	3.87, 4.10	1	1
4212	Social and community service workers	2.04, 1.87	0	0	3.50, 3.42	1	1	3.71, 3.87	1	1	3.50, 3.67	1	1	3.87, 4.12	1	1
6221	Technical sales specialists- wholesale trade	1.82, 1.44	0	0	3.32, 3.12	1	1	3.63, 4.00	1	1	3.12, 3.25	1	1	3.44, 3.75	1	1
6322	Cooks	3.12, 2.38	0	0	3.00, 2.88	0	0	2.88, 2.88	0	0	3.12, 2.88	0	0	3.00, 2.88	0	0
6521	Travel counsellors	1.75, 0.75	0	0	3.00, 2.88	0	0	4.00, 3.75	1	1	3.38, 3.00	1	1	3.12, 3.75	1	0
6541	Security guards and related security service occupations	2.31, 2.13	0	0	3.07, 2.91	0	0	3.25, 3.28	1	1	3.25, 3.16	1	1	3.41, 3.32	1	1
6733	Janitors, caretakers and building superintendents	2.12, 2.00	0	0	2.12, 2.00	0	0	2.38, 2.00	0	0	2.25, 2.12	0	0	2.75, 2.12	0	0
7201	Contractors and supervisors, machining, metal forming, shaping and erecting trades and related occupations	2.88, 3.12	0	0	3.12, 3.00	1	1	3.50, 3.62	1	1	3.12, 3.00	1	1	3.75, 3.25	1	1
7203	Contractors and supervisors, pipefitting trades	2.88, 3.12	0	0	3.12, 3.00	1	1	3.50, 3.62	1	1	3.12, 3.00	1	1	3.75, 3.25	1	1
7204	Contractors and supervisors, carpentry trades	2.88, 3.12	0	0	3.12, 3.00	1	1	3.50, 3.62	1	1	3.12, 3.00	1	1	3.75, 3.25	1	1
7205	Contractors and supervisors, other construction trades, installers, repairers and servicers	2.94, 3.12	0	0	3.12, 3.25	1	1	3.50, 3.69	1	1	3.25, 3.19	1	1	3.69, 3.50	1	1
7231	Machinists and machining and tool inspectors	3.25, 3.38	1	1	2.88, 3.00	0	1	3.00, 3.00	1	1	2.88, 2.75	0	1	3.12, 3.12	1	1
7235	Structural metal and platework fabricators and fitters	2.50, 2.38	0	0	2.38, 2.25	0	0	3.00, 2.38	0	0	2.38, 2.38	0	0	3.00, 2.25	0	1
7236	Ironworkers	3.19, 2.69	0	0	2.88, 2.63	0	0	2.69, 2.56	0	0	2.94, 2.75	0	0	3.06, 3.00	1	1
7237	Welders and related machine operators	3.00, 2.79	0	1	2.67, 2.38	0	0	2.71, 2.50	0	0	2.71, 2.37	0	0	2.95, 2.79	0	1
7241	Electricians	3.00, 3.12	1	1	3.12, 3.12	1	1	3.00, 3.25	1	1	3.38, 3.25	1	1	3.38, 3.62	1	1
7242	Industrial electricians	3.38, 3.37	1	1	3.31, 3.00	1	1	2.94, 3.07	0	1	3.32, 3.19	1	1	3.44, 3.37	1	1
7251	Plumbers	3.12, 3.12	1	1	3.12, 3.12	1	1	3.00, 3.00	1	1	3.25, 3.00	1	1	3.62, 3.62	1	1
7252	Steamfitter, pipefitter and sprinkler system installer	3.00, 2.75	0	0	3.00, 3.12	1	1	3.12, 3.12	1	1	3.00, 3.00	1	1	3.12, 3.12	1	1
7271	Carpenters	3.50, 3.12	1	1	2.88, 2.75	0	0	2.88, 2.62	0	0	3.00, 2.88	0	0	3.00, 3.00	1	1
7301	Contractors and supervisors, mechanic trades	3.44, 3.50	1	1	3.25, 3.06	1	1	3.31, 3.31	1	1	3.19, 3.00	1	1	3.75, 3.25	1	1
7302	Contractors and supervisors, heavy equipment operator crews	2.88, 3.12	0	1	3.12, 3.00	1	1	3.50, 3.62	1	1	3.12, 3.00	1	1	3.75, 3.25	1	1
7311	Construction millwrights and industrial mechanics	3.94, 3.94	1	1	3.06, 3.00	1	1	2.94, 3.06	0	1	3.12, 3.00	1	1	3.56, 3.31	1	1
7312	Heavy-duty equipment mechanics	3.75, 3.50	1	1	3.12, 3.25	1	1	3.12, 3.38	1	1	3.12, 3.12	1	1	3.25, 3.38	1	1
7321	Automotive service technicians, truck and bus mechanics and mechanical repairers	3.54, 3.33	1	1	3.21, 3.12	1	1	3.21, 3.21	1	1	3.25, 3.08	1	1	3.54, 3.29	1	1
7371	Crane operators	3.46, 3.08	1	1	2.96, 2.58	0	0	2.87, 2.75	0	0	3.00, 2.83	0	1	3.17, 3.00	1	1
7372	Drillers and blasters- surface mining, quarrying and construction	4.00, 4.00	1	1	3.00, 2.75	0	0	2.75, 2.50	0	0	2.88, 2.62	0	1	3.25, 3.00	1	1
7452	Material handlers	3.42, 3.29	1	1	2.92, 2.75	0	0	2.92, 2.96	0	0	3.00, 2.71	0	0	3.17, 2.92	0	0
7511	Transport truck drivers	3.75, 3.12	1	1	2.88, 2.88	0	0	3.00, 3.00	1	1	2.88, 2.75	0	1	3.00, 3.00	1	1
7521	Heavy equipment operators (except crane)	3.60, 3.32	1	1	2.75, 2.53	0	0	2.65, 2.45	0	1	2.90, 2.52	0	1	2.95, 2.90	0	1
7611	Construction trades helpers and labourers	3.21, 3.00	1	1	2.79, 2.58	0	0	2.88, 2.75	0	0	2.67, 2.37	0	0	2.92, 2.71	0	0
7612	Other trades helpers and labourers	3.38, 2.88	0	0	2.75, 2.38	0	0	2.62, 2.38	0	0	3.00, 2.62	0	0	3.12, 3.12	1	1
8221	Supervisors, mining and quarrying	2.88, 3.12	0	0	3.12, 3.00	1	1	3.50, 3.62	1	1	3.12, 3.00	1	1	3.75, 3.25	1	1
8231	Underground production and development miners	3.64, 3.55	1	1	3.02, 2.84	0	0	2.78, 2.69	0	0	3.03, 2.69	0	0	3.41, 3.05	1	1
8411	Underground mine service and support workers	3.62, 3.38	1	1	2.88, 2.62	0	0	2.75, 2.50	0	0	3.00, 2.62	0	0	3.12, 2.88	0	0
8614	Mine labourers	3.62, 3.38	1	1	2.88, 2.62	0	0	2.75, 2.50	0	0	3.00, 2.62	0	0	3.12, 2.88	0	0
9211	Supervisors, mineral and metal processing	3.12, 3.25	1	1	3.25, 3.50	1	1	3.88, 3.62	1	1	3.75, 3.25	1	1	3.88, 3.88	1	1
9212	Supervisors, petroleum, gas and chemical processing and utilities	3.12, 3.25	1	1	3.25, 3.50	1	1	3.88, 3.62	1	1	3.75, 3.25	1	1	3.88, 3.88	1	1
9231	Central control and process operators, mineral and metal processing	3.88, 3.88	1	1	3.00, 2.88	0	1	3.00, 2.88	0	1	2.75, 2.75	0	1	3.00, 3.00	1	1
9241	Power engineers and power systems operators	3.86, 3.77	1	1	3.09, 2.83	0	1	3.11, 3.06	1	1	3.11, 2.99	0	1	3.35, 3.25	1	1
9243	Water and waste treatment plant operators	3.88, 3.75	1	1	3.00, 3.00	1	1	3.12, 3.25	1	1	3.12, 3.00	1	1	3.25, 3.25	1	1
9411	Machine operators, mineral and metal processing	3.88, 3.88	1	1	3.00, 2.88	0	0	3.00, 2.88	0	0	2.75, 2.75	0	0	3.00, 3.00	1	1
9412	Foundry workers	3.07, 2.75	0	0	2.81, 2.44	0	0	2.62, 2.44	0	0	2.88, 2.44	0	0	2.94, 2.69	0	0
9415	Inspectors and testers, mineral and metal processing	3.00, 3.12	1	1	2.75, 2.62	0	0	3.12, 3.12	1	1	3.00, 2.88	0	1	3.12, 3.38	1	1
9416	Metalworking and forging machine operators	3.60, 3.47	1	1	2.84, 2.65	0	0	3.05, 2.99	0	0	2.90, 2.61	0	0	3.06, 2.99	0	0
9417	Machining tool operators	3.82, 3.56	1	1	2.75, 2.63	0	0	2.94, 2.88	0	0	2.82, 2.57	0	1	3.13, 2.88	0	0
9418	Other metal products machine operators	3.75, 4.00	1	1	2.75, 2.50	0	0	3.00, 2.50	0	0	2.62, 2.50	0	0	2.88, 2.75	0	0
9423	Rubber processing machine operators and related workers	3.56, 3.59	1	1	2.79, 2.63	0	0	2.91, 2.78	0	0	2.88, 2.53	0	0	2.97, 2.78	0	0
9611	Labourers in mineral and metal processing	2.75, 2.50	0	0	2.25, 2.00	0	0	2.62, 2.25	0	0	2.25, 1.88	0	0	2.75, 2.25	0	0
9612	Labourers in metal fabrication	2.75, 2.50	0	0	2.25, 2.00	0	0	2.62, 2.25	0	0	2.25, 1.88	0	0	2.75, 2.25	0	0
9619	Other labourers in processing, manufacturing and utilities	3.00, 2.69	0	0	2.63, 2.38	0	0	2.75, 2.50	0	0	2.63, 2.32	0	0	3.00, 2.57	0	0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