The Future of Work: the Changing Skills Landscape for Miners

A report for the Minerals Council of Australia

Building a better working world

Table of contents

1. Executive Summary

What does the minerals industry skills landscape look like now and into the future when considered through the lens of the Digital Mining Report? This is the question this report seeks to answer.

This report is built upon EY's Digital Mining Report on the minerals industry, generating insight on the influence and impact of technology across the mining value chain. By better understanding the future skills required of the mining industry workforce, industry stakeholders will be able to strategically plan their workforce and sustain their competitive advantage in global markets. Further analysis of the findings from the Digital Mining Report have revealed the following impacts on the workforce across the value chain:

- Robotics and Automation through drones, autonomous vehicles and remote-controlled operational systems will be rolled out more widely to enhance exploration efforts and mining operations. These innovations are predicted to redesign traditional occupations such as drill operators, surveyors and field geologists, and increase demand for remote vehicle operators and geologists, to name a few, with greater skills in contemporary data and digital technologies.

- There will be increasing demand for *Data and Digital* literacy skills across all phases of the mining value chain that will redesign most occupations as the human-to-machine interface evolves and becomes more prevalent. These skills can be expected to increase in demand into the future and play an important role in enhancing decision-making and optimising everyday work.

- Cloud computing, information sharing and big data continue to change the nature of work and enable integrated operating centres so more work can be performed remotely and more flexibly. This trend will accelerate within the sector and increasingly take employees away from hazardous on-site events to an improved work health and safety rating and enhanced workplace conditions.

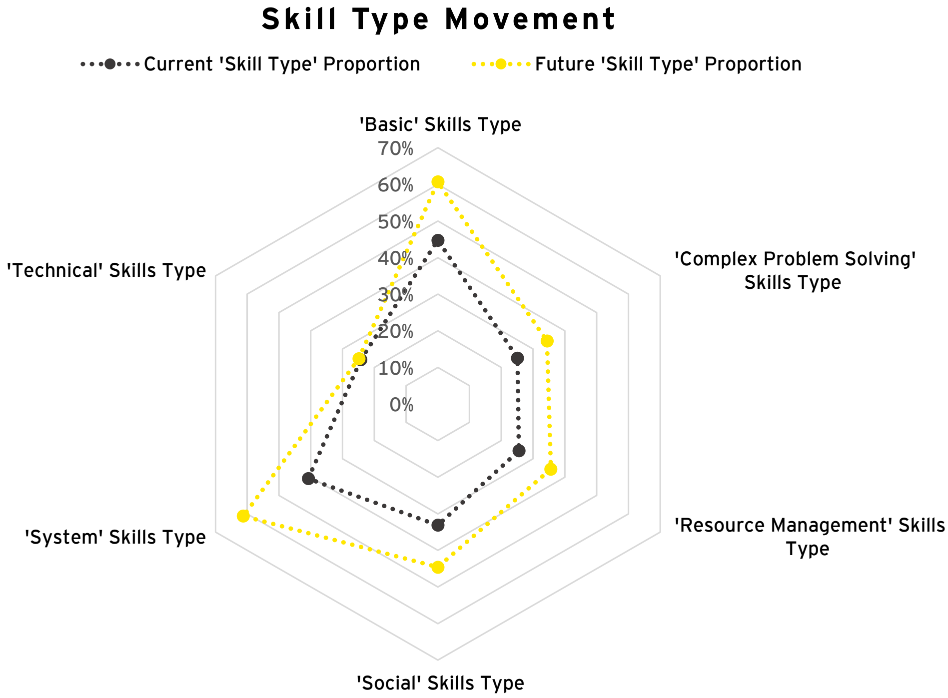
Across industry and academic literature, there is consensus that skills requiring greater degrees of task creative intelligence, social intelligence, and perception and manipulation will be more resilient to the impacts of technology and automation. Analysis identified the following future skills as increasingly important for occupations in the sector, and also most resistant to the impact of technology.

- Change Management
- Collaboration
- Complex Stakeholder Engagement
- Creativity
- Data Analysis
- Data and Digital Literacy
- Design Thinking
- Stakeholder Analysis
- Strategic Planning

A Technology Impacts Index was applied to occupations in the industry to assess the likely impact of technology. Overall, 42% of occupations were categorised as being 'enhanced' and more productive through technological adoption and innovation, 35% of occupations were considered largely 'redesigned' through the lens of technology and 23% of occupations with the potential to be 'automated'. Analysis suggests that the main impact of technology on the industry will be to enhance or redesign occupations, with a small proportion of occupations likely to decrease in demand as a consequence of technology and automation. Furthermore, analysed through the value chain, findings reveal the 'end-to-end' mining stage has the highest proportion of occupations enhanced by the impacts of technology, and the 'mining operations' stage to contain the greatest proportion of redesigned occupations (Table 5).

This report collates all data into an industry Skills Map, illustrating the shifting nature of the skills required now and into the future. The skills map labels industry occupations according to three scenarios: enhanced, redesigned, and automated as a result of technological impacts. The Skills Map also provides a deconstructed view of occupations and the skills they are comprised of, their corresponding 'skill type' category, field/level of education, and a percentage factor indicating the likely future demand of the skill.

Through the lens of the Digital Mining Report, all industry *Skill Types* are observed as increasing in demand, illustrated in the figure below, with some skills in the 'Technical' skill type category representing decreasing/slow growth in demand. Overall, *System*, *Basic* and *Social Skills* type categories present the greatest demand of skills into the future. Certain technical skills, i.e. Vehicle Operations and Materials Extraction, are observed as having the least net growth in demand into the future. Further analysis against each skill type category can be found in Table 4.



Further analysis of the five most common occupation groupings in the industry (comprising 48% of the workforce) indicate that these occupations are likely to be redesigned or enhanced, rather than automated. This analysis suggests that the dominant response required of the sector will be to support the workforce through contemporary training/education offerings, and strategic workforce planning to benefit from drivers of change shaping the future of work.

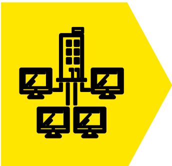
The minerals industry will require a strategic, proactive and creative response to the future of work. Overall, industry employment projections are set to increase over the next five years, and looking at the industry through the Digital Mining Report, approximately 77% of occupations in the sector can be considered enhanced or redesigned. On balance, it can be said the industry will benefit from the productivity gains of technology and complement current operations in achieving better outcomes. This report concludes with high-level areas to consider, across five practical dimensions that organisations may adopt and adapt to be more future-ready.

2. The Future of Work: the impact of digital

The Future of Work is not a thing of tomorrow, but the reality of today. The relationship between people, work and organisations is rapidly evolving in this digital age and organisations of tomorrow are realising the need to act now to prepare for impacts of disruption. In understanding the future, it is important to consider the dominant drivers of change shaping the future of work.

Shifting workforce expectations

The workforce has evolved into a more fluid network of employees which encompass not only the traditional employee, but also contractors, consultants and freelancers- defined by working relationships often more flexible and non-permanent.
With an increasingly diverse labor market, employers are now faced with a workforce that expects more flexible working options, purpose-driven workplaces and corporate cultures that champion a culture of lifelong learning.



Convergence of technology, robotics and artificial intelligence

Emerging technologies, such as Artificial Intelligence (AI), Robotic Process Automation (RPA), blockchain and chatbots, are changing work environments as innovations are increasingly being adopted and integrated. These technologies have the potential to perform lower-value, manual and routine work more efficiently than humans would, freeing up employees to undertake more high-value work and boosting efficiencies.

Social and demographic factors

We are entering a period significant ageing of populations and a consequent global negative working age population growth. Increasing global competition for talent, migration, including that driven by the rise of the Asian economies and their global expansion may reduce Australia's competitive position, challenging our ability to retain local talent and attracting talent from elsewhere. Workforces are now increasingly comprised of multi-generational, multi-skilled and diverse individuals.

The known unknowns

With increasing technological innovation, we can expect more blind disruptors- those things that will hit us unexpectedly, and have a more immediate impact. We face a future of work with more unknowns than knowns, where constant vigilance and proactive attitudes/capacities to change are what steer organisations forward. These capacities to both steer constant change, but also pivot as necessary will be likely scenarios organisations face on a frequent basis.

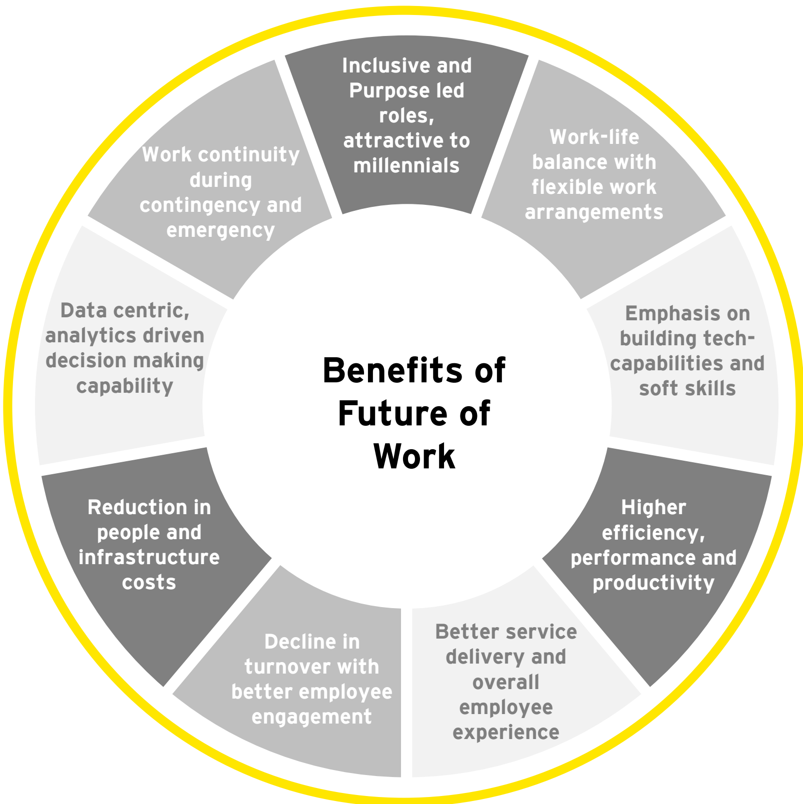
In the minerals industry, henceforth referred to as 'the industry', the future of work through the impact of technological transformation will require proactive rethinking of policies, skilling requirements and emerging technologies that drive efficiencies, elevate customer focus and strengthen diversity and inclusion in the sector.

Changing Nature of Work
How can MCA contribute to public policy in response to the evolving work environment? How can we empower and support industry to recruit/train/retain/retrain the best employees and get the most powerful/applicable digital assets into organisational work streams? How do we integrate the two realities for a more prosperous future?

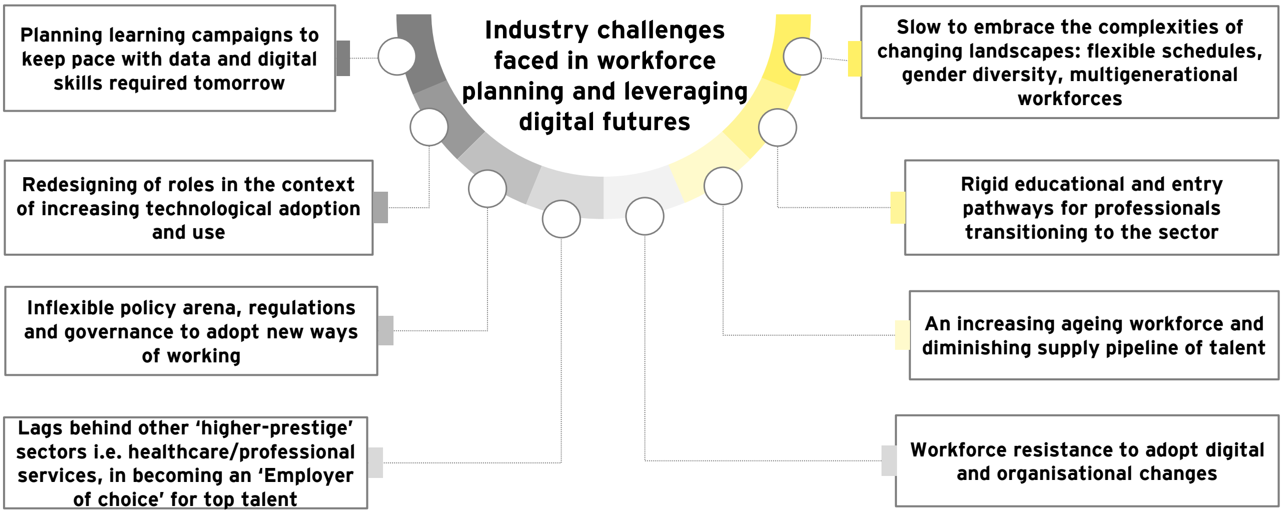
The speed of evolution and technological disruption is demanding greater responsiveness and innovation from organisations to retain their competitive advantage. Future work will challenge traditional roles and drive new types of employee profiles and capabilities. Whilst disruption may convey an unsettling departure from established practice; its increasing prevalence poses a major opportunity for the sector to innovate and proactively anticipate the shifting landscape it may bring in workforce demographics and practice.

The nature of work is evolving and its landscape is drastically different from what existed even just two decades ago. Where work in the past may have relied on a fixed schedule, we are moving to a work anywhere and anytime model, a trend complementing aspects already practised in the industry previously. Work in the past had a focus on planned working styles, a focus on knowledge, inputs, control, whereas the trends we observe now show a shift towards more agile, experimental working styles, a focus on adaptive learning, outcomes and fostering trust oriented cultures.

As a major employer in the Australian economy the industry has a lot to benefit from the opportunities the future of work presents, but only if it actively prepares its workforce for the future.

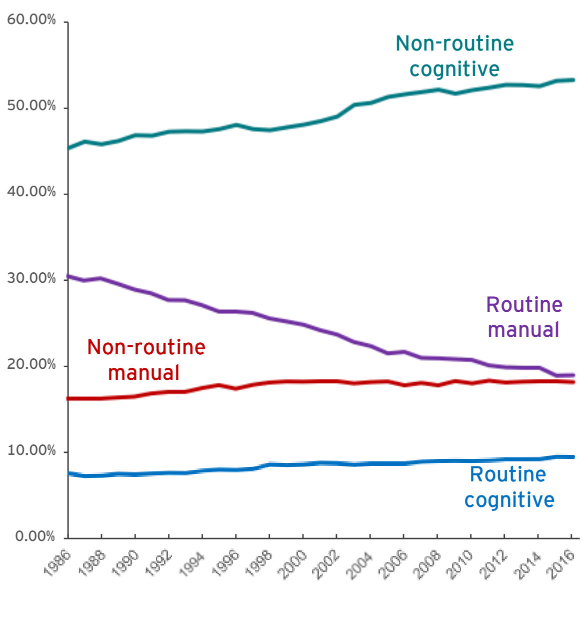


The industry is unique in that its workforce supply-side challenges are rarely found in other sectors. It is an industry marked by heavy capital investment and is a major contributor to the economic prosperity of Australia, especially in remote and rural areas. The industry also faces unique challenges to leverage opportunities in the digital future of work and workforce plan, due to its entwined relationship with global commodity markets, adoption of new technologies, a distributed skilled workforce both in geography and skill level, and unique occupational conditions that some of its workforce faces, to name a few factors adding complexity.



A useful analytical framework to consider impacts of the future of work is modelling done by Autor, Levy and Murnane[1] who distinguished workplace tasks as being either routine or non-routine tasks, and manual or cognitive tasks. Routine tasks can be considered those that are well-defined, follow explicit rules that can be accomplished by machines; while non-routine tasks are more difficult to understand and articulate in computer code. Either of these tasks can in turn, be either manual or cognitive in nature i.e. whether they relate to physical labour or knowledge work. The graph illustrates the most notable changes in the nature of work has been the increase in non-routine cognitive employment which has risen to over half of total employment. In contrast, a significant decline of routine manual employment has also been observed, which has fallen from approximately 30% to less than 20% of total employment. Both non-routine manual and routine cognitive work have progressively increased albeit slightly. These trending shifts in employment can in part be attributed to the rate of technological innovation and adoption in workplaces[2].

Share of Total Employment by Skill Type



Source: ABS Cat. 6291 and EY calculations

Historically, computerisation, automation and digital disruption have largely been relegated to manual, routine and cognitive tasks involving explicit rule-based activities. However, recent technological progress in artificial intelligence and machine learning has been making strides towards capturing more tasks traditionally

[1] Autor, D, Levy, F and Murnane, R 2003, 'The skill content of recent technological change: an empirical exploration', *Quarterly Journal of Economics*, 118(4), 1279-1334.

[2] Ibid.

considered to lie within the human domain, specifically those tasks considered non-routine and cognitive[3]. For example, driving a car through unpredictable traffic[4] or deciphering irregular handwriting were once considered tasks only humans could do, but are now being tested by driverless cards and algorithms that can decipher handwriting[5].

[3] Frey, C.B. and Osborne, M.A. 2013, '*The Future of Employment: How Jobs are Susceptible to Computerisation',* Oxford Martin Programme on Technology and Employment.

[4] Rutkin, A 2015, 'Autonomous cars are learning our unpredictable driving habits', *New Scientist*. [Online]. Available at: https://www.newscientist.com/article/mg22730362-900-autonomous-cars-are-learning-our-unpredictable-driving-habits/ [Accessed 5 December 2018].

[5] Oliveira, S A, and Kaplan, F 2018, 'Comparing human and machine performance in transcribing 18th century handwriting', *Digital Humanities Laboratory*.

3. Skills Map Methodology

In order to identify the effects of the future of work on the skills in the sector there was a need to first identify the current skills in the sector and then the future skills required. To determine the skills base within the sector's workforce, EY adopted the following methodology:

- ABS Census data[6] was used to identify those occupations that encompass 85% of the current workforce in the Australian minerals industry.
- These were aggregated at the occupational Unit-group level (ANZSCO level 4), so that subsequent analysis could best balance the need for both granularity and the ability to make high-level observations.
- The occupations were mapped against the O*Net skills database to identify those skills that were considered "important" for each occupation and these were included in the skills map for the sector.
- Finally, a set of dominant industry-specific technical skills commensurate to the major proportions of occupation groupings in the sector were identified and added to the final skills map.

To identify the skills required in the future workforce the following methodology was applied:

- Using the Digital Mining Report as a base, a set of future-focussed skills was identified and added to the current skills landscape to culminate in a skills map.
- A 'Technology Impacts Index' was developed from the future of work literature and applied against the occupations to identify how technology and automation would affect the prevalence of occupations in the future, and the subsequent impact on the skills required in the future.
- Occupations were divided into three comparative 'Occupation Type' categories based on the likely impact of technology and digital, these were:
    - Automated,
    - Redesigned, and
    - Enhanced.
- This mapping was then used to predict the future composition of the workforce[7] which was then mapped onto the skills map to identify the likely movement or prevalence of each of these skills as a proportion of the future workforce.
- From this analysis the most prevalent skills in the industry were identified along with those skills that are likely to both increase and decrease in demand in the future.
- Throughout this process, there was an iterative feedback and refinement to ensure the Skills Map was both an accurate representation of the data and fit-for-purpose for the minerals industry.

This methodology is illustrated in Figure 1.

[6] For consistency throughout modelling projections, data from the last ABS Census (2016) has been utilised.
[7] Workforce projections to 2023 have been derived from the Department of Jobs and Small Business forecast. Projections to 2030 have been extrapolated using EY calculations using projection modelling based on industry forecast factors.

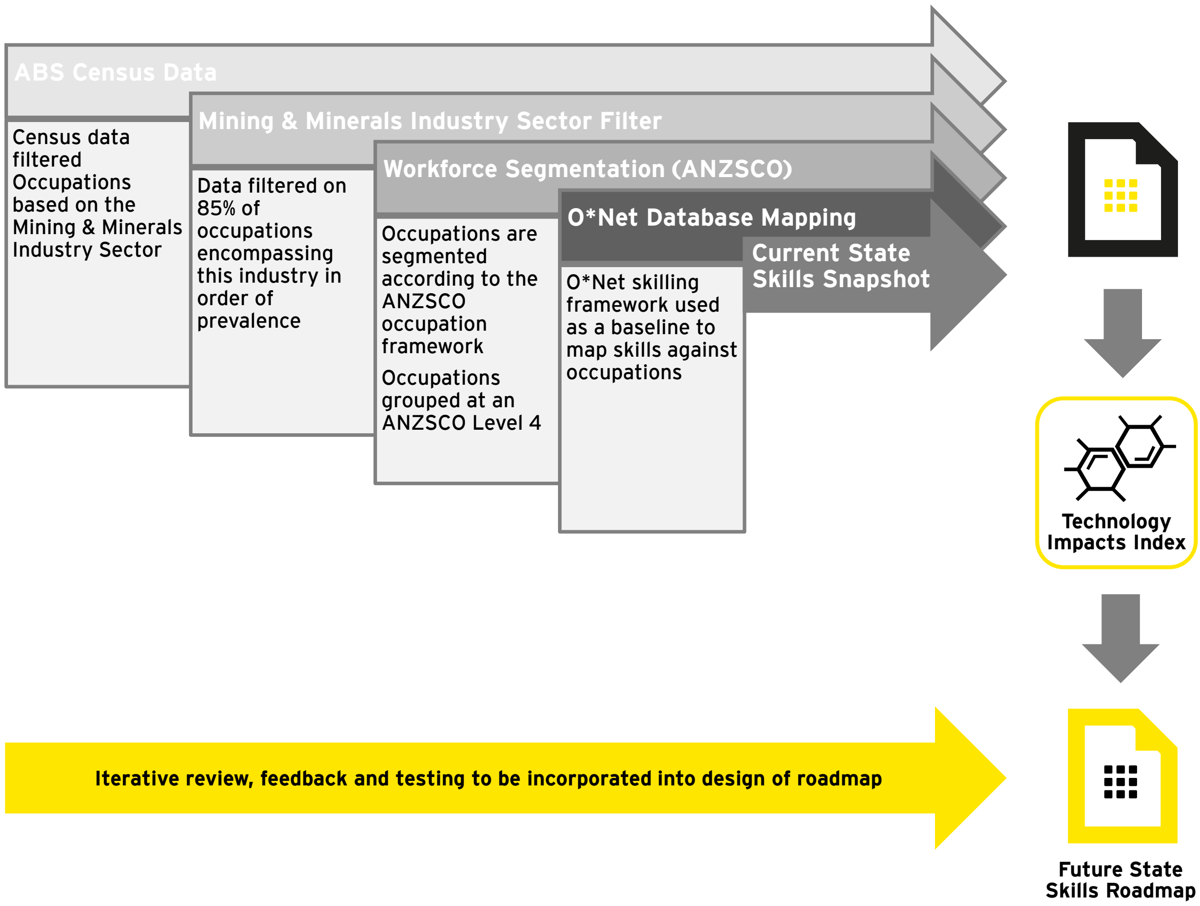


Figure 1 Skills Map Methodology

3.1 Technology Impacts Index

Building on the work of Autor and Murname (2003), Frey and Osborne (2013) developed an index that identified the likely impact of digitalisation on occupations. Central to this work was the view that the two factors in Autor and Murname's (2003) framework, that were seen as resistant to computerisation: whether the work was non-routine and whether it was cognitive work, had been overtaken by technology and were no longer factors in making an occupation resistant to computerisation. Instead, Frey and Osborne (2013), built on this and identified three task-factors that were considered least susceptible to technological disruption and the impact of computerisation, these were: social intelligence tasks, perception and manipulation, and creative intelligence tasks. These were combined in a probabilistic model to identify the likelihood that an occupation would be affected by digitalisation.

We have called this the Technology Impacts Index and it ranged from 0 to 1 (Appendix A) with lower indices representing an occupation that was less likely to be affected by technology and higher indices those more likely to be computerised. Indices ranged from, for example, 0.01 for HR Managers, Sales Managers, and Training and Development Professionals to 0.98 for Accounting Clerks and Transport and Dispatch Clerks.

The Technology Impacts Index was applied to occupations and an analysis of the distribution of the Index across occupations was made to identify a set of parameters that could be used to segment occupations based on existing evidence. This approach gave the following segmentation: 0 to 0.3 were occupations deemed '*Enhanced*' that is, technology and digital is more likely to enhance work in these occupations and these occupations will change somewhat to accommodate the new capability provided. Probabilities between '0.3 to 0.84' were deemed '*Redesigned*', which meant that some of the work in these occupations will be replaced but other skills will be greatly augmented and there will be a need to redesign elements of these occupations. Probabilities ranging between '0.85 to 1' were deemed most likely 'Automated' as a result of technology and digital, that is, most of the work in this occupation is likely to be replaced and these occupations will be substantially reduced in the industry.

These indices were used with workforce data to identify the likely size of each occupation in the future workforce, that is, the future composition of the workforce. These proportions were then mapped against the skills map to determine the change in the prevalence of skills in the workforce.

3.2 Using the Skills Map

The Skills Map is provided as an addendum to this report, and is intended to be a tool to understand how skills map against occupations. Due to the large volume of information summarised on the skills map, a snapshot illustrating how this can be analysed for one occupation is presented below.

The skills map provides other contextual information relevant for occupations in the industry such as: Occupation Type (Automated, Redesigned, and Enhanced), ANZSCO Skill Level, and ASCED Field of Education. Using the technology impacts index, a skills prevalence percentage at the end of the table provides an indication of whether the skill will increase or decrease in demand in the future.

	ANZSCO Code	223311	
	ANZSCO Occupation Unit-Group	Training and Development Professionals	
	Occupation Impact Category	Enhanced	
	ASCED (Field of Education) Label	Business and Management	
	ANZSCO Skill Level Label	Bachelor or higher qualification	
	Qual Experience equivalence (years)	5	
Skill Type	***Technology Impacts Index***	0.01	**Skills Prevalence as prop of future workforce (Change %)**
Basic	Active learning	1	18%
Basic	Active listening	1	19%
Basic	Critical thinking	1	17%
Basic	Learning strategies	1	14%
Basic	Mathematics		24%
Basic	Monitoring	1	14%
Basic	Reading comprehension	1	18%
Basic	Science		7%
Basic	Speaking	1	17%
Basic	Writing	1	20%
Basic	Data and Digital Literacy	1	22%
Basic	Stakeholder Analysis	1	8%
Basic	Data Analysis	1	23%
Basic	Creativity	1	4%
Complex Prob	Complex Problem Solving	1	17%

Occupation

Occupation Type

Technology Impacts Rating

Numerical (1) indicates presence of skill within occupation

Likely future skill demand

Future Skills coded in green (*Section 4.1*)

Figure 2 Skills Map Snapshot

4. Digital Mining Report Findings

A recent EY report on the 'Future of Work: Economic analysis of the implication of digital on mining' (2018, 'the Digital Mining Report') explored the impacts of digitalisation and technological innovation across the minerals industry value chain. The study anticipates a total overall improvement in productivity between 9%-23% due to the adoption of digital and technology, with stages in the value chain such as Mining Operations estimated to achieve up to 25% productivity improvements. To achieve these however, will require some work redesign and an initial investment in the workforce as a result.

Across all stages in the minerals industry value chain, we are seeing traditional occupations being redesigned by the introduction of new technologies. Stages such as Exploration, Mining Operations and Transportation see a slight reduction in certain occupations due to technological innovations such as autonomous vehicle technologies, and integrated operating centres enabling remote exploration and drilling. Whilst a 'destruction effect' or loss of occupations may be felt due to technological disruption; this is compensated for by a 'capitalisation effect' (Aghion & Howitt 1994) where an investment in productive technologies fuels greater demand for occupations that contribute to greater efficiencies. Analysis reveals that workforce enhancement and redesign is more likely, with only a small majority of occupations, whose tasks are largely routine and well-defined, are likely to be completely automated. The net effect is a change in the occupational composition of the workforce; with some occupations demanded less into the future, whilst other occupations consisting of future skills, growing in demand.

Another characteristic shared across all stages is the increasing demand for occupations to demonstrate Data and Digital Literacy skills as the human-to-machine interfaces become more prevalent, and the nature of work shifts to integrated remote operating centres. More fundamentally, it can be expected that most occupations will use data and digital technologies much more comprehensively, especially to support decision making.

Other trends observed in the minerals industry are the continued integration of current and emerging technologies across the value chain. Underpinned by technologies such as robotics, autonomous transportation, and machine learning, these forces will continue to redesign operations and require personnel to have greater data and digital literacy. Divergent capital and resource ownership models, the way organisations recruit, retain and extend employees, and key cross-sector collaborations are all factors that will continue to fundamentally change the sector. Beyond 2030, continued digital and technological adoption in the industry can be expected, requiring workforces to remain focussed on their data and digital capabilities.

Technological adoption and innovations in the minerals industry have yielded important efficiencies that do not necessarily correlate to an immediate reduction in the workforce. For example, 'driverless trucks' result in shifting skills profiles from heavy-licence drivers to employees with data processing, digital literacy and technical planning skills capable of operating these. For employees, the ability to transition, upskill, cross-skill and reskill will be essential. This innovation has not necessarily reduced the number of operators but it has changed the modality of work, from mine site to remote and integrated operating centres, leading to benefits in terms of increased employee safety, improved recruitment and retention, achieving greater diversity targets and more efficient operations.

Outlined in
Table 1 is analysis highlighting key workforce related insights identified by the Digital Mining Report and the consequent impacts arising from introducing greater levels of technology in the sector.

Minerals Industry Value Chain Phase	Impact of Digital	Impact on the Workforce	Skills Demands Identified
Exploration	▸ Historical databases utilised more strategically to optimise drilling exploration ▸ Real time results assessment and design re-alignment to correct operations on the go	▸ Reduced demand for Drill operators, traditional surveyors and field geologists required ▸ Increased remote working modalities	▸ Data Analytics, design and modelling skills ▸ Contemporary methods of surveying and conducting field geology will be required ▸ Decision-support skills underpinned by capabilities in Data and Digital literacy and collaboration skills
Mining Operations	▸ Improved Drill & Blast designs through the use of al geological information ▸ Adaptive drill and blast ▸ Predictive blast displacement ▸ Asset utilisation optimisation ▸ Alternate continuous solutions, truck-less operations, continuous miners ▸ Predictive, risk based asset management strategies ▸ Safer work environment ▸ More aggressive mining strategy (increased reserve to resource conversion) ▸ Predictive grade and blast design ▸ Predictive rock mechanics	▸ Reduced demand for Drill and traditional truck operators ▸ Reduction in underground workforce due to autonomous remote operations ▸ Geologists skill set will need to evolve to encompass use of data and digital in designing geological models for drill and blast designs ▸ Increase in demand for skilled mining professionals for day-to-day management, advanced system development and system integration; as well as geotechnical engineers, data scientists and modellers ▸ Improved workforce safety due to reduced employee exposure to hazardous on-site environments, operator fatigue and repetitive tasks ▸ Increased remote working modalities due to data analytics, model design and autonomous drilling systems	▸ Data Analytics and Geological Model Design Skills ▸ Increased Data and Digital literacy skills ▸ Integrating upstream and downstream operations require higher-level operational and planning activity skills
Processing	▸ Integrated upstream and downstream operations to optimise processing ▸ Asset utilisation optimisation ▸ Plant set-point optimisation ▸ Automated Ore sorting ▸ Predictive asset management strategies ▸ Alternative sources of energy	▸ Minimal changes to the workforce at this stage of the mining value chain ▸ Increase in demand for data scientists and modellers capable of advanced analytics ▸ Maintainers and operators are expected to remain on-site	▸ Advanced data analytics skills ▸ Data and information management ▸ Business information systems operations and analysis
Transport	▸ Predictive Asset Management Strategies ▸ Optimisation of asset utilisation ▸ Optimised ship loading	▸ Reduced demand for traditional operators due to autonomous trains/vehicles, shifting needs towards management of autonomous trains/vehicles ▸ Increasing remote working opportunities from remote operating centres, thereby improving safety for workers on-site	▸ Data and Digital literacy skills in human-to-machine interface operations (from traditional operators to managing autonomous trains and planning systems) ▸ Advanced systems development skills and integration to manage autonomous systems and shipping platforms
Trading	▸ Digital Contracts and logistics ▸ On-Demand products ▸ Tailored mining, supported through Integrated Operating Centres	▸ Minimal impacts on workforce numbers at this phase ▸ Increased demand for marketing professionals with an integrated view of operations and understanding of product development strategies	▸ Change management skills, required to instil a customer centric focus ▸ Market forecasting and modelling skills

Minerals Industry Value Chain Phase	Impact of Digital	Impact on the Workforce	Skills Demands Identified
End-to-end Value Chain	▸ End-to-end optimised and integrated planning and scheduling through increasing use of Integrated Operation Centres (IOC) ▸ Enhanced asset lifecycle management strategies, improving the reliability of assets across the value chain, resulting in a reduction of maintenance costs ▸ Responsiveness to asset health, process performance and geological variances increased ▸ Integration and centralisation of planning, decision making, execution and quality management better integrated ▸ Integrated batch production order with customer integration ▸ Centralised, real-time and end-to-end event management and response planning analysis	▸ Streamlined roles and integrated operations may consolidate and reduce the number of roles in corporate functions. Most roles are anticipated to be transitioned and augmented to integrated roles. ▸ Revised roles, responsibilities, performance metrics and target setting will need to be realigned to support a new integrated operating model ▸ Skilled mining professionals will be required to manage increased complexity of planning, scheduling and advanced decision making brought together at Integrated Operating Centres ▸ Enhancements in asset management strategies may reduce the maintenance workforce slightly ▸ Maintenance planners to require upskilling in change management	▸ Systems thinking skills ▸ Change Management and collaboration skills ▸ Enhanced decision-making support skills underpinned by Data & Digital literacy skills ▸ Technical modelling and advanced geological and geospatial capabilities will be critical to support operational decision making ▸ Scenario planning, predictive modelling and options analysis skills, to enhance decision-making support ▸ Complex stakeholder engagement and interpersonal skills to reach across diverse stakeholder groups

Table 1 Digital Mining Report Workforce Insights

4.1 Future Skills

To identify any skills that would be required in the future, the Digital Mining Report was used as a basis for analysis; which incorporated existing industry occupational groupings, industry research, analysis of the O*Net database, and stakeholder discussions to develop an understanding of relevant and appropriate skills required of the workforce.

Through iterative testing and occupational gap analysis, 17 new skills were added to produce a Skills Map that reflects the nature of the sector (Industry Focussed skills), but also include relevant skills of the future, informed by industry reports and research, constituting a Skills Map. For purposes of clarifying terminology in the report, references to future skills henceforth refer to skills captured in **Table 2** (for a full list of skills and their definitions see Appendix D).

Future Focussed Skills...	**Change Management**	**Collaboration**	**Complex Stakeholder Engagement**
Creativity	**Data Analysis**	**Data and Digital Literacy**	**Design Thinking**
Stakeholder Analysis	**Strategic Planning**		

Table 2 Future Skills

Industry Focussed Skills...			
Blast Hole Drilling	**Configuration and Maintenance**	**Geospatial Analytics**	**Governance and Risk Management**
Load Handling	**Materials Extraction**	**Vehicle Operations**	**Work Health and Safety**

Table 3 Industry focussed skills

5. Impacts on the Workforce

Historically the sector has taken a relatively narrow focus in responding to workforce impacts across the economic cycle which has had consequential effects on workforce supply. In response to downturns, the sector has typically reduced the workforce due to lack of demand. This has had a negative effect on the retention of relevant skills, subject-matter expertise and sector-wide experience which has been costly to address in subsequent upturns in workforce demand. The lack of preparedness to consider the 'long play', and foresight to interrupt the costly pattern of workforce reduction and growth mirroring the commodity price cycle needs to change.

Moreover, declining enrolments in engineering and mining related degrees[8], supply shortages of experienced mining and engineering professionals who are either retiring or attracted to other sectors with more favourable work conditions, and mismatches between skills present and needed, add to the complex narrative of skilling in a sector being disrupted by technology.

In this section, the impact of technology on skills, in light of increasing adoption and technological innovation has been considered. The Digital Mining Report and Skills Map form the basis for this analysis. In addition, the impact of technology and innovation on skills is analysed against the: minerals industry value chain, industry skills movements, sector occupations and education and training.

5.1 Findings

Through the lens of the Digital Mining Report, all industry *Skill Types* are observed as increasing in demand, with some skills in the Technical skill type category representing decreasing/slow growth in demand. Overall, *System*, *Basic* and *Social Skills* type categories present the greatest demand of skills into the future. This is illustrated in Figure 3 below.

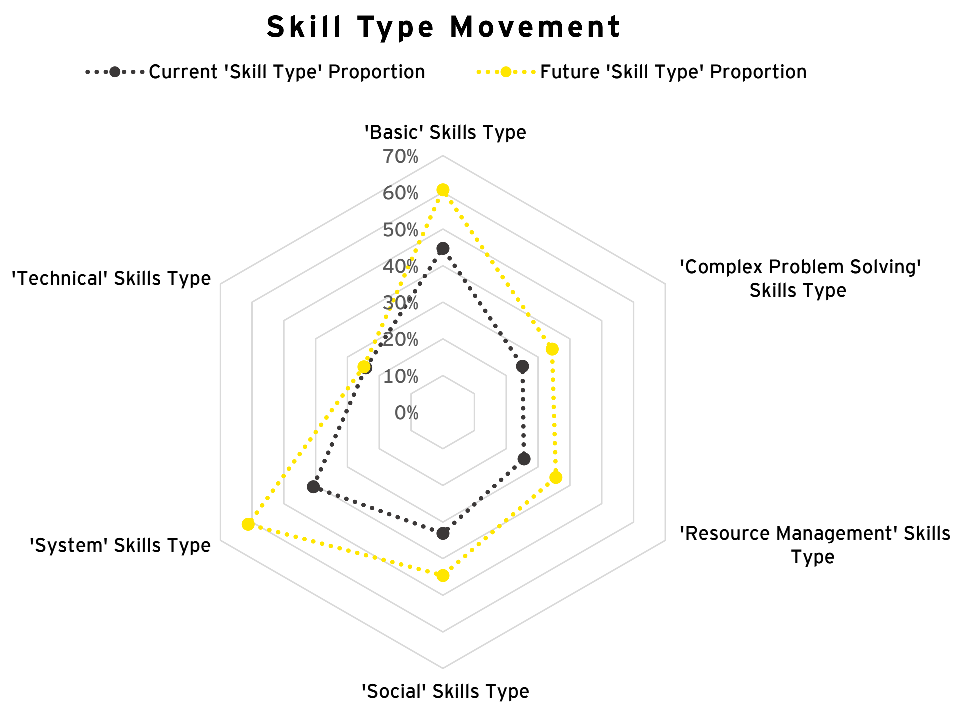


Figure 3 Skill Type Movement

[8] Minerals Council of Australia 2018, 'Minerals Tertiary Education Council: Key Performance Measures Report'

Figure 3 also illustrates '**Skills Movement**' capturing the prevalence of skill type between current and future workforce proportions, adjusted for the impact of technology. If the skill has a positive growth percentage it is interpreted as having growing future demand, and vice versa if negative. Appendix C also presents an analysis of 'skills movement' from a more granular perspective for each skill in the industry.

Technical Skills, i.e. Vehicle Operations and Materials Extraction, are observed as having the least net growth in demand into the future. As showcased through the Digital Mining Report, the declining growth may be attributed to increasing adoption and implementation of technologies capable of accomplishing tasks encompassed within these technical skills. Table 4 below articulates findings on the prevalence of skills, and how they are shifting into the future.

Skill Type	Findings
Basic	► Within this skill type category, the following top three skills emerge as those with the greatest demand: Mathematics; Data Analysis, Data and Digital Literacy. ► Skills in: Critical thinking, Speaking, Active listening, Reading comprehension and Monitoring are the most commonly occurring skills in occupations across industry and each of these skills present themselves in at least 85% of industry occupations (for detail, please refer to the Skills map).
Complex Problem Solving	► Within this skill type category, the following top three skills emerge as those with the greatest demand: Complex Problem Solving, Complex Stakeholder Engagement, and Design Thinking. ► Complex Problem Solving skills presents itself as a skill in 79% of industry occupations, with a 17% increase in demand in the future.
Resource Management	► Within this skill type category, the following top three skills emerge as those with the greatest demand: Time Management, Management of Personnel Resources, and Management of Material Resources. ► Time Management skills presents itself as a skill in 85% of occupations.
Social Skills	► Within this skill type category, the following top three skills emerge as those with the greatest demand: Instructing, Collaboration, Persuasion. ► Coordination and Collaboration skills present themselves as skills in 85% and 83% of industry occupations respectively.
System Skills	► 'Systems skills' have the greatest demand and growth from current to future workforce proportions. Specifically, skills in 'Systems evaluation' and 'Systems analysis' representing the biggest growth in this skill type category. Contrastingly, these skills can be found in 40% and 52% of industry occupations respectively (for detail, please refer to the Skills map). ► The demand for System skills, defined as 'developed capacities used to understand, monitor, and improve socio-technical systems' can be explained through evidence of case studies throughout the Digital Mining Report that illustrate a greater use of data analytics, increasing frequency in human-to-machine interfaces, and integrated operating centres, requiring a more holistic overview of the minerals industry value chain to optimise streamlined operations.
Technical Skills	► Within this skill type category, the following top three skills emerge as those with the greatest demand: Operations Analysis, Configuration and Maintenance and Quality Control Analysis. ► Within this skill type, 'Operation monitoring' skills present itself as the most prevalent; appearing in 37% of industry occupations, but contrastingly also observed as declining in growth for the future.

Table 4 Skill Type Findings

5.2 Impact of Technology across the Value Chain

Each stage of the minerals industry value chain incorporates a number of different occupations. Analysed through the value chain, analysis reveals that the end-to-end stage has the highest proportion of occupations enhanced by the impact of technology.

The 'Transport' and 'Trading' stages on the other hand, have a greater number of occupations susceptible to automation. 'Mining Operations' represents a phase with the greatest level of redesign as technology is increasingly optimising operations or more closely integrating them through use of technologies such as drones, integrated information systems and geospatial technologies.

Overall, analysis reveals that whilst there will be some occupations automated, the enhancements and productivity gains that technology and innovation will facilitate are far greater. This analysis can draw attention to where effort in areas such as revising educational/training curriculums and overall job redesign, can be expected and prioritised when workforce planning.

Value Chain Stage	Unique Occupations	Enhanced	Redesigned	Automated
Exploration	20	45%	35%	20%
Mining Operations	29	38%	45%	17%
Processing	28	43%	43%	14%
Transport	14	36%	43%	21%
Trading	13	38.50%	23%	38.50%
End-to-end	21	57%	24%	19%

Table 5 Occupation Type by Value Chain

5.3 Impact of Technology on Sector Occupations

Industry employment growth in the past couple of years has been recovering, and Department of Jobs and Small Business projections estimate an overall positive 2.4% employment growth for the minerals industry in the five years to May 2023[9].

ABS Census Data was used to develop an understanding of the composition of the industry's workforce by occupation (Appendix G). A total of 52 occupations make up 85% of the sector's current workforce. The Technology Impacts Index was applied to these occupations to determine the likely distribution of occupations in future industry workforces. This analysis revealed there were some differences in the occupation mix in the future; those occupations representing more than 1% of the current workforce and the future workforce are shown in the table below.

Occupation Group	Current Proportion of the workforce	Future Proportion of the workforce
Drillers, Miners and Shot Firers	22%	17%
Metal Fitters and Machinists	11%	15%
Other Building and Engineering Technicians	6%	13%
Truck Drivers	5%	2%
Electricians	4%	8%
Production Managers	3%	6%

[9] Department of Jobs and Small Business 2018, Industry Employment Projections Report. [Online]. Available at: http://lmip.gov.au/default.aspx?LMIP/EmploymentProjections [Accessed 5 December 2018].

Structural Steel and Welding Trades Workers	2%	1%
Other Stationary Plant Operators	2%	1%
Geologists, Geophysicists	2%	3%
Mining Engineers	2%	4%
Earthmoving Plant Operators	2%	< 1%
Industrial, Mechanical, and Production Engineers	1%	2%
Human Resource Manager	1%	2%
Occupational and Environmental Health Professional	1%	2%

Table 6 Proportion of Current and Future Workforce

Table 6 shows how the distribution of occupations in the workforce will change due to the impacts of technology. When categories of occupations are considered, the difference is clearer with a decreasing proportion of 'Automated' occupations remaining in the workforce, although skills associated with these occupations likely to be redirected into 'Enhanced' and 'Redesigned' occupations. There is also a reduction in the proportion of 'Redesigned' occupations in the workforce, however these changes are compensated for by a substantial increase in the proportion of 'Enhanced' positions in the workforce (see Figure 4).

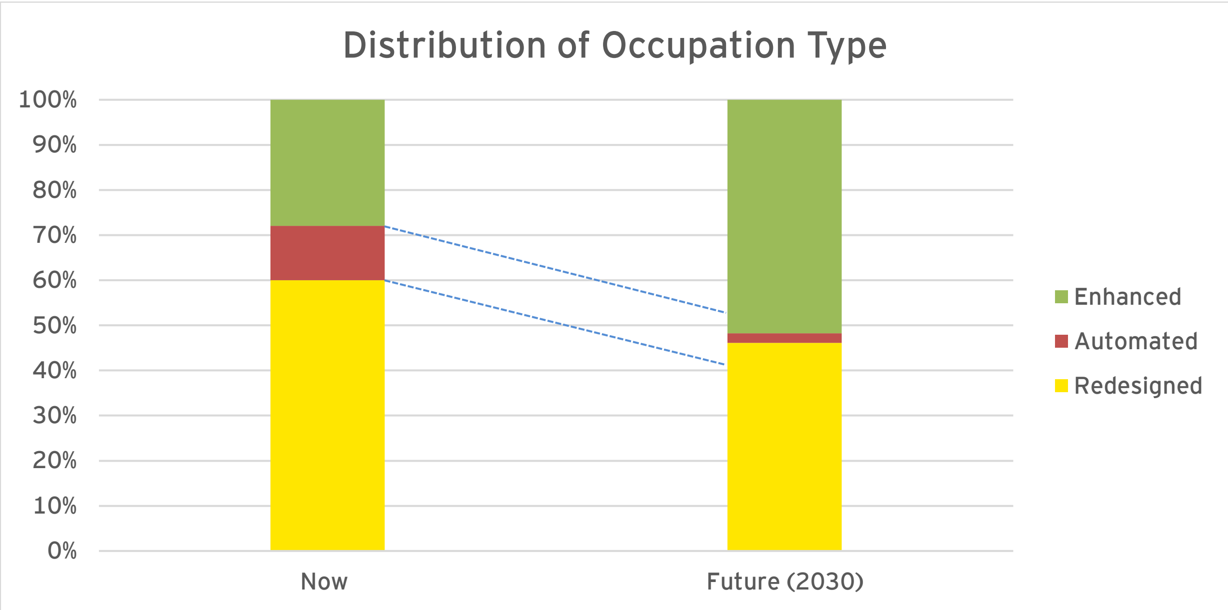


Figure 4 Distribution of Occupation Type

It is not expected that an occupation completely vanishes, the complex nature of the organisations in the industry is such that there are likely to be situations where an occupation cannot be completely automated, merely certain tasks in its role. The analysis suggests that occupations in the industry will continue to be redesigned and enhanced in taking advantage of technology.

5.4 Impact of Technology on Skills

The shifting distribution of occupation types in future industry workforces will also bring with it a different distribution of skills in the workforce. Analysis of the skills map using the future composition of the workforce shows movement in the demand for certain skills in the future workforce. The table below shows ten skills with the greatest growth in demand 'Growing Skills' and those with the greatest decrease in demand- 'declining skills' (Appendix C shows the relative growth and movement of all skills in the minerals industry).

Skills with growing demand	Skills with declining demand
Systems Evaluation	Vehicle Operations
Systems Analysis	Materials Extraction
Mathematics	Operation and Control
Instructing	Operation Monitoring
Data Analysis	Troubleshooting
Data and Digital Literacy	Equipment Maintenance
Writing	Blast Hole Drilling
Judgement and decision making	Equipment selection
Active Listening	
Active Learning	

Table 7 Movement of Skills

5.5 Impact of Technology on Education

The future of work will not only affect the skills required in the industry, but also the education base required. A focus on future skills needs to be complimented with an understanding of the education needs of the future workforce.

The largest occupation grouping in the sector, '*Drillers, Miners and Shot Firers*', are described in ANZSCO as requiring qualifications at a Certificate II or III (AQF Level 2 or 3), not including other industry certifications, to demonstrate adequate performance for one's role. The education requirements for the five largest occupation groups require education qualifications ranging from a Cert II or III level qualification to an Advanced Diploma.

When considered against their occupation types, analysis of education levels shows a general increase in occupation groups requiring a degree qualification (20 of the 23 enhanced occupations). As the occupational composition of the workforce changes consideration needs to be given to the fields of education required and the revision of these curriculums to keep pace. The table below shows the required fields of education by occupational type (enhanced, redesigned, and automated). The complexity is that in some cases the same field of study is present in some occupations that will be automated (i.e. General clerks) and some that will be enhanced by technology (i.e. HR Managers). However, when the Level of education (determined as per ANZSCO) is considered, the enhanced occupations all require a Bachelors level qualification while the automated occupations on average require a Certificate 2 or 3 level qualification. Appendix F provides a more detailed view of what fields of education are present and how they present themselves across occupation types.

This analysis observes the higher the prescribed level of education for an occupation, the more likely it is to be redesigned or enhanced, and vice versa. Table 8 categorises respective Fields of Education against each occupation type.

Enhanced Occupations- Field of Education	Redesigned Occupations (Field of Education)	Automated Occupations (Field of Education)
Banking, Finance and Related Fields	Automotive Engineering and Technology	Accounting
Business and Management	Business and Management	Building
Civil Engineering	Earth Sciences	Business and Management
Electrical and Electronic Engineering and Technology	Employment Skills Programmes	Civil Engineering
Environmental Studies	Mechanical and Industrial Engineering and Technology	Employment Skills Programmes
Information Systems	Other Management and Commerce	Mechanical and Industrial Engineering and Technology
Mechanical and Industrial Engineering and Technology	Other Natural and Physical Sciences	
Other Engineering and Related Technologies	Personal Services	
Other Management and Commerce	Process and Resources Engineering	
Other Natural and Physical Sciences		
Process and Resources Engineering		
Public Health		
Sales and Marketing		

Table 8 Fields of Education as per Occupation Type

6. Looking ahead

The narrative around digital transformation is changing, from one where the focus of technology deployment has been on cost reduction and efficiencies, to one where the focus is on workforce preparation to take advantage of how technology can redesign and enhance work. In the context of constant change, it is important now more than ever that organisations in the sector look at workforces as an asset to grow, rather than a fluctuating resource, expendable in response to volatile changes in external environments. Focus and consideration of an organisation's people operating model across the following five domains will better position firms to take advantage of the benefits technology offers, and strategically respond to the future of work.

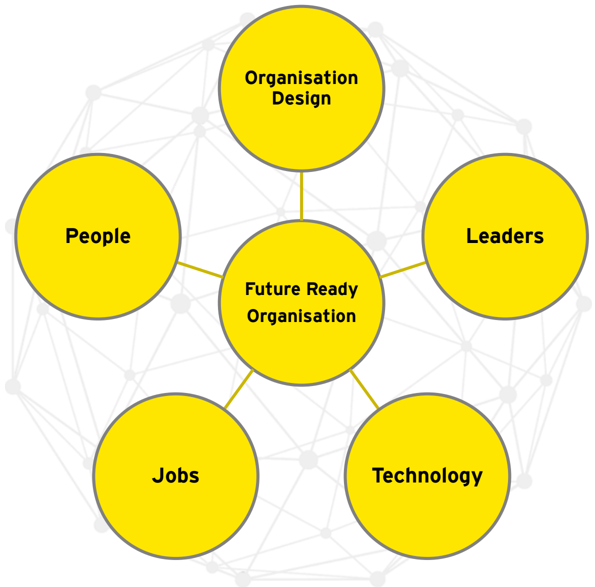


Figure 5 Factors to future-ready organisations

Against each of the organisational domains below are exemplar approaches and design principles to consider when preparing organisations for the future.

Organisation Design	▸ Focus less on boundaries and more on chemistry between people & functions ▸ Integrate technology and people in your operating model more closely ▸ Understand that organisational key performance indicators are not achieved by individual roles but diverse and multi-functional teams
Leaders	▸ Develop an informed view of the future that draws on robust data and activate strategies to proactively respond ▸ Draw on the full suits of capabilities and experience across the leadership group
Technology	▸ Create a clear digital strategy and agree on a technology partnering strategy ▸ Clarify the leadership skills and cultural change required ▸ Prioritise skill development
Jobs	▸ Understand the impact of technology on jobs & develop career pathing solutions ▸ Apply dynamic and sophisticated workforce planning methods ▸ Proactively match employment arrangements to business requirements ▸ Align technology and people strategies
People	▸ Building employee awareness of the future outlook ▸ Inform the policy debate on the nature and role of learning in securing ongoing employability and how this should be supported across government and industry

6.1 Skills of the Future

Skills of the future present themselves as resistant to the impact of automation, or those skills enhanced by technology resulting in greater productivity. Across a range of models forecasting future skills, common denominators indicate skills such as: entrepreneurship, art, collaborating with people, team work, communication, and design, remain resistant to the impacts of automation and digital. Furthermore, tasks that have elements of social intelligence, perception and manipulation, and creative intelligence are domains where digital technologies have yet to surpass human endeavour (Fray & Osborne 2013). Thus, the question of what skills remain applicable for the future reveal themselves as those most resistant, and those likely to be enhanced in the face of technology and innovation. In the context of the Digital Mining Report and as evidenced via the skills map, the following future skills have been articulated as highly relevant.

	Change Management	**Collaboration**	**Complex Stakeholder Engagement**
Creativity	**Data Analysis**	**Data and Digital Literacy**	**Design Thinking**
Stakeholder Analysis	**Strategic Planning**		

The Skills Map illustrated in Appendix B provides a snapshot of how skills map against occupations, provided as an addendum dashboard to this report. As a trend, it can be noted that occupations with higher skill levels, roles interpersonal by nature, and possessing greater educational attainment have an increased presence of future skills and likely to be enhanced and redesigned by technology. The skills map illustrates this visually through a heat map.

6.2 Addressing the Workforce

In addressing the unique supply-side challenges of the industry, the following thematic areas should be considered to equip organisations into the future:

- **Activating the right skills and capabilities**
    - Workforces need to be adequately equipped not only with the skills they need now, but also the skills demands of the future. A phased campaign of learning transformations, as appropriate to each organisation in the sector, may seek to enhance future workforce readiness, and the agility with which organisations can respond to the evolving future of work.
    - Relevant skill based training should be introduced with foresight, scaffolded with effective change management practice advocating the case for change- the why, and introduced realistically in tandem with technological implementation so knowledge-based training can be effectively utilised on the job. Talent development has a lag effect between learning event and realisable business outcome and this should also be factored into productivity timelines.
    - Skill development initiatives need to be balanced across both technical and soft skill competencies. The future demands more individuals who are collaborative, innovative, system-thinkers who can manage complexity and see the interconnectedness and improvements across the value chain.

- There is also the need for education pathways that enable mobility between and into the sector. Australia's growing investments in infrastructure projects have seen workers from the minerals industry move into the infrastructure sector, highlighting the need for training that support these cross-sector competencies.

- Retention
    - Cherishing the deep experience of senior and seasoned mining professionals is essential for the systematic translation of corporate knowledge, industry foresight and transference of skills and knowledge to lead the sector, especially through turbulent times.
    - Potential role evolutions for those with deep sector experiences, are to upskill these individuals in skills of strategic planning, design thinking and leadership through a digital age.
    - As more mining professionals reach retirement age, or temptations to move into other sectors with more favourable working conditions arise, flexible working arrangements (FWAs) should be exercised. EY research has also indicated that female workers on FWAs are 3.5% more productive than their full-time peers.[10]
    - Tailored rewards programs to meet personal requirements.
    - Structured mobility programs can support employee retention by structuring programs which minimize family disruption. This can have the domino effect of improving the mental health of employees.

- Workforce Conditions
    - Leveraging technology to minimise the need for FIFO whilst also enhancing safety and accessibility may enhance the value proposition of the role.
    - Opportunities for rotation of people across mine sites within the organisation's portfolio.
    - Consider labour sharing amongst smaller organisations with single product focuses with non-competing industry partners, in response to fluctuations in demand for products.

- Diversity
    - Given the high-degree of males in the sector, the sector can seem almost prohibitive or barring to those whose gender identify does not align with the majority. A perceived homogenous membership of the industry may also bar other minority sub-groups i.e. culturally and linguistically diverse communities, people with disability, to name a few, and may also deter innovative thinkers entering from other sectors. Awareness campaigns communicating the benefit of diverse teams, partnerships with higher education institutions and registered training organisations to highlight shifting workforce trends and co-design content, cognitive-bias training to reinvigorate recruitment strategies, and championing inclusive work cultures should be initiatives continually championed in order to attract leaders of tomorrow.

[10] EY 2013, 'Untapped opportunity: the role of women in unlocking Australia's productivity potential'.

- **Curriculum Design**
    - The 'future skills' articulated in this report should be a more prevalent and underpinning feature of the Resources and Infrastructure Industry Training Package. References to out-dated technologies should be replaced by contemporary needs and uses of technology in the sector, supported through a revised skills gap analysis.
- **Strategic Workforce Planning**
    - The industry workforce is not immune to global trends in commodity prices, economic growth and cyclical demands for resources. As such, organisations in the past have taken a reactive approach to managing workforces in light of these trends. Shrinking the workforce in times of downturn, and rapid acquisition of capital and workforce capacity in times of upswing. A more nuanced approach to sustaining workforce will be required for the future that can be achieved through more focussed workforce modelling, estimating future workforce demand and supply, relevant skills based development, and activating strategies to attract, retain and retrain their workforces.
    - As succession plans indicate the likelihood of individuals transitioning to retirement, mentoring and coaching models to effectively pair and cross-skill individuals in the lead up should be considered. Once employees are lost to the sector, it is hard to attract them back. This loss of the sector-specific knowledge and skills exacerbates workforce capability and can be mitigated through proactive and phased interventions such as reverse mentoring programs, and establishing communities of practice to sustain experience and skills.

Appendix A Technology Impacts Index

The Technology Impacts Index captures probabilities against each occupation in the table below, primarily building on work by Frey and Osborne[11]. Probabilities have a range of 0 to 1, with a higher value indicating the likelihood of computerisation and automation.

Occupation	Probability
Accountants	0.94
Accounting Clerks	0.98
Advertising, Public Relations and Sales Managers	0.01
Automotive Electrician	0.61
Chief Executives and Managing Directors	0.02
Civil Engineering Professionals	0.02
Commercial Cleaner	0.66
Contract, Program and Project Administrators	0.73
Crane, Hoist and Lift Operator	0.78
Drillers, Miners and Shot Firers	0.67
Earthmoving Plant Operators	0.94
Electrical Engineer	0.1
Electricians	0.15
Engineering Manager	0.02
Engineering Production Worker	0.92
Environmental Scientists	0.03
Finance Manager	0.07
General Clerks	0.96
General Managers	0.16
Geologists, Geophysicists and Hydrogeologists	0.32
Human Resource Manager	0.01
Human Resource Professionals	0.31
ICT Managers	0.04
Industrial, Mechanical and Production Engineers	0.02
Machine Operators	0.86
Machinery Operators and Drivers	0.86
Management and Organisation Analysts	0.13
Metal Fitters and Machinists	0.41
Mining Engineers	0.14
Motor Mechanics	0.59
Occupational and Environmental Health Professionals	0.17
Office Managers	0.73
Other Building and Engineering Technicians	0.03
Other Construction and Mining Labourers	0.88
Other Miscellaneous Labourers	0.85
Other Natural and Physical Science Professionals	0.02
Other Specialist Managers	0.03
Other Stationary Plant Operators	0.82
Personal Assistant	0.86
Production Managers	0.16
Purchasing and Supply Logistics Clerks	0.93
Science Technicians	0.77
Storepersons	0.64
Structural Steel and Welding Trades Workers	0.83
Structural Steel Construction Workers	0.83
Supply, Distribution and Procurement Managers	0.25
Surveyors and Spatial Scientists	0.38
Technicians and Trades Workers, not further defined	0.17
Train and Tram Drivers	0.77
Training and Development Professionals	0.01
Transport and Despatch Clerks	0.98
Truck Drivers	0.79

[11] Frey, C.B. and Osborne, M.A. 2013, '*The Future of Employment: How Jobs are Susceptible to Computerisation*', Oxford Martin Programme on Technology and Employment.

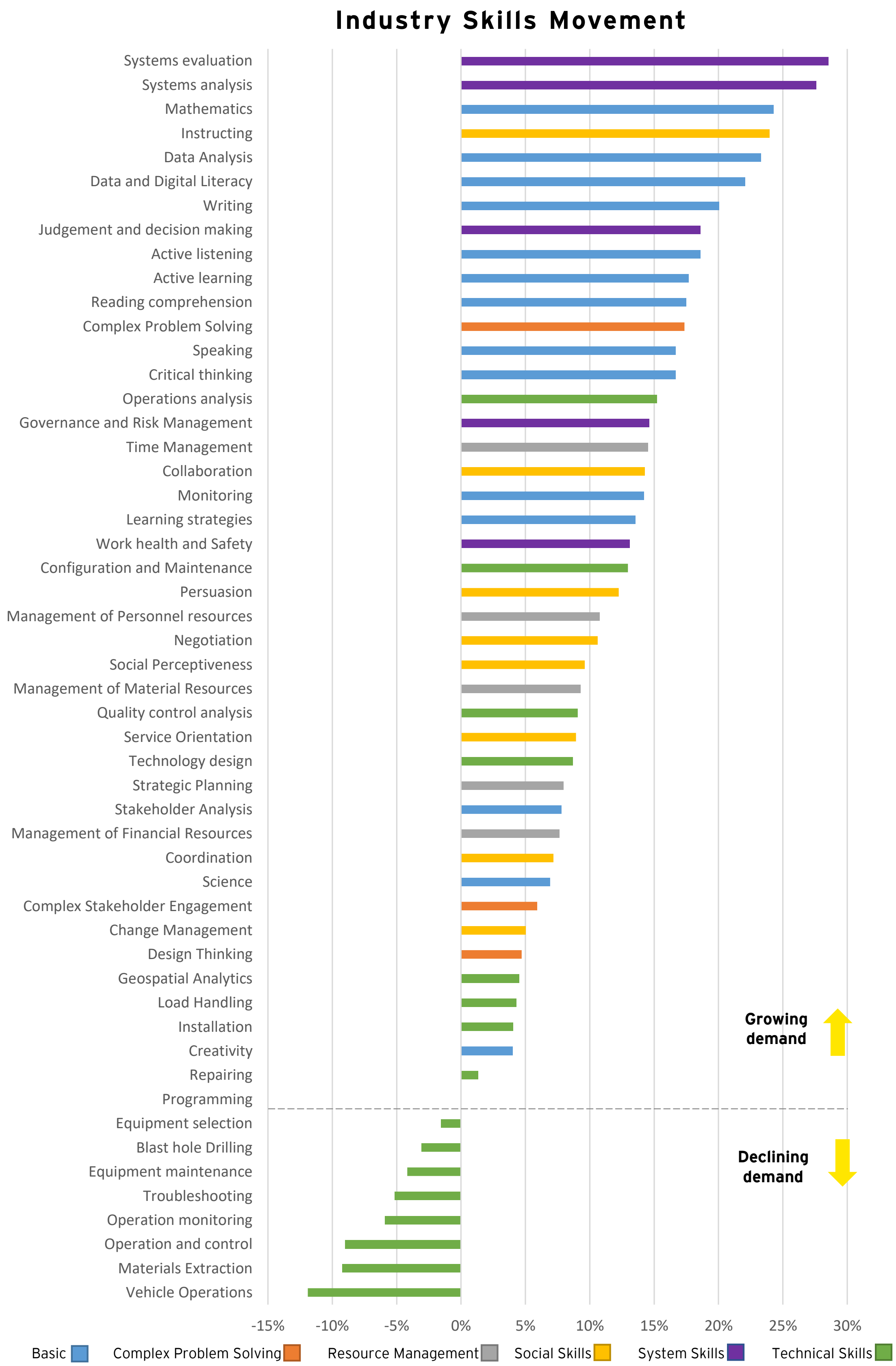
Appendix B Skills Map (Exemplar Snapshot)

A Skills Map is articulated as an attached addendum supporting this report, exemplar snapshot below, also further explained in Section 3.2.

ANZSCO Occupation Unit-Group	Storepersons	Structural Steel and Welding Trades Workers	Structural Steel Construction Workers	Supply, Distribution and Procurement Managers	Surveyors and Spatial Scientists	Technicians and Trades Workers, nfd	Train and Tram Drivers	Training and Development Professionals	Transport and Despatch Clerks	Truck Drivers	
Occupation Impact Category	Redesigned	Redesigned	Redesigned	Enhanced	Redesigned	Enhanced	Redesigned	Enhanced	Automated	Redesigned	
Technology Impacts In	0.64	0.83	0.83	0.25	0.38	0.17	0.77	0.01	0.98	0.79	**Skills Prevalence as prop of future workforce (Change %)**
Active learning		1	1	1	1	1	1	1	1		18%
Active listening	1	1	1	1	1		1	1	1		19%
Critical thinking		1	1	1	1	1	1	1	1	1	17%
Learning strategies				1	1			1			14%
Mathematics				1	1						24%
Monitoring		1	1	1	1	1	1	1	1	1	14%
Reading comprehension				1	1	1	1	1	1	1	18%
Science					1						7%
Speaking	1	1	1	1	1	1	1	1	1	1	17%
Writing				1	1	1		1	1		20%
Data and Digital Literacy				1	1			1			22%
Stakeholder Analysis				1				1			8%
Data Analysis				1	1			1			23%
Creativity								1			4%
Complex Problem Solving		1	1	1	1	1	1	1	1		17%
Design Thinking								1			5%
Complex Stakeholder Engagem				1							6%
Management of Financial Re											8%
Management of Material Res				1							9%
Management of Personnel re				1	1	1		1			11%
Time Management		1	1	1	1	1	1	1	1	1	15%
Strategic Planning				1							8%
Coordination	1	1	1	1	1	1	1	1	1		7%
Instructing				1	1	1		1			24%
Negotiation				1		1		1			11%
Persuasion				1		1		1	1		12%
Service Orientation	1			1	1	1	1	1	1		9%
Social Perceptiveness				1	1	1	1	1	1		10%
Change Management								1			5%
Collaboration		1	1	1	1	1	1	1		1	14%
Judgement and decision ma		1	1	1	1	1	1	1	1		19%
Systems analysis				1	1			1			28%
Systems evaluation				1				1			29%
Governance and Risk Managen				1							15%
Work health and Safety	1	1	1	1	1	1	1			1	13%
Equipment maintenance											-4%
Equipment selection						1					-2%
Installation											4%
Operation and control		1	1				1			1	-9%
Operation monitoring		1	1				1			1	-6%
Operations analysis					1			1			15%
Programming											0%
Quality control analysis		1	1			1					9%
Repairing											1%
Technology design											9%
Blast hole Drilling					1						-3%
Vehicle Operations	1					1	1		1	1	-12%
Load Handling		1	1			1					4%
Materials Extraction					1	1	1		1	1	-9%
Configuration and Maintenance					1						13%
Geospatial Analytics					1						5%
Troubleshooting										1	-5%

Appendix C Movement of Skills

Illustration of how skills can be expected to grow or decline in demand as a proportion of future workforces. Net positive skills can be expected to remain as a feature of the skills landscape and increase in demand.



Appendix D Skill Descriptors

Skill	Skill Descriptor
Active Learning	Understanding the implications of new information for both current and future problem-solving and decision-making.
Active Listening	Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.
Blast Hole Drilling	Adept use of appropriate technologies, or mechanisms to facilitate extraction efforts during the exploration and operations phases of minerals and mining sector.
Change Management	Managing people through change events in a systematic way to achieve successful personal transitions and desired future-state outcomes set by the business.
Collaboration	Process of teaming, cooperation and working with people, in physical or virtual environments, to achieve outcomes.
Complex Problem Solving	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.
Complex Stakeholder Engagement	Identifying stakeholder interest and influence groups and communicating effectively to involve these stakeholders strategically into the long-term.
Configuration and Maintenance	Diagnosing issues arising with technology platforms and systems, and determining appropriate methods for repair and reuse.
Coordination	Adjusting actions in relation to others' actions.
Creativity	Formulating new ideas and thinking by incorporating divergent perspectives and connecting unrelated phenomena to generate options, solutions and theories.
Critical Thinking	Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.
Data Analysis	Evaluating and transforming data sources using analytical and logical approaches to inform decision making.
Data and Digital Literacy	Ability to derive meaningful information from data sources and utilise technology platforms/systems (i.e. using 'Building Information Modelling' systems) to support decision making and participation in workplaces.
Design Thinking	Utilising an iterative, and systematic solution-based approaches to problem solving.
Equipment Maintenance	Performing routine maintenance on equipment and determining when and what kind of maintenance is needed.
Equipment Selection	Determining the kind of tools and equipment needed to do a job.
Geospatial Analytics	Ability to utilise various technological platforms and data analytics techniques to acquire, manipulate and store geographic information to inform operations.
Governance and Risk Management	Identification, analysis, assessment, control, and avoidance, minimization or elimination of unacceptable risk which extends to environmental considerations.
Installation	Installing equipment, machines, wiring, or programs to meet specifications.
Instructing	Teaching others how to do something.
Judgment and Decision Making	Considering the relative costs and benefits of potential actions to choose the most appropriate one.
Learning Strategies	Selecting and using training/instructional methods and procedures appropriate for the situation when learning or teaching new things.
Load Handling	Ability to handle loads appropriately, observe safe handling techniques i.e. adhering to load limits and safety measures, when transporting materials.
Management of Financial Resources	Determining how money will be spent to get the work done, and accounting for these expenditures.
Management of Material Resources	Obtaining and seeing to the appropriate use of equipment, facilities, and materials needed to do certain work.

Skill	Skill Descriptor
Management of Personnel Resources	Motivating, developing, and directing people as they work, identifying the best people for the job.
Materials Extraction	Collection of raw materials from the natural environment using appropriate mechanisms and contemporary technologies like autonomous drilling or plant operators.
Mathematics	Using mathematics to solve problems.
Monitoring	Monitoring/Assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.
Negotiation	Bringing others together and trying to reconcile differences.
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.
Operations Analysis	Analysing needs and product requirements to create a design.
Persuasion	Persuading others to change their minds or behaviour.
Programming	Writing computer programs for various purposes.
Quality Control Analysis	Conducting tests and inspections of products, services, or processes to evaluate quality or performance.
Reading Comprehension	Understanding written sentences and paragraphs in work related documents.
Repairing	Repairing machines or systems using the needed tools.
Science	Using scientific rules and methods to solve problems.
Service Orientation	Actively looking for ways to help people.
Social Perceptiveness	Being aware of others' reactions and understanding why they react as they do.
Speaking	Talking to others to convey information effectively.
Stakeholder Analysis	Ability to identify and segment stakeholder groups as they relate to an organisation to support decision making and engagement.
Strategic Planning	Determining priorities, resourcing requirements and allocations in the short to long term, using data and digital techniques, to support organisational decision making
Systems Analysis	Determining how a system should work and how changes in conditions, operations, relating systems and the environment will affect outcomes.
Systems Evaluation	Identifying measures or indicators of system performance and the actions needed to improve or correct performance, relative to the goals of the system.
Technology Design	Generating or adapting equipment and technology to serve user needs.
Time Management	Managing one's own time and the time of others.
Troubleshooting	Determining causes of operating errors and deciding what to do about it.
Vehicle Operations	Ability to operate heavy trucks and site-approved vehicles in enabling and supporting mining operations
Work Health and Safety	Hazard identification and controls setting according to industry standards, in order to promote ongoing occupational safety for employees, including mental health safety.
Writing	Communicating effectively in writing as appropriate for the needs of the audience.

Appendix E Literature Review

Source	Yeates, G, 2018, 'Education Summit Presentation'.

Insights	► Drivers for new operating models:
	  ► Data rich collaboration platforms
	  ► Global connectedness with virtual and augmented reality
	  ► The millennial generation
	  ► The rise of the gig economy
	  ► An agile approach to all aspects of work
	  ► More nuanced metrics

Source	Yeates, G, & Farrelly, C 2017, 'Business Opportunities in Mining & Energy Resources for Internet of Things Applications'.

Insights	► Digitalisation of mining is one of the most significant value creating opportunities for miners, with monitoring of equipment being the first area providing a growing set of data about how equipment is operating.
	► Historically, proprietary data systems have created deep 'vertical' islands of data, exacerbating siloes that remote operating centres are seeking to democratise to enable a more horizontal process view.
	► Applications of new technologies are most anticipated in yielding the greatest benefits in the mining value chain in the following categories: geoscience technologies, new mining technologies, new processing technologies, and digital control and optimisation.
	► Exploration, Mining Operations and Processing are having the biggest impact of automation.
	► The monitoring of equipment has been the first area to be instrumented in detail to collect data about how equipment is operating. However, measurement of mining and extraction process is lagging with some critical information required to manage the process simply not being available due to the lack of appropriate sensing, or the lack of understanding of customer needs by the equipment supplies. To ameliorate, new sensors that will measure the mining process in real time and enhance operational decision making are being trailed and tested.
	► Systems fragmentation across various parts of the mining value chain through bespoke products from various vendors have meant the mining industry has had no product or service large enough to provide the level of integration needed across the core value chain. This has contributed to a much slower uptake of technology, with few linking horizontals to provide the linking of data across the value chain.
	► The vendor landscape is changing with new players like Amazon and Schneider Electric, setting up Mining Division to respond to requests for proposals from the sector.
	► Areas of Opportunity for the Mining Sector:
	  ► Spatial and temporal platforms for integrating data.
	    ► Platforms currently available need to be enhanced to enable them to store and interoperate on data that is both spatial and temporal in nature; also to enable the horizontal end-to-end process view of mining operations. These platforms must be open, scalable and allow seamless integration of third party applications. The definition of the common and fundamental mining objects should be integral to such a platform.
	  ► Short term interval control for mining operations.
	    ► Companies are dealing with the complexity of multitude of systems. Short term mine planning, fleet management, stockpile management, fixed plant process control, product inventory are all run from different systems, however all these processes are high interdependent and mining companies are now realizing the huge value to be gained by looking to optimize the whole or at least consider the interdependencies
	  ► End to End process simulation.
	    ► Mining does not use simulations to information decision making historically due to a lack of capability. This is an opportunity, to aid longer term planning processes and in short term decision making as well.
	  ► Ore Tracking and reconciliation
	    ► Extraction, separation and delivery of product is the goal of every mining company. Currently mining companies are unable to track a parcel of material that is mined through the process to final product whilst maintaining the location from which it came and the operating parameters used to produce the final product. Without the ability to track parcels of material and then understand the performance through the process it is not possible to improve and predict the performance of the entire process.

Source	SkillsDMC 2015, 'RII Resources and Infrastructure Industry Training Package'.
Insights	► Industry Training Packages specify the skills and knowledge required to perform effectively in the workforce. They are developed to meet the training needs of an industry, or a group of industries. ► The Australian Resources and Infrastructure Industry is comprised of five sectors: coal mining, civil infrastructure, metalliferous mining, drilling and quarrying (extractive). ► These sectors are heavily reliant on each other for commercial success within a single eco-system. They have workforce development challenges which include:

	► An ageing workforce nearing retirement age, especially at managerial and operational level ► New worker attractions in the face of often negative public perceptions of the Industry ► Remote operation locations requiring sophisticated workforce movement practices ► Engaging regional communities as a source for an operational workforce ► Ongoing skill enhancement to support safety, operational and technological requirements ► Attraction and retention of female workers ► Up-skilling and cross-skilling workers who move across from related industries so they are able to fill skills gaps in a timely manner; and ► Global economic shifts that dictate changes in workforce direction

Source	EY, 2018, 'Future of Work: Economic Implications of Technology and Digital Mining A Report for the Minerals Council of Australia.'
Insights	► Adoption of digital and technological innovation has the potential to deliver productivity improvements to the industry of between 9% and 23% ► Advancement in automation and remote operations will dramatically shift the type and severity of risks workers are exposed to thus improving overall workforce health and wellbeing as well as reducing the financial impact of safety related events. ► People and culture will likely be the limiting factor to productivity gains, not the introduction of new technology ► Significant investment in the capability and structure of the workforce will be required to support successful implementation of new technologies. An investment ranging between $5b - $12.8b across the industry will be required to unlock the potential productivity gains identified. ► Digital mining will see the demand for traditional operators greatly reduce, with a more technologically savvy workforce required and traditional roles redesigned ► Mining professionals will combine technical mining skills with digital technological competency, while newer capabilities such as data scientists, modellers etc. will provide core functional support ► The place of work will shift to more remote operations centres

Source	Regional Australia Institute, 2016, 'The Future of Work'
Insights	► In-demand jobs of the future will mix high tech aspects, personal contact and care activities ► Future jobs will be flexible, entrepreneurial and dynamic ► Individuals will need a mix of digital and soft personal skills for success in the 2030 job market ► Hard specialist knowledge skills like Science, Technology, Engineering and Maths, plus Entrepreneurship, Art and Design- STEAMED are deemed as an essential category of skill ► Furthermore, soft people skills like critical thinking, communication, collaboration, connectivity, creativity, and culture, are deemed the second-half of that essential future skills equation ► The future of work is not a question of how do we develop skills to race against technology, but instead, what mix of skills provides the greatest opportunity to race ahead with technology. ► Jobs with the strongest future are those with a combination of high levels or at least one of these skill sets, from: big data analysts to personal care givers. ► Debates on the future of work always hinge on the epistemological limitations of our experience. There are a range of jobs we have yet to think of. The field is changing so rapidly, forecasting with any degree of certainty becomes an iterative task to understand the landscape with greater certainty.

Source	Minerals Council of Australia 2018, 'Industry Education Summit'.
Insights	► Resource companies employ approximately 222,000 people in high-wage, high-skilled jobs, predominantly in remote and regional Australia. Considering the broader METS sector increases this workforce to over 1.1 million people ► Australia's resources workforce covers a range of scientific fields and professional occupations. ► The composition of Australia's minerals workforce is changing as technological innovation is further integrated into the mining value chain. For example, white collar workers now represent the largest share of Australia's minerals workforce. **Demand-side skills requirements:** ► Essential to the future of the minerals workforce are the development of core/technical skills, coupled with cognitive or 'soft skills' and interpersonal skills. ► Business pressures to improve safety and increase productivity are placing greater demands for new ways of operating and organizing workforces **Supply-side skill shocks:** ► The decline in mining engineers continues into 2018, with only 34 first year enrolments across the 4 MEA universities who supply 80% of Australian mining engineering graduates. Down 87% from the high of 267 first year enrolments in 2012. ► MCA and MEA modelling suggest that industry requires in-excess of 200 new graduates annually to replace natural attrition in the workforce. When added to the decrease in uptake of STEM subjects in schools over the last decade, this presents future skilling issues to an industry that depends on **engineers, geologists, geoscientists, geophysicists and increasingly pure mathematicians.** **Priority actions MCA has agreed to:**

	► Establish a Future Minerals Workforce Working Group to guide the creation and implementation of the future **Minerals Workforce Strategy**
	► Develop and deliver education and training options with new and existing partners to increase the future pipeline and provide opportunities for the existing workforce, including:
	    ► Creating post graduate qualifications to provide a pathway for graduates of other engineering disciplines to qualify as mining engineers
	    ► **Identifying skills and capabilities for existing workforces to upskill, cross-skill and re-skill through Vocational Education and Training, including micro-credentialing**
	    ► Mapping career and employment pathways to show the opportunities of the sector

Source	**PwC 2018, 'Industry Skills and Forecast and Proposed Schedule of Work- Mining, Drilling and Civil Infrastructure'.**

Insights	► The Mining, Drilling and Civil Infrastructure (MDCI) Industry Reference Committees (IRC) puts industry at the heart of Australia's qualifications and training system. This report details the training product priorities for the IRC
	► Nationally recognised training for this sector is housed within the Resources and Infrastructure Industry (RII) Training Package, providing a clear, structured pathway to support the development of MDCI workforce to meet the needs of the MDCI sector now and into the future.
	► In the context of the changing workforce, key trends in training are emerging:
	    ► An increased demand for workforce agility, and the ability to move between sectors and industries in response to market demand. This is particularly pertinent to the MDCI sector given the boom and bust cycles it is subject to.
	    ► Increased investment in the infrastructure industry from the Australian government, leading to an increased demand for civil infrastructure skills and the relevant training to support this workforce.
	    ► The impact of emerging technology on ways of working, with new techniques and equipment requiring new training units to be developed to ensure workers have the most up to date skills and knowledge
	    ► An increased focus on safety measures in the MDCI sector to meet regulatory requirements and ensure the safety of workers in challenging and hazardous environments
	    ► A need to support the development of managerial skills alongside technical competence as workers progress into leadership roles
	► Employer Challenges from the MDCI Sector:
	    ► Technical skills developed outside the sector are often not applicable, and a greater need for customization is required, increasing the perceived barriers to entry
	    ► The MDCI sector is subject to increasing regulation, which raises the cost and administrative burden for employers.
	► A typical Learner profile in the MDCI sector:
	    ► Predominantly male
	    ► More likely to be Indigenous than learners of other Training Packages- Indigenous learners make up 8% of enrolments for the RII Training Package, compared to 4% across all Training Packages
	    ► In Queensland- 56% of RII qualifications are delivered in Queensland, compared to 23% across all Training Packages. This is partly due to QLD legislative requirements.
	► PwC's Skills for Australia has been commissioned to develop Training Package components that address skill needs across industries in four cross sector skills areas: Cyber Security, Big Data, Teamwork and Communication, and Inclusion of People with Disability in VET.
	► Four key trends shaping the MDCI workforce were identified in the medium to long term:
	    ► Industry growth opportunities
	        Greater demand for training that spans sectors to enhance mobility options for individuals
	        Skill needs: abilities to use new technology and techniques in the civil infrastructure industry, analytical skills to predict future demand of resources and optimise current production, strong management and supervisory skills to reside over remaining life of coal mines and large civil infrastructure projects
	    ► Environmental Issues
	        Major buyers of Australian coal like China and Japan are progressively moving their economies towards greener more renewable technologies. Furthermore, increasing environmental protections and regulations are pushing for lower emissions technology to be used in power production globally.
	        Investment in renewable energy projects will create more jobs in the civil infrastructure sector.
	        There is an uncertainty in demand for coal miners. Increase in metalliferous miners, sustained demand for coking coal miners and increased demand for civil infrastructure skills.
	    ► Technological change
	        Innovation in the Mining sector has historically been slow. However, firms like RioTinto are deploying autonomous technologies as part of their 'Mines of the Future' program to remotely operation mines from a central location. The company continues to expand their 69 strong autonomous fleet with 38 haul

	trucks to be retrofitted with technology by mid-2019 as part of a $5billion productivity drive. The evolution of the digital mine uses advanced technologies such as real-time data capture with low cost sensor to feed information back to operators to improve planning, control and decision making with the ultimate aim of extracting greater value at a lower cost, whilst also increasing health and safety of mine workers. **Building Information Modelling (BIM),** is emerging as an increasing demand. BIM allows construction workers to view a digital representation of a project, from planning through to construction and operation, **serving as a central platform of collaboration for all stakeholders**. Infrastructure Australia recommended that BIM be mandatory for all large scale, complex infrastructure projects. **Job demands in: increased digital designers, remote operators, data interpreters, ongoing/agile learners, decreased demand for low skilled labour** **Digital technology skills, such as BIM, digital design and data interpretation, analytical skills to optimise current production. Software skills to understand the capabilities and limitations of software used in the workplace.** ► The impact of new technology on ways of working has led to change in the skills required for the workforce of the future. Key developments include the increased use of automated vehicles, remotely operated vehicles, remote operation centres and drone technology particularly in mining, and of cyber chair, sonic drilling, and coil tube rigs in drilling. There is a need for skills in operating these new technologies, in addition to maintenance and programming of the new equipment used on site.

Source	PwC 2018, 'Mine 2018: Tempting times'
Insights	► Continual recovery in commodity prices, fuelled by general economic growth, has seen revenue for the sector rise by 23%. ► Cost-saving strategies, stable capital expenditure, a heightened focus on safety in operations, and avoidance of aggressive investment in new capacity indicates management is proceeding in a measured and deliberate way. ► The question of how the top 40 firms in the mining sector will react in response to this positive upturn will decide the next decade. Will firms fall into the traps of previous management action or innovatively chart their way through new terrain? ► Current temptations are to acquire mineral-producing assets at any price in order to meet rising demand. In the previous cycle, many miners disregarded prudent capital discipline in the pursuit of higher production levels, which set them up to suffer when the downturn came. Miners will need to resist the urge to pursue project or acquisitions at any price, exercise discipline in capital investment, and instead focus on mining for profit not for tonnes. ► In response to favourable balance sheets, stakeholders such as government, workers, and shareholders will increasingly demand a bigger share of the profits through higher dividends, taxes and wages. Miners will need to strike a balance between near-term demands and their long-term vision to deliver value. ► Projections state that this current cycle of growth has several more years to run. Steady global annual GDP growth over the next five years, along with significant infrastructure growth in emerging economies is expected to underpin continued demand for mining products. ► The mining sector is cyclical due the lag between investment decisions and new supply, thereby also impacting workforces. ► However, success is never assured, and there are many disruptive factors like: geopolitical uncertainty, regulatory risk, technology and cyber risks, and social licence risks are all on the rise. ► Impacts of Technology and Cyber have been deemed as a major likelihood and impact on the workforce. ► Employee costs are set to increase by 5% ► Fatalities down by 36% ► Female board representation increased to 19% ► Labour continues to be a significant component of input costs for Top 40 Companies, representing an estimated 32% of operating costs

Appendix F Industry Fields of Education

The table below outlines ASCED Fields of Education (FoE) as found in the sector occupations, and the correlating occupations that relate to it, sub-grouped. Also indicated are the proportion of these fields of education based off sector occupation totals, and whether they can be expected to be augmented, automated or enhanced based off their rating on the Technology Impacts Index.

Fields of Education (Occupations sub grouped)	FoE as a proportion of Occupations	Enhanced	Redesigned	Automated
Accounting	**3.85%**			**16.67%**
Accountants	1.92%			8.33%
Accounting Clerks	1.92%			8.33%
Automotive Engineering and Technology	**3.85%**		**11.11%**	
Automotive Electrician	1.92%		5.56%	
Motor Mechanics	1.92%		5.56%	
Banking, Finance and Related Fields	**1.92%**	**4.55%**		
Finance Manager	1.92%	4.55%		
Building	**1.92%**			**8.33%**
Other Construction and Mining Labourers	1.92%			8.33%
Business and Management	**23.08%**	**31.82%**	**16.67%**	**16.67%**
Chief Executives and Managing Directors	1.92%	4.55%		
Contract, Program and Project Administrators	1.92%		5.56%	
General Clerks	1.92%			8.33%
General Managers	1.92%	4.55%		
Human Resource Manager	1.92%	4.55%		
Human Resource Professionals	1.92%		5.56%	
Management and Organisation Analysts	1.92%	4.55%		
Office Managers	1.92%		5.56%	
Other Specialist Managers	1.92%	4.55%		
Personal Assistant	1.92%			8.33%
Production Managers	1.92%	4.55%		
Training and Development Professionals	1.92%	4.55%		
Civil Engineering	**7.69%**	**9.09%**		**16.67%**
Civil Engineering Professionals	1.92%	4.55%		
Earthmoving Plant Operators	1.92%			8.33%
Engineering Production Worker	1.92%			8.33%
Other Building and Engineering Technicians	1.92%	4.55%		
Earth Sciences	**3.85%**		**11.11%**	
Geologists, Geophysicists and Hydrogeologists	1.92%		5.56%	
Surveyors and Spatial Scientists	1.92%		5.56%	
Electrical and Electronic Engineering and Technology	**3.85%**	**9.09%**		
Electrical Engineer	1.92%	4.55%		
Electricians	1.92%	4.55%		
Employment Skills Programmes	**7.69%**		**11.11%**	**16.67%**
Other Miscellaneous Labourers	1.92%			8.33%
Train and Tram Drivers	1.92%		5.56%	
Transport and Despatch Clerks	1.92%			8.33%
Truck Drivers	1.92%		5.56%	
Environmental Studies	**1.92%**	**4.55%**		
Environmental Scientists	1.92%	4.55%		
Information Systems	**1.92%**	**4.55%**		
ICT Managers	1.92%	4.55%		
Mechanical and Industrial Engineering and Technology	**15.38%**	**4.55%**	**27.78%**	**16.67%**
Crane, Hoist and Lift Operator	1.92%		5.56%	
Industrial, Mechanical and Production Engineers	1.92%	4.55%		
Machine Operators	1.92%			8.33%
Machinery Operators and Drivers	1.92%			8.33%
Metal Fitters and Machinists	1.92%		5.56%	
Other Stationary Plant Operators	1.92%		5.56%	

Fields of Education (Occupations sub grouped)	FoE as a proportion of Occupations	Enhanced	Redesigned	Automated
Structural Steel and Welding Trades Workers	1.92%		5.56%	
Structural Steel Construction Workers	1.92%		5.56%	
Other Engineering and Related Technologies	**3.85%**	**9.09%**		
Engineering Manager	1.92%	4.55%		
Technicians and Trades Workers, nfd	1.92%	4.55%		
Other Management and Commerce	**5.77%**	**4.55%**	**5.56%**	**8.33%**
Purchasing and Supply Logistics Clerks	1.92%			8.33%
Storepersons	1.92%		5.56%	
Supply, Distribution and Procurement Managers	1.92%	4.55%		
Other Natural and Physical Sciences	**3.85%**	**4.55%**	**5.56%**	
Other Natural and Physical Science Professionals	1.92%	4.55%		
Science Technicians	1.92%		5.56%	
Personal Services	**1.92%**		**5.56%**	
Commercial Cleaner	1.92%		5.56%	
Process and Resources Engineering	**3.85%**	**4.55%**	**5.56%**	
Drillers, Miners and Shot Firers	1.92%		5.56%	
Mining Engineers	1.92%	4.55%		
Public Health	**1.92%**	**4.55%**		
Occupational and Environmental Health Professionals	1.92%	4.55%		
Sales and Marketing	**1.92%**	**4.55%**		
Advertising, Public Relations and Sales Managers	1.92%	4.55%		

Appendix G Occupations in the workforce

Percentage Proportion of Occupation Groups (ANZSCO Level 4) in sector (Source: ABS Census Data 2016).