RESEARCH STUDY TO INVESTIGATE THE NATURE AND EXTENT OF 4IR INNOVATION AND RELATED IMPACT ON OCCUPATIONAL PROFILING IN THE MINING AND MINERAL SECTOR ("MMS")

Final Report

(Inclusive of All Sub-sectors)

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List of Acronyms

AI	Artificial Intelligence
AMIHRP	Association of Mining Industry Human Resource Practitioners
AMMSA	Association of Mine Managers South Africa
AR	Augmented Reality
CLAS	Cement, Limestone, Aggregates and Sand
CSIR	Council for Scientific and Industrial Research
DOIT	Diffusion of Innovation Theory
DMRE	Department of Mineral Resources and Energy
DST	Department of Science and Technology
DTIC	Department of Trade, Industry and Competition
HR	Human Resource
IoT	Internet of Things
IPAP	Industrial Policy Action Plan
IT	Information Technology
MQA	Mining Qualifications Authority
MMS	Mining and Minerals Sub-sectors
MRS	Market Research Society
OEM	Original Equipment Manufacturer
NQF	National Qualifications Framework
PGM	Platinum Group Metals
PC4IR SIP	Presidential Commission on the Fourth Industrial Revolution Strategic Implementation Plan
QCTO	Quality Council For Trades & Occupations

SAQA	South African Qualifications Authority
SETA	Sector Education and Training Authority
SME	Small and Medium Sized Enterprises
UAV	Unmanned Aerial Vehicle
VR	Virtual Reality

Glossary of Terms

4IR	An era where people are using smart, connected and converged cyber, physical and biological systems and smart business models to define and reshape the social, economic and political spheres.
Artificial Intelligence (AI)	The ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings.
Automation	Automatically controlled operation of an apparatus, process, or system by mechanical or electronic devices that take the place of human labour
Data Analytics	The collection, transformation, and organisation of data in order to draw conclusions, make predictions, and drive informed decision making.
Innovation	A process by which a domain, a product, or a service is renewed and brought up to date by applying new processes, introducing new techniques, or establishing successful ideas to create new value
Internet of Things (IoT)	Physical objects embedded with sensors and actuators that communicate with computing systems via wired or wireless networks—allowing the physical world to be digitally monitored or even controlled.
Machine Learning	The use and development of computer systems that are able to learn and adapt without following explicit instructions, by using algorithms and statistical models to analyse and draw inferences from patterns in data.
Modernisation	The process of starting to use the most recent methods, ideas, equipment, etc. so that something becomes or seems more modern
Reskilling	The acquisition of new work-related skills by employees in a company that allows them to perform an existing activity in a different way or to take up a completely new activity.
Robotics	Technology dealing with the design, construction, and operation of robots in automation

Skills Gaps	Discrepancies between skills available and the skills required for specific roles.
Technology	The use of scientific knowledge or processes in business, industry, manufacturing, etc.
Upskilling	To provide someone (such as an employee) with more advanced skills through additional education and training.
Virtual reality (VR)	The use of computer modelling and simulation that enables a person to interact with an artificial three-dimensional (3-D) visual or other sensory environment.

Executive Summary

The Fourth Industrial Revolution ("4IR") refers to the convergence and complementarity of emerging technological domains, including trends such as the Internet of Things ("IoT"), robotics, virtual reality ("VR") and artificial intelligence ("AI"), in changing the way people live and work. The 4IR is a fundamental shift in the way that technology, communications, data, and analytics affect society and the economy. It represents an era of innovation in technology which is enhancing human-machine relationships and opening new opportunities for growth across the global economy (Schwab, 2016).

The South African mining sector has faced several challenges impacting profitability and sustainability, including high operating costs and health risks in deep mining operations. The advent of advanced 4IR technologies offers the potential to enhance miner safety, boost productivity, ensure quality and customer satisfaction, optimise costs, and reduce environmental impact in the sector. The modernisation (i.e. the process of updating, upgrading or adapting something to contemporary standards (Kumar, 2023)) and mechanisation (i.e. the use of machinery or mechanical equipment to perform tasks traditionally carried out by manual labour (Britannica, 2019)) of the mining sector, which, similarly to the 4IR, has led to the adoption of advanced technologies, however, has disrupted the value chains and triggered firm-specific responses to technology-driven changes, transforming the mining sector's operations and subsequently impacting organisations' business processes .

While some organisations have demonstrated proficiency in incorporating new technologies, a notable portion of mining enterprises have encountered challenges in adopting the 4IR technologies, with a prominent obstacle being a lack of requisite skills among the existing workforces. This predicament is exacerbated by the composition of the workforce engaged in mining operations, characterised by limited literacy levels and a general unfamiliarity with advanced operational tools. This is of significant importance, particularly in light of the projection that approximately 95% of emerging jobs related to the 4IR in the mining industry will require skilled labour. It underscores the imperative to undertake robust upskilling and reskilling initiatives within the present Mining and Minerals Sub-sectors ("MMS") workforce (PWC, 2021).

Therefore, this research aimed to understand the impact and the nature (positive or negative) of the impact of the 4IR on the MMS, specifically in terms of skills requirements and occupational changes. The study assessed the current state or the 'As-is situation' as it pertains to 4IR adoption in different mining sub-sectors, analysed how technological advancements are affecting the workforce, and evaluated the supply of skills in relation to the demands of 4IR developments. This Report presents the findings from the research conducted on the impact of the 4IR ("the Project" or "the Study") as well as specific recommendations that the Mining Qualifications Authority ("MQA") may consider moving forward to respond to the key findings from the Study.

<u>Research Methodology</u>

The approach adopted for the project was aimed at understanding the changes brought about by the 4IR and its impact on occupational profiling in the MMS. The conceptual research approach involved both qualitative[1] and quantitative[2] methods, adopting a mixed methods approach to overcome the limitations of a single design, allowing the two to complement each other. The qualitative methods included interviews to capture individual experiences and perceptions of 4IR in mining. Quantitative approaches, such as surveys, measured broader trends statistically, ensuring a robust examination of the multifaceted impact of 4IR technologies on the industry. Both desk-based and consultative (i.e. fieldwork) data collection methods were used to obtain the findings contained within this report.

The desk-based research included conducting an in-depth literature review to understand the current extent of the 4IR adoption in the sector, its impact on different areas of the MMS Value Chain, potential skills and occupational changes, relevant policy frameworks, and international best practices. Additionally, a review of relevant reports including MQA's Sector Skills Plan (2023/24); Strategic plan (2020-2025); and Annual Performance Plan (2023/24) was conducted.

Field research included surveys, interviews and focus groups with key stakeholders such as employers from companies across the 9 sub-sectors, employer affiliation bodies, labour/union representatives within the MMS, training providers within the MMS, Nelson Mandela Mining Precinct, CSIR and MEMSA. The following table provides a breakdown of the number of completed consultations against the target consultations for the project, per stakeholder type. A total of 445 consultations were completed.

Table 0-1: Target Consultations Against Completed Consultations

Stakeholder	Number of Planned Consultations	Completed Consultations
In-depth Interviews		
Companies across 9 sub-sectors	Up to 45	33
Employer Affiliation Bodies (e.g., AMIHRP, AMMSA etc.)	Up to 2	2
Labour/Union Representatives within the MMS	Up to 2	3

[1] Qualitative research involves the collection of data that is expressed in words, which is used to understand concepts, thoughts or experiences (Streefkerk, 2023).

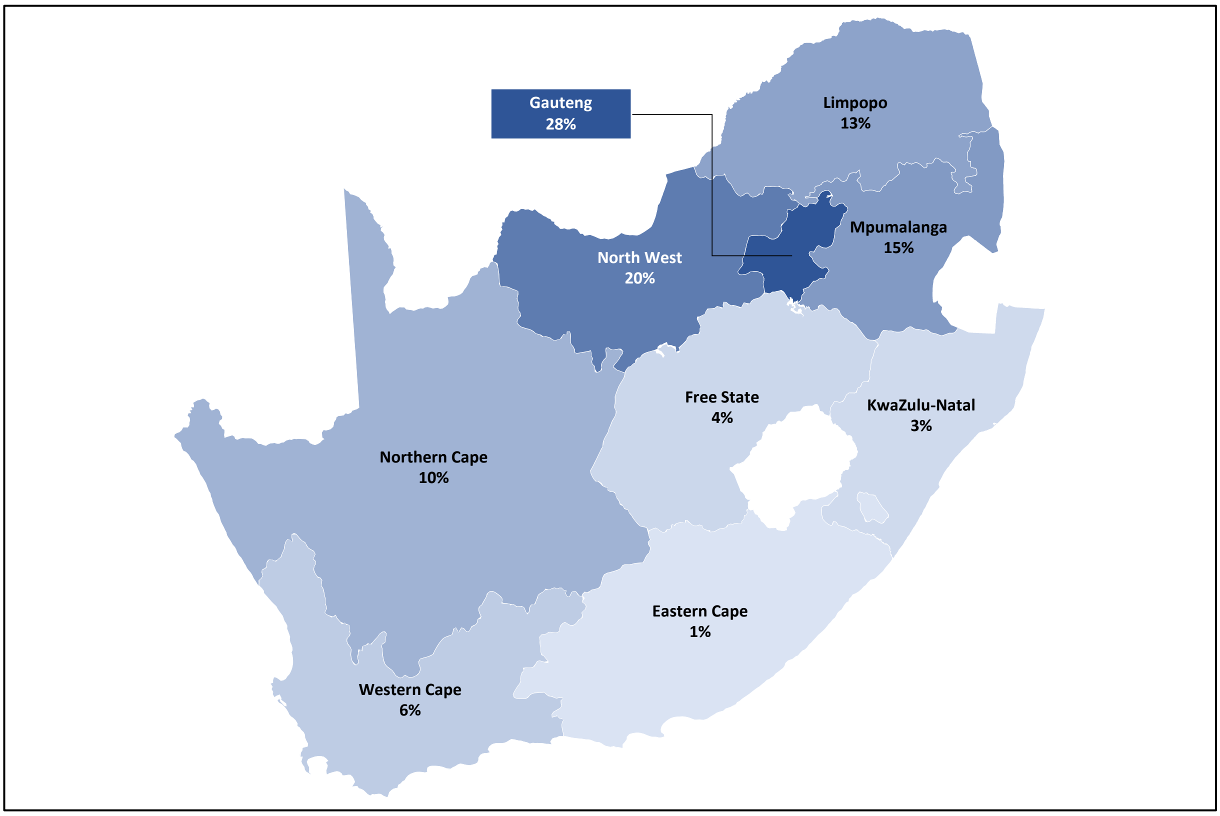
[2] Quantitative research involves the collection of data that is expressed in numbers and graphs (Streefkerk, 2023).

Stakeholder	Number of Planned Consultations	Completed Consultations
Training Providers within the MMS	Up to 18	22
Nelson Mandela Mining Precinct	1	1
CSIR	1	1
MEMSA	1	1
Total	**70**	**63**
Surveys		
Employers	318	321
Training Providers		27
Total	**318**	**348**
Provincial Focus Groups		
Employers	7 with up to 8 participants each	7 with 34 participants
Total	**444**	**444**

<u>Provincial Representation of Respondents</u>

The figure below illustrates the provincial representation of the organisations that responded to the survey.

Figure 0-1: Provincial Representation of Respondents

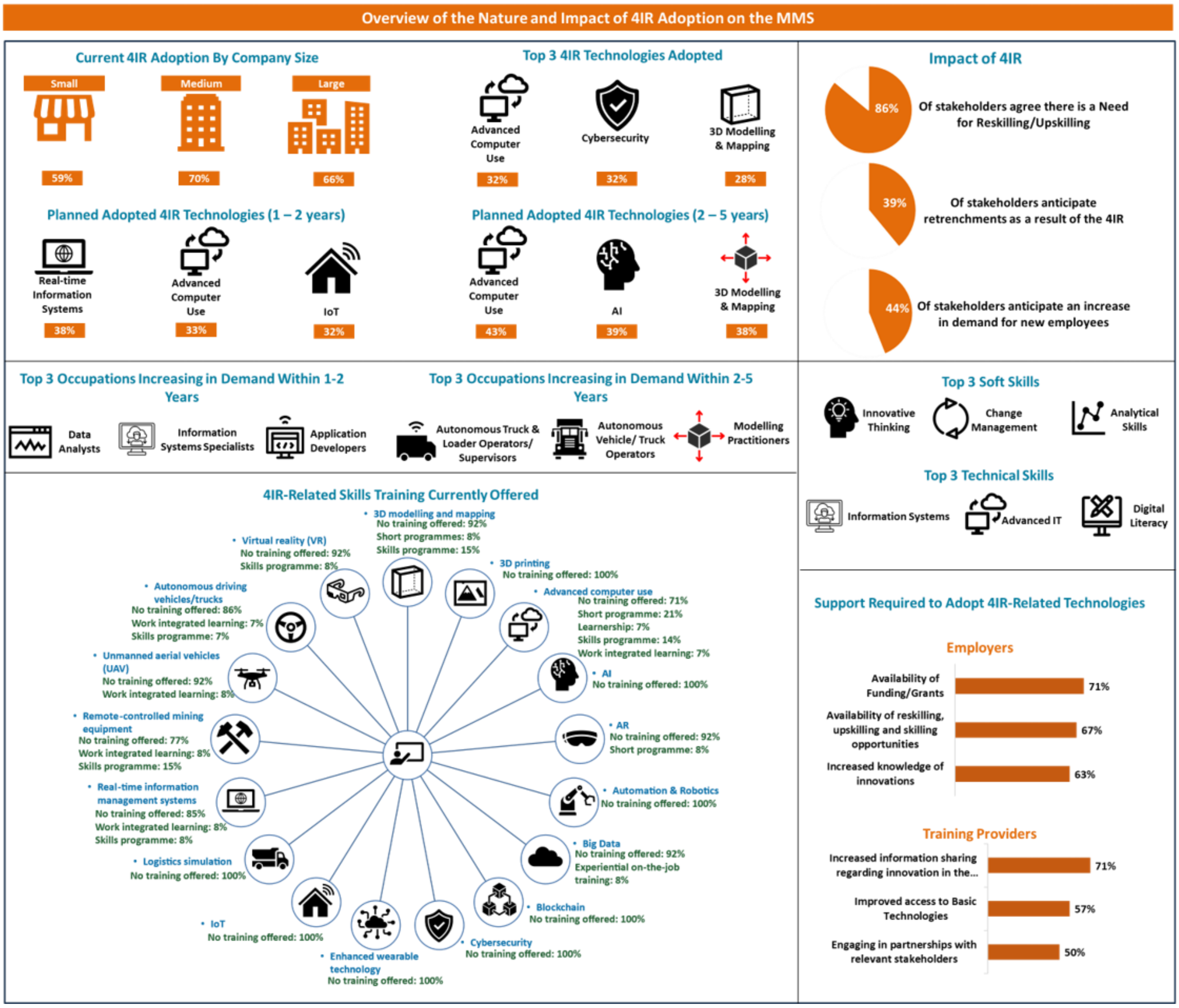


Source: MQA Impact of 4IR Survey, 2023 n= 303

<u>Research Findings</u>

The dashboard below provides a high-level overview of the findings from the project. The dashboard provides an overview of the impact of the 4IR on occupations and skills. Additionally, it looks at the provision 4IR related training to meet the demand.

Figure 0-2: Summary Dashboard



Source: MQA Impact of 4IR Survey, 2023

<u>Adoption of the 4IR in the MMS</u>

The study found that the majority of medium-sized companies are adopting new technologies, with 70% indicating this. In comparison, small and large companies demonstrate a lower adoption rate, with 59% and 66% of small and large companies, respectively, indicating that they had adopted new technologies. Overall, the top 3 4IR-related technologies that have been adopted include advanced computer use (32%), cybersecurity (32%), and 3D modelling and mapping (28%). A sub-sectoral analysis indicated that Platinum Group Metal ("PGM") mining organisations appear to have implemented the greatest proportion of 4IR-related technologies compared to that of the other sub-sectors, having implemented technology such as IoT and cybersecurity (56% of all PGM organisations that responded to the survey), as well as 3D modelling and mapping and real-time information management systems (44% of all PGM organisations that responded to the survey).

With regard to the potential future adoption of 4IR-related technologies, the study found that the top three technologies that may be adopted by organisations within the MMS that have not yet adopted 4IR-related technologies in the next 1 to 2 years, include real-time information management systems (38%), advanced computer use (33%), which refers to which refers to the use of sophisticated computing technologies such as advanced software or computational methods that may enhance mining processes, and IoT (32%), while those that may be adopted in the next 2 to 5 years include advanced computer use (43%) - for companies that have not yet adopted such technologies, AI (39%), as well as 3D modelling and mapping and automation and robotics (38%).

One of the key factors that were noted as having contributed to the limited adoption of 4IR-related technologies within the MMS was a lack of relevant skills. Various forms of support were, thus, identified that would facilitate the adoption of the technologies across the sub-sectors. The top 3 forms of support required by employers include availability of funding/grants (indicated by 71% of employers), availability of reskilling/upskilling and skilling opportunities (67%) and increased knowledge of innovations (63%). The availability of reskilling, upskilling, and skilling in particular, is crucial in ensuring accessible and available training, empowering the workforce to acquire new skills essential for navigating the challenges posed by the 4IR and thus enabling employees to effectively harness emerging technologies.

Section 6 provides a detailed analysis of the current and planned adoption of 4IR-related technologies within the sector.

Impact of the 4IR on the MMS

In order to understand the impact of the 4IR on the MMS, the broader impact was assessed in addition to the impact on occupations and skills. Findings from the study indicate that the majority of stakeholders were of the view that the adoption of 4IR-related technologies may result in greater innovation (with 90% of stakeholders indicating this) and may have a positive impact on business growth (86% of stakeholders). On the other hand, fewer respondents (58%) believed that the 4IR will have a positive impact on employment within the sector. Further to this, it was noted that 39% of stakeholders anticipated retrenchments to occur in the sector, with lower-level occupations being flagged as being the most at risk. Stakeholders noted, however, that rather than retrenching employees as a result of the 4IR, focus would be placed on reskilling and upskilling initiatives – with 86% of stakeholders agreeing that these initiatives would be necessary.

The need to reskill and upskill employees may be as a result of the changing nature of work and skills occurring as a result of the 4IR. Overall, 73% of stakeholders agreed that the nature of work within their organisation has changed as a result of the adoption of 4IR-related technologies, while 89% of stakeholders believed the nature of skills required has changed. It was further noted that in addition to the changing nature of occupations and skills, the 4IR may result in the demand for various occupations and the importance of various technical and soft skills to increase.

The occupations for which demand is anticipated to increase in the short-term include data analysts (with 64% of employers noting this), information systems specialists (59%) and application developers (57%), while the demand for autonomous truck and vehicle loaders (56%), autonomous truck and vehicle operators (51%) and modelling practitioners (51%) is anticipated to increase in the medium term.

Some of the soft skills for which significance is anticipated to increase include innovative thinking, change management and analytical skills in the short-term, as well as judgement and decision making, innovative thinking, problem solving and leadership skills in the medium-term. The technical skills anticipated to increase in significance in the short term include information systems and advanced information technology ("IT"), digital literacy and computer literacy, while robotics, AI and 3D simulation are anticipated to increase in significance in the medium-term.

In terms of the occupation levels most likely to be impacted by the 4IR, it was found that mid-level employees would require the most 4IR related knowledge and skills within the short to medium-term. In the short-term, this includes knowledge and skills in areas such cybersecurity, real time information management systems and advanced computer use, while in the medium term, information management systems, cybersecurity and cloud computing were identified as key. Basic computer use, autonomous driving trucks/vehicles and remote-controlled mining equipment were found to be key for lower level employees across both the short and medium terms.

Section 7 of the report outlines the impact of the 4IR on occupations and skills within the MMS in detail.

Training for Future Skills

In addition to understanding how the 4IR has impacted occupations and skills, it is key to understand how training and skills development interventions should be adopted in order to ensure there is sufficient supply of skills to meet the changing demand. In terms of the 4IR-related skills training offered to employees within the MMS, the study found that only a limited proportion is currently being offered. Various factors were found to be contributing to the low proportion of employees who have received training including the limited use of the technologies (as indicated by 41%, 55% and 40% of large, medium and small organisations, respectively) as well as a lack of qualified training providers (highlighted by 40%, 29% and 27% of the large, medium and small organisations, respectively).

In addition, all of the training providers surveyed indicated that they do not currently offer training related to certain 4IR related technologies, including cybersecurity as well as 3D printing, AI, automation and robotics, blockchain, enhanced wearable technology, IoT, and logistics simulation. Furthermore, it was noted that the percentage of training being provided on the other technologies was also minimal. Although there is growing demand for 4IR skills, the majority of training providers currently seem to place more focus on non-4IR skills. Occupational health and safety and operational management are the skills for which the majority of training providers offer training. Overall, it can be see that the availability of 4IR skills training is limited. Placing focus on increasing the supply of 4IR-related skills and occupations through training and skills development interventions should therefore be considered key, in light of the planned adoption of these 4IR technologies within the MMS, as already highlighted.

In order to be able to effectively provide training on 4IR related skills, it was noted that the key forms of support required by training providers were information sharing sessions – to ensure that information is adequately shared with regard to emerging innovations, funding – to increase affordability of relevant equipment, as well as partnerships with relevant stakeholders, such as original equipment manufacturers ("OEMs").

Section 8 provides an overview of 4IR-related training initiatives currently being offered within the MMS.

Recommendations

Section 10 details the key findings identified from the Project as well as the recommendations related to these key findings. The recommendations provide the MQA with strategic, practical and innovative ways to respond to the skills development needs, related to the 4IR in the MMS. In order to respond to the key findings identified, the MQA may:

- Create specific qualifications and unit standards, such as short and skills programmes, focusing on emerging skills and occupations. Notable examples include the Occupational Certificate: Data Science Practitioner, developed and accredited by MICT SETA and SAQA, respectively.
- Implement mandatory basic and advanced computer courses as integral components of mining-related qualifications, supported by the MQA through accessible resources. Consider grants to training providers for essential educational tools, including textbooks and software, ensuring the attainability of these courses for individuals pursuing mining-related qualifications.
- Revise the current technical curriculum (i.e. all mining related learning programmes with a practical and/or theoretical component) accredited by the MQA, incorporating elements for students to enhance soft skills through group projects, presentations, and teamwork exercises. Emphasise the development of communication, leadership, teamwork, innovative thinking, and problem-solving skills.
- Consistently monitor training programs and skills initiatives to ensure ongoing effectiveness and alignment with industry standards. Establish measurable indicators before program implementation for systematic monitoring and evaluation against these benchmarks.

- Disseminate email circulars to all MQA registered organisations, detailing training opportunities for identified scarce skills and high-demand skills, like management skills, as revealed in this study and organisations' WSP submissions.
- Continue prioritising funding for Foundational Learning Competence Programmes and Adult Education and Training Programmes, emphasising the development of fundamental literacy and numeracy skills and consider revising the funding guidelines for AET and FLC programmes to prioritise the enrolment of individuals within certain occupational groups on such programmes.
- Develop and conduct regular information-sharing campaigns for training providers through workshops, seminars, and webinars, along with newsletters.
- Organise bi-annual roadshows at training centres within the sector to educate learners, current employees, and employers about emerging technologies in the mining sector, the associated skills and occupations, and training opportunities stemming from the 4IR.
- Establish collaborative forums or working groups that bring together OEMs, MMS organisations and training providers
- Adopt and implement the Framework for Future Skills Needs Identification.

1 Introduction

This Report, drafted by Redflank on behalf of the MQA, presents the findings from the research conducted on the impact of the 4IR on the MMS.

The report illustrates and analyses feedback received from key stakeholders regarding the extent to which 4IR and related innovations have been adopted in the sector, benefits and barriers of the 4IR and the potential skills and occupational changes that may be experienced within the sector as a result of the 4IR. The report also provides recommendations on the strategic, practical and innovative ways that the MQA may respond to skills development and the emerging skills and occupations as a result of the 4IR.

The following table provides an outline of the sections contained in this document.

Table 1-1: Section Overview

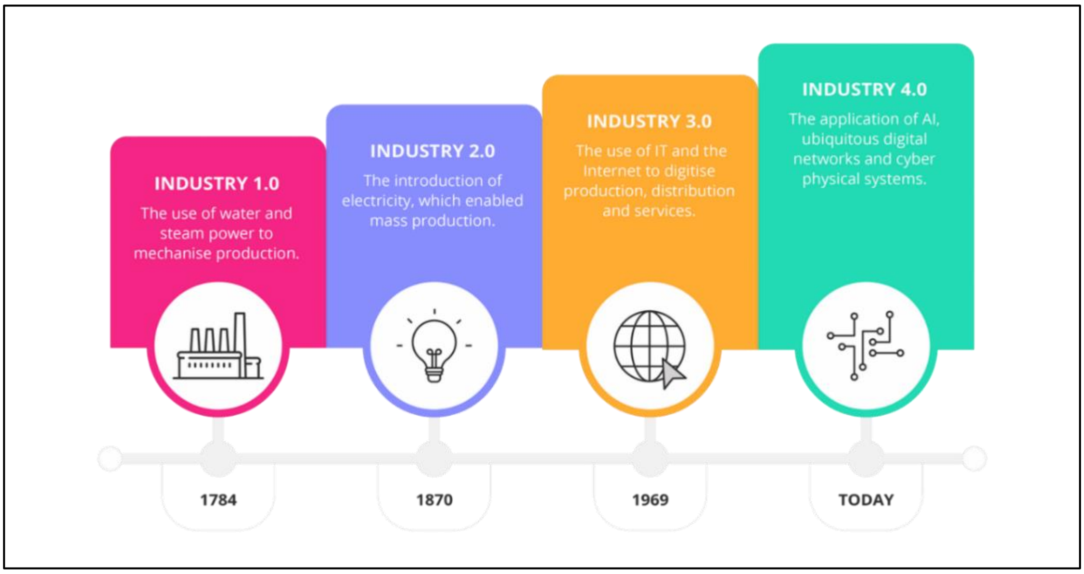
Section	Contents	Description
1	Introduction	This section provides an introduction to the report and an overview of the Project background and scope.
2	Research Methodology	This section outlines the approach followed in completing the project, highlighting the desk-based and field research that was undertaken and the key limitations experienced.
3	Theoretical Framework	This section provides detail regarding the theoretical framework adopted for this Study.
4	Literature Review	This section provides a summary of the literature review conducted as part of this Study. The purpose of this is to provide the context required to analyse the findings that follow.
Research Findings		
5	Demographic Details of Respondents	This section provides a demographic breakdown of the consultation participants, including the provinces in which their organisations are located, insight into the mining techniques currently being adopted by these organisations as well as the average level of education of employees.
6	Adoption of 4IR in the MMS	This section provides an overview of the current and planned adoption of 4IR technologies within the MMS.

7	Impact of the 4IR on the MMS	This section explores some of the potential benefits of 4IR for the MMS and considers the potential disruptive impact of 4IR on the industry, including the impact the occupational landscape.
8	Training for Future Skills	This section provides an overview of 4IR-related training initiatives currently being offered within the MMS as well as an overview of the support required in order to capacitate training providers to provide 4IR related training.
9	Discussion of Key Research Findings	This section highlights the key findings discussed within the report and provides the basis for which recommendations will be made.
10	Recommendations	This section highlights the key findings and recommendations that the MQA may consider going forward in order to respond to the key findings identified as part of the Study.

1.1 Project Background

The 4IR, refers to the convergence and complementarity of emerging technological domains, including trends such as the Internet of Things ("IoT"), Robotics, Virtual Reality ("VR") and Artificial Intelligence ("AI"), in changing the way people live and work. It builds on the three previous revolutions, as illustrated in the figure below.

Figure 1-1: The Four Industrial Revolutions



Source: GetSmarter (2019)

The 4IR is a fundamental shift in the way that technology, communications, data, and analytics affect society and the economy. It represents an era of innovation in technology which is enhancing human-machine relationships and opening new opportunities for growth across the global economy. In essence, the 4IR represents entirely new ways in which the lines between the digital, physical and biological worlds work (Schwab, 2016).

Within the context of the South African mining industry, the industry has faced challenges that have been unfavourable to the profitability and financial sustainability of the sector over the last few decades. Amongst these challenges are high-operating costs and the exposure of employees to health risks associated with deep mining operations. The emergence of advanced 4IR technologies has therefore opened up opportunities within the mining industry to, among other things, improve the health and safety of mineworkers; maximise productivity; ensure quality products and customer satisfaction; and improve the cost-effectiveness of mining operations, while reducing the carbon footprint of the sector .

Zulu, et al. (2021) suggest that the modernisation and mechanisation of the mining industry has disrupted the industry value chains and triggered firm-specific responses to technology-driven changes. In other words, the 4IR has transformed the mining sector's operations and subsequently impacted organisations' business processes.

Therefore, for the purpose of this Project, it is important to understand and unpack the nature and extent of 4IR innovation occurring in the sector and the broader impact this is having on organisations and employees within the sector. This can assist in determining the potential skills requirements that may arise from the 4IR and the impact that these changes may have on occupational profiling within the sector. It is in light of the context that the MQA appointed Redflank to conduct research to investigate the changes brought by the 4IR and its impact on occupational profiling in the MMS.

1.2 Project Scope

The overall objective of this study was to investigate the extent of 4IR innovation and related impact on occupational profiling in the 9 sub-sectors of the MMS. The table below provides the key objectives of the study, including an overview of the sections in this report which respond to these objectives.

Table 1-2: Project Scope

#	Objective	Relevant Section in Report
1	Assess the 'As is situation', which involves an analysis of the level or extent of innovation and application of the 4IR in all the sub-sectors within the MMS.	**Section 6.1**
2	Determine the nature and type of technological developments that are affecting the occupational landscape (or the effects of technological developments on the occupational structure, and	**Section 7.2**

#	Objective	Relevant Section in Report
	the current occupations and the ways they are affected and reasons thereof).	
3	Determine the nature (positive and negative) of the impact of the 4IR in the MMS.	**Section 7.1**
4	Identify the key technological developments and the way they shape the labour dynamics in the landscape.	**Section 7.2**
5	Outline the current nature of skills supply vs required skills supply to support 4IR developments.	**Section 8**
6	Identify specific recommendations on strategic and practical innovative ways of responding to skills development related to 4IR in the MMS.	**Section 10**

1.3 Significance of the Study

In an era dominated by the 4IR, understanding the implications of technological advancements on various sectors becomes imperative for informed decision-making. Studying the impact of the 4IR offers crucial insights for sectoral planners, such as the MQA, to proactively discern opportunities, address challenges, and cultivate an innovation-friendly environment. This knowledge provides a foundation from which adaptive and responsive sectoral plans that align with the dynamic landscape shaped by the 4IR, may be built. Undertaking this study to understand the impact of the 4IR on the MMS, thus, holds paramount significance in the domain of sectoral planning within the MMS as it contributes to planning strategies that are future-ready, contributing to sustainable growth amidst the ongoing technological transformations.

2 Research Methodology

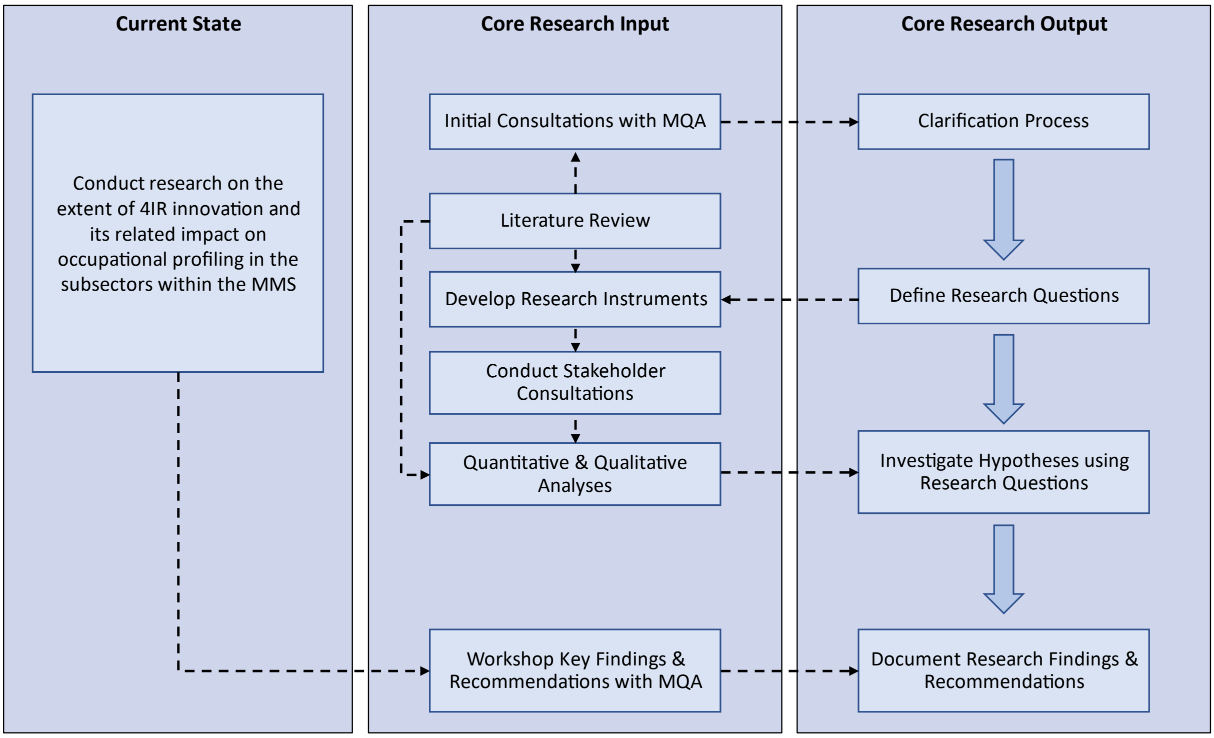
The following section outlines the significance of the study to sectoral planning, as well as the methodology that was adopted for the Project, including the research design, sampling approach, instrumentation as well as an overview of the data collection and analysis. In addition, the section outlines the approaches adopted to ensure reliability and validity of the findings, the ethical considerations applied, as well as the research limitations and how these were overcome.

2.1 Research Design/Conceptual Approach

The approach adopted for the project was aimed at understanding the changes brought about by the 4IR and its impact on occupational profiling in the MMS. The conceptual research approach involved both qualitative and quantitative methods, adopting a mixed methods approach to overcome the limitations of a single design, allowing the two to complement each other. In investigating the Impact of the 4IR, the combination of qualitative and quantitative research methods was essential in order to provide a nuanced exploration of the multifaceted changes within the mining sector. Qualitative methods, such as in-depth interviews and focus groups, allowed researchers to capture the intricacies of individuals' experiences, perceptions, and attitudes towards 4IR technologies. This qualitative lens provided depth and context, uncovering the human aspects of the impact. Meanwhile, quantitative methods, such as surveys, allowed for the measurement and statistical validation of broader trends and patterns across a larger population. The interaction between these methods facilitated a comprehensive understanding of the topic at hand, as qualitative insights illuminated the "how" and "why," while quantitative data verified the prevalence and significance of observed trends. This synergy ensured a robust and holistic examination of the diverse dimensions of the 4IR impact on the mining industry.

The figure below illustrates the key components of the approach adopted for this Project.

Figure 2-1: Conceptual Project Approach



2.2 Sampling Method

A key focus of this study was ensuring appropriate sampling sizing. Sampling is defined as the process of selecting people or organisations from a population and studying the behaviour, characteristics or traits to arrive at meaningful conclusions (Adwok, 2015). These conclusions allowed for the development of appropriate recommendations moving forward.

The following sections outline the types of sampling adopted when selecting participants (i.e. target population) for this study, including purposive sampling and snowball sampling. The target population included Employers and Training Providers across the 9 sub-sectors, Employer Affiliation Bodies, Labour/Union Representatives, the Nelson Mandela Mining Precinct, Centre for Scientific and Industrial Research (“CSIR”) and the Mining Equipment Manufacturers of South Africa (“MEMSA”).

2.2.1 Purposive Sampling

Purposive sampling is a non-random sampling technique where researchers intentionally select specific individuals or groups from a population based on their unique characteristics or qualities (Nikolopoulou, 2023). This method of sampling presents a number of advantages, such as the opportunity to select all parties relevant to the study and the ability to target niche demographics to obtain specific data points. In conducting purposive sampling for this study, the steps which were followed included (Heath, 2023):

- Defining the purpose of the study: understanding the objectives of the project was essential in order to select the right participants.

- Defining the criteria for selection: this refers to specific criteria or characteristics that potential participants must possess to be included in the sample. These criteria, or guiding principles, are directly related to the research objectives and were used to inform the participants selected to participate in interviews and focus groups, are outlined in Table 2-1 below.
- Identifying, selecting and extracting the sample of individuals/ participants: the sample was identified from the research population according to the pre-determined criteria.

Purposive sampling was adopted in order to select participants for in-depth interviews and focus groups. The table below highlights the principles that were used to guide the stakeholders, that were selected for the consultations.

Table 2-1: Purposive Sampling

Data Collection Tools	Stakeholder Type	Purposive Sample's Guiding Principles
Interviews	Companies across 9 sub-sectors	• Sub-sector • Size of organisation
	Employer Affiliation Bodies (e.g., AMIHRP, AMMSA etc.)	• Relevance to project
	Labour/Union Representatives within the MMS	• Relevance to project
	Training Providers within the MMS (2 per sub-sector)	• Sub-sector • Geographical location
	Nelson Mandela Mining Precinct	• Relevance to project
	Centre for Scientific and Industrial Research ("CSIR")	• Relevance to project
	Mining Equipment Manufacturers of South Africa ("MEMSA")	• Relevance to project
Provincial Focus Groups	All relevant stakeholders	• Geographical location

2.2.2 Snowball Sampling

In addition purposive sampling, snowball sampling was adopted in order to increase and encourage stakeholder participation in electronic surveys and in-depth interviews. Snowball sampling is a is a non-probability sampling approach in which new participants are recruited into the sample through referrals from existing participants.

In adopting snowball sampling, existing participants were requested, at the conclusion of consultations, to invite new participants into the study by either providing their contact details so that the new participants may be requested to complete a survey or participate in an interview, or sharing the survey link with said new participants so that they may also provide their input.

This approach was adopted to ensure the inclusion of certain participants that the MQA would not have contact details for, predominately employer representatives on the operations or technical side of mining organisations.

2.3 Instrumentation

Primary data collection for this project consisted of:

- An electronic survey questionnaire;
- In-depth interviews; and
- Focus groups.

2.3.1 Electronic Surveys

The electronic survey questionnaire was administered through the online survey platform, Survey Monkey. The survey platform allowed for a large amount of data to be collected, tracked and securely stored on the platform, and enabled the monitoring of response rates throughout the course of data collection. An email containing a description of the project, the purpose of the survey and a link to the survey was distributed to all stakeholders (i.e., employers and training providers) contained in a mailing list (i.e., the research sample) that contained the email addresses of the stakeholders. The recipients were requested to complete the survey online by a specified date.

The survey sought to gain an understanding of the following:

- The current as well as planned adoption of 4IR-related technologies across the sub-sectors;
- Factors preventing organisations within the MMS from adopting 4IR-related technologies;
- The extent to which new skills and occupations will emerge as a result of the adoption of 4IR-related technologies;
- The extent to which new skills and occupations will either emerge or increase in demand as a result of the adoption of 4IR-related technologies;
- The extent to which some skills and occupations may become redundant as a result of the adoption of 4IR-related technologies;
- The extent to which Training Providers are capacitated to provide training on new and emerging 4IR-related skills;

- Forms of support required by Employers in order to implement 4IR innovations within their operations, and Training Providers in order to be able to provide 4IR-related skills training.

2.3.2 In-Depth Interviews

Key informant interviews were undertaken to further understand the above-mentioned themes in a more qualitative manner, whereby the intention was not to collect 'hard' data, but to explore key opportunities and obstacles around the adoption of 4IR-related activities within the MMS and to document what interviewees see as key impacts that need to be considered.

A sample of stakeholders, selected through purposive sampling, was contacted telephonically and requested to participate in interviews. As part of this process, interviewees were informed about the project background and the purpose of the interview and were asked whether they were willing to participate.

2.3.3 Focus Groups

Similarly, for the focus groups, a sample of stakeholders, selected through random sampling, were contacted telephonically and their participation in the focus groups requested. Focus groups were conducted with employers using both in person and virtual methods. The following provincial focus groups were conducted in person i.e., in each of the respective provinces:

- Gauteng
- Northern Cape
- Mpumalanga
- North West

The abovementioned provinces were selected for in person focus groups due to the level of mining activity being conducted in the respective provinces, as well as the number of employers located in said provinces.

The remining provinces (viz. Eastern Cape, Free State, Western Cape, KwaZulu-Natal and Limpopo) were conducted across three virtual focus groups (e.g., MS Teams, Zoom, Skype, etc.). The first virtual focus group consisted of participants from Eastern Cape and Free State. These two provinces were grouped together due to the limited number of contact details available. In order to ensure the involvement in the focus group discussion by all participants, a second virtual focus group was hosted for participants from Western Cape and KwaZulu-Natal. Similarly, these provinces were grouped due to the limited number of contact details available. A third focus group was then conducted for participants from the Limpopo province.

The purpose of the Focus Groups was to assess the adoption of new 4IR-related technologies within the MMS and to explore the anticipated impact of the 4IR on the sector. Discussions within the sessions delved into predicting changes in mining operations and activities as a result of 4IR-related technologies and understanding how organisations that embraced these changes adapted. Additionally, the focus group explored the evolving occupational landscape, discussing shifts in roles brought about by the 4IR. It also examined current skills gaps, their underlying reasons, and reflected on the influence of the 4IR on the sector's skills requirements. Finally, the sessions explored challenges that are anticipated to impact on workforces and how employers may be supported in this regard, as well as the capacity of the skills delivery system in ensuring the workforces have the necessary 4IR-related skillsets.

2.4 Data Collection

Both desk-based and field research was used to obtain the findings contained within this report.

The desk-based research conducted consisted of:

- An in-depth literature review in order to obtain a baseline understanding of:
    - The MMS in South Africa;
    - The current extent of adoption of the 4IR and related innovations in the sector including the current adoption of the 4IR within various areas of the MMS Value Chain;
    - The impact of the 4IR on the MMS including benefits and barriers of the 4IR and the potential skills and occupational changes that may be experienced within the sector as a result of the 4IR;
    - The relevant policy frameworks affecting the 4IR; and
    - International best practices highlighting successful cases of 4IR integration, skilling, reskilling and upskilling related to the 4IR, and collaboration related to the effective cooperation and partnerships among stakeholders.
- A review of relevant reports including MQA's Sector Skills Plan (2023/24); Strategic plan (2020-2025); Annual Performance Plan (2023/24).

Field research included consultations with key stakeholders, and, as mentioned above, consisted of surveys, in-depth interviews and focus groups. The following table provides a breakdown of the number of completed consultations against the target consultations for the project, per stakeholder type. A total of 445 consultations were completed.

Table 2-2: Target Consultations Against Completed Consultations[3]

Stakeholder	Number of Planned Consultations	Completed Consultations
In-depth Interviews		
Companies across 9 sub-sectors	Up to 45	33
Employer Affiliation Bodies (e.g., AMIHRP, AMMSA etc.)	Up to 2	2
Labour/Union Representatives within the MMS	Up to 2	3
Training Providers within the MMS	Up to 18	22
Nelson Mandela Mining Precinct	1	1
CSIR	1	1
MEMSA	1	1
Total	**70**	**63**
Surveys		
Employers	318	321
Training Providers		27
Total	**318**	**348**
Provincial Focus Groups		
Employers	7 with up to 8 participants each	7 with 34 participants
Total	**444**	**444**

2.4.1 Employer Interviews

In-depth interviews were conducted with various representatives from the different Employers, including Skills Development Facilitators ("SDFs"), Human Resource

[3] While consultations were initially planned with Organised Labour Representatives, the Department of Mineral Resources and Energy ("DMRE") and related agencies, as well as the Department of Trade, Industry and Competition ("DTIC"), during further discussions with the Project Sponsor, it was agreed that as a result of the unavailability of some stakeholders and the number of consultations completed, consultations with these stakeholders would no longer be required.

Development ("HRD") Managers, and Learning and Development Managers. The following table provides further detail regarding the designation of the representatives.

Table 2-3: Employer Interview Participant Details

Participant #	Designation	Participant #	Designation
1	HRD Manager	18	HRD Manager
2	Learning and Development Manager	19	Talent Management Specialist
3	HRD Manager	20	SDF
4	SDF	21	Director
5	Training Manager	22	Training and Development Manager
6	SDF	23	Compliance Manager and Head of HR
7	SDF	24	SDF
8	Owner	25	HR Consultant
9	SDF	26	HR Generalist
10	HRD Practitioner	27	HR Officer
11	HR Manager	28	Business Development Manager
12	• HRD Coordinator • Education, Training and Development Manager	29	HR Consultant
13	HRD Manager	30	Talent Management Specialist
14	HRD Manager	31	HR Business Partner
15	SDF	32	HR Manager
16	SDF	33	Operations Director
17	Training Superintendent		

2.4.2 Training Provider Interviews

The Training Provider interviews were conducted with various representatives from the different organisations, including SDFs, training managers, and project coordinators. The following table provides further detail regarding the designation of the representatives with whom interviews were conducted.

Table 2-4: Training Provider Interview Participant Details

Participant #	Designation
1	Director
2	SDF
3	SDF
4	Not Specified
5	Training Manager
6	Managing Director
7	HRD Superintendent
8	COO
9	SDF
10	CEO
11	Centre Manager
12	Project Coordinator
13	Managing Director
14	Managing Director
15	SDF
16	SDF
17	Training Head
18	Managing Director
19	Managing Director
20	General and Administrative Manager
21	Founder and Director
22	Not Specified

2.5 Data Analysis

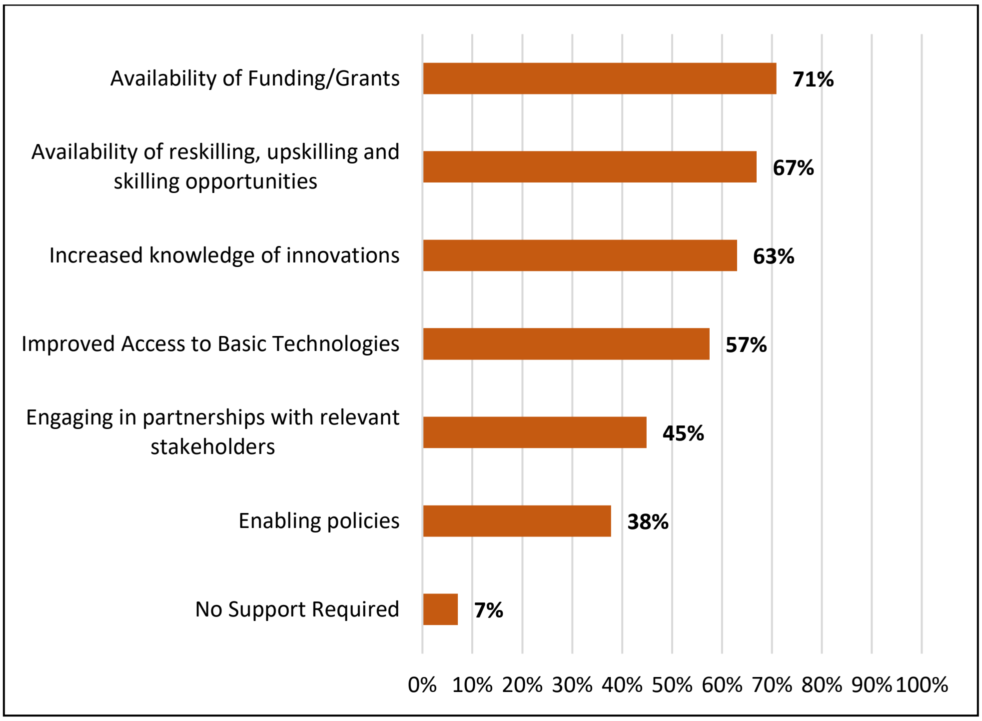
The quantitative data presented throughout this Report in the form of graphs was obtained through electronic surveys. The majority of the graphs presented measure the percentage of respondents who selected a specific option/s over the total number of respondents for that question. Figure 2-2 below provides an illustrative sample of survey results related to the support that organisations require to be able to adopt 4IR innovations currently or in the next 5 years.

Figure 2-2: Illustrative Sample Survey Results

What support does/ will your organisation require to be able to adopt 4IR innovations now or in the next 5 years? (Please select all that apply)	
No Support Required	7%
Enabling policies	38%
Engaging in partnerships with relevant stakeholders	45%
Improved Access to Basic Technologies	57%
Increased knowledge of innovations	63%
Availability of reskilling, upskilling and skilling opportunities	67%
Availability of Funding/Grants	71%

The figure below provides an illustrative example of how this data is then presented.

Figure 2-3: Illustrative Sample Graph



Further to the overall analysis conducted, where applicable, cross-tabulation was conducted in order to add depth to the results and understand the view per sub-sector or organisation size. For the purpose of this Study, small organisations are classified as those with between 1 and 49 employees, medium organisations are classified as those with between 50 and 149 employees, and large organisations are classified as those with more than 149 employees. The table below provides an illustrative example of how these cross-tabulated results were presented. In order to emphasise key areas in which focus should be placed when developing interventions, the top 3 options (i.e., the top 3 occupations, as per the example below) were highlighted in light green shading.

Table 2-5: Illustrative Sample Table[4]

Occupations	Coal Mining	Gold Mining	Diamond Mining	PGM	CLAS Mining	Other Mining	Services Incidental	Diamond Processin	Jewellery Manufactu
Data Analysts	63%	67%	50%	73%	60%	70%	61%	50%	33%
Cloud computing developers	59%	50%	50%	44%	33%	57%	76%	0%	29%
Unmanned Aerial Vehicle (UAV) operators	50%	75%	0%	36%	13%	44%	46%	0%	67%
Information Systems Specialists	47%	100%	0%	75%	44%	61%	75%	0%	43%
Workplace and worker experience reformers (change management specialists)	47%	83%	0%	67%	30%	50%	57%	50%	40%
Alternative energy specialists	47%	60%	50%	75%	78%	42%	63%	50%	0%
Application developers	47%	33%	50%	73%	67%	67%	71%	0%	20%
Laser machines technicians	46%	33%	0%	50%	0%	43%	46%	0%	50%
Re-mining of waste dumps Specialists	44%	67%	0%	75%	0%	44%	69%	0%	33%
Electrical engineers	42%	50%	0%	91%	38%	50%	73%	0%	67%
Systems Engineers	42%	67%	0%	75%	33%	42%	58%	0%	40%

In addition to the above, a selection of the survey questions were based on a Likert scale. Likert-type or frequency scales use fixed choice response formats and are designed to measure attitudes or opinions (Bowling, 1997). An example of a Likert scale used in this report is the scale used to measure the extent of a state, ranging from "not at all" to "completely" (see below), for instance, the extent to which the adoption of 4IR innovations in the industry is being limited by a lack of relevant skills.

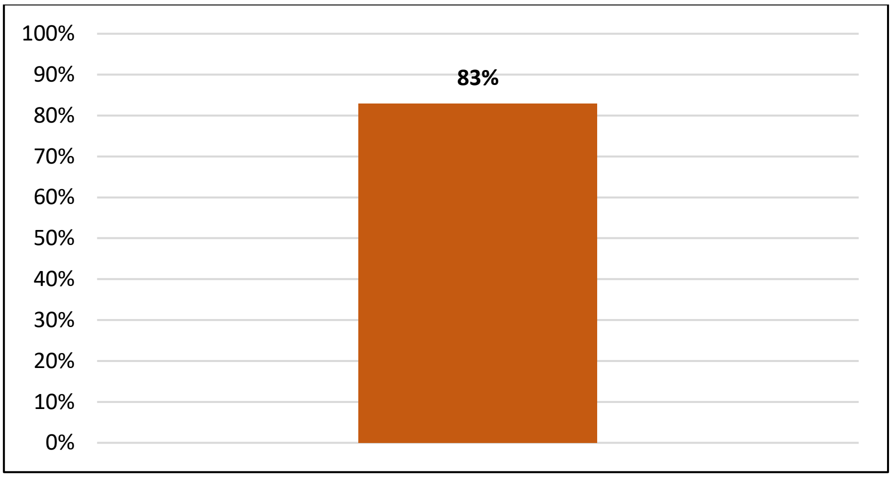
[4] CLAS- Cement, Limestone, Aggregates and Sand

Table 2-6: Likert Scale

Likert Scales of Extent				
Not at All	Minimally	Somewhat	Significantly	Completely

Where questions were based on a Likert scale, graphs were presented as a sum of the positive responses (i.e. the sum of "Somewhat", "Significantly", and "Completely"). These results were then presented graphically, as follows:

Figure 2-4: Illustrative Sample Graph



In instances where respondents were requested to indicate the extent to which they agree with a statement, a Likert scale ranging from "Strongly disagree" to "Strongly agree" was applied, for instance, the extent to which stakeholders believed that training providers were adequately capacitated to provide training on emerging skills. Similar to the above, results were presented as the sum of positive responses (i.e. the sum of 'Agree', and 'Strongly Agree').

Further to the analysis conducted as per the above, inferential analysis was conducted on a number of key areas. The Chi-square test utilised serves as a valuable statistical tool for assessing the relationship between two categorical variables. By comparing observed and expected frequencies, it helps researchers infer whether changes in one variable are significantly associated with changes in another. This test aids in hypothesis testing, providing insights into the nature and strength of associations within categorical data, and guides decision-making regarding the independence or dependence of the variables under investigation (Biswal, 2023). For the purposes of this study, the significance level was set at 0.05. The results of this analysis contribute valuable insights into understanding the interdependence of the studied categorical variables.

In addition to the above, qualitative data was also assessed for the study. This entailed collating qualitative data received from in-depth interviews and focus groups into a consolidated sheet. Based on the collated data, thematic analysis was conducted where prevailing themes, which also aligned to the quantitative analysis conducted, were identified from the responses. For purposes of incorporating into the report, key extracts were taken from the collated responses and included in the relevant sections to support and validate quantitative findings made.

2.5.1 Triangulation

A key aspect of the research approach involved the cross validation and triangulation of data, to ensure robust research findings. The methods of triangulation adopted for this study are outlined below:

- Data Triangulation: this refers to the simultaneous use of data from a variety of sources including interviews, surveys, focus groups, and a literature review, as was done as part of this study. Cross-referencing information gathered from these diverse sources, aimed to ensure a comprehensive and robust understanding of the research topic, enhancing the credibility and validity of the findings. For example, the nature and type of technological developments within the MMS were established initially from an analysis of literature, and then validated and refined against findings from surveys, interviews and focus groups; with interviews and focus groups further exploring and assessing areas of technological developments and its impact on occupational profiling and skills supply and demand within the MMS.
- Methodological Triangulation: this involved the combination of various research methods, including interviews, surveys, focus groups and a literature review to respond to the same research question(s). This approach was chosen to strengthen the overall research design, providing a more comprehensive and reliable perspective on the study's objectives and questions.
- Space Triangulation: the study included participants from different provinces in order to examine variations and differences in the impact of 4IR based on their specific regional contexts.
- Data Source Triangulation: this was adopted through the integration of multiple and diverse data sources, such as interviews with various stakeholders such as Employees, Employer Affiliation Bodies, Labour Union representatives and Training Providers. This approach was employed to gain a comprehensive and well-rounded understanding of the research topic, ensuring a more robust analysis of the findings.

2.6 Ensuring Validity and Reliability

Ensuring the validity and reliability of research is crucial for maintaining the accuracy and credibility of the study. Validity refers to the extent to which the research method is accurate in measuring the intended variable, whereas reliability refers to the extent to which a research method consistently produces the same outcome if presented to the same stakeholders multiple times. Overall, both elements are essential for trustworthy and meaningful research (Surucu & Maslakci, 2020).

In order to ensure validity and reliability for this study, the following steps were adopted:

- Clearly defining the research question and hypothesis to ensure that appropriate target respondents were selected;
- Appropriate data collection methods and instruments were selected, which included surveys, in-depth interviews, and focus groups, to ensure that both qualitative and quantitative data can be sourced from participants;
- Data was analysed using appropriate and robust statistical techniques, which include the use of Advanced Microsoft Excel for qualitative and quantitative analysis;
- Through the analysis, results were interpreted and reported accurately and transparently in the findings Report. Quantitative results were illustrated in the form of graphs, while qualitative results were incorporated as extracts into the report;
- The limitations of the research were addressed by adopting mitigating strategies when limitations were identified, where possible.

2.7 Ethical Considerations

Four key ethical considerations were employed for the purpose of this study, being quality of resources, standards, research policy and employee policies and practices. These are outlined below:

2.7.1 Quality of Resources

The research team was committed to delivering high-quality research and analysis. As demonstrated in the inception report's resourcing section, the team had a wealth of experience. Recognising the importance of meeting or surpassing customer expectations, the researchers, equipped with diverse degrees and postgraduate qualifications in fields like engineering, business science, and economics, brought a range of quantitative and qualitative research skills to ensure comprehensive and rigorous analysis.

2.7.2 Standards

The team and its members consistently adhered to the Code of Conduct outlined by the Market Research Society ("MRS"). This comprehensive code encompassed all stages of research, from inception and design to execution and use, and was applicable to market, social, and opinion research. The principles of the MRS Code, diligently followed by the team, included commitments to honesty in professional relationships, transparency in data collection purposes, respect for the rights and well-being of individuals, prevention of harm to respondents, a balance between individual needs and professional activities, independent professional judgment, ensuring appropriately trained personnel conducted activities, and safeguarding the reputation and integrity of the profession.

Furthermore, the MRS outlines regulations for the administering of incentives, which researchers and their team adhere to when offering incentives. These regulations include ensuring that incentives used to encourage participation are proportionate and not perceived as bribes. When offering incentives, participants were clearly informed about the administrator, the nature of the incentive, and any associated conditions. The team ensured that incentives did not require participants to spend money, except for permissible monetary vouchers. Additionally, client goods, services, or vouchers for client goods or services were not used as incentives or gifts for research projects. Participants were not promised gifts of client goods or branded materials. The team took measures to prevent the misuse of incentive administration for collecting personal details for unrelated purposes and maintained confidentiality when incentives were offered by an organisation's in-house research department.

2.7.3 Research Policy and Practices

Respondents were given the content, sponsorship, and purpose of the research in order for them to make an informed judgment about whether they wished to participate. Any assurances, such as confidentiality or anonymity, were also be kept. Additionally, researchers and their team fully disclosed to the MQA the limitations and shortcomings of the research and avoided the use of methods that deliberately introduced bias into the results. Survey, interview and focus group questionnaires, including the exact wording and sequencing of questions used in the study, description of the population and how a sample was selected, sample sizes, and the method place and dates of data collection, were also submitted to the MQA.

Furthermore, the following practices were adopted to ensure anonymity, confidentiality and informed consent from participants:

- **Anonymity**

Respondents were assured that their personal information and linked responses would not be provided to the MQA.

- **Confidentiality**

Data collected from all survey tools was kept strictly confidential and no data or form of data was shared with any person not authorised to view it.

- **Informed Consent**

It was not possible with online survey tools to provide an oral explanation of the study, or to take oral consent. This meant that all of the relevant information had been given in the first ‘page’ of the survey or in the email containing the link to the survey. This followed the pattern of a paper-based information sheet and covered the identity of the researcher(s), contact details, the reason for conducting the survey, the uses to be made of the data and so on. Participants were given the option to provide consent to participate at the beginning of the survey, where the survey would end immediately for all persons who did not provide consent.

- **Right to Withdrawal**

Respondents were able to exit the survey at any point. However, the responses already submitted could not be withdrawn at the point of exit.

2.8 Research Limitations

Two major challenges were experienced during the data collection process. The table below lists these challenges, and the approach that was adopted to overcome said challenges.

Table 2-7: Data Collection Challenges and Responses

	Data Collection Challenge	Response to Challenge
1	**Invalid/Outdated Stakeholder Contact Details** The databases containing stakeholder contact details had invalid/outdated email addresses and phone numbers, resulting in unsuccessful attempts to contact some stakeholders. This challenge may be attributed to contact details such as email addresses and cell phone numbers being deactivated after some time, for instance if an individual had exited a specific organisation or if their contact details had changed.	• Where a stakeholder could not be reached for an interview due to invalid contact details, they were replaced with another contact from the database.
2	**Stakeholder Unavailability** Several stakeholders did not honour invitations to participate in interviews, despite agreeing to participate telephonically or via email correspondence.	• In instances whereby stakeholders did not honour appointments, appointments were rescheduled at the convenience of stakeholders.

3 Theoretical Framework

The theoretical framework adopted for this Project is outlined in the section that follows and provides an overview of the key theoretical paradigms that underpinned the research. This framework provided a blueprint which guided the research design process and provided a lens through which research results could be understood. The key theories that framed this study were the Diffusion of Innovation Theory ("DOIT") and Grounded Theory. Each theory is outlined below.

Diffusion of Innovation Theory ("DOIT")

DOIT is a framework commonly applied when one is conducting research that looks into the adoption of technology. This framework looks to explain how and why new innovations (i.e., technologies, products, or practices) are adopted and spread through a social system over time and provides key perspectives when looking to assess the extent to which innovations have been adopted or accepted by a specific population (Boston University, 2022). The concept of diffusion, i.e., the ways in which information regarding an innovation is spread through certain channels over time by the members of a social system, is central to DOIT. Various factors such as communication channels[5], time[6], and social system[7] characteristics typically influence diffusion (Minishi-Majanja & Kiplang'at, 2005). As part of this Project, DOIT was used to provide a framework to understand 4IR-related technology adoption patterns and facilitated an understanding of the current level of 4IR-related technology adoption within different segments of the MMS employer population.

Key to note is that DOIT is premised on the idea that the adoption of an innovation does not occur simultaneously across the entire social system but is instead a process in which specific individuals demonstrate an enhanced willingness to adopt innovationsBoston University, 2022). Five adopter categories which segment individuals within a specific social system into five groups, based on their likelihood to adopt the innovation are outlined with the DOIT. These adopter groups are detailed below (Boston University, 2022):

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[5] The means through which messages about innovations are transmitted amongst members of a social system. Communication channels are important because information about the innovation must be disseminated to introduce the innovation, change attitudes towards the innovation, and influence decisions relating to the innovation (Minishi-Majanja & Kiplang'at, 2005).

[6] Refers to the time of diffusion and is focused on three dimensions namely (a) the decision-making process, (b) the individual's level of innovativeness and (c) the rate of adoption. The decision-making process considers the time involved between the introduction of the innovation and the decision to accept/reject the innovation. The individuals' level of innovativeness considers the degree to which individuals within the social system accept/reject an innovation. The rate of adoption refers to the speed in which a new idea is adopted (Minishi-Majanja & Kiplang'at, 2005).

7 A social system can be defined as a set of interrelated units such as individuals, groups, and organisations that are engaged in activities associated with a common goal.

Adopter Group	Description	Contextual Example
Innovators	Individuals within a social system that eagerly embrace new innovations. These individuals often serve as 'champions' of innovation.	Mining engineers or mining technicians at the forefront of technological advancements within a specific sub-sector.
Early Adopters	Individuals who follow the innovators and who are opinion leaders. These individuals are typically found within leadership roles, and often embrace opportunities to innovate. These individuals play a critical role in influencing other members of the social system to acquire and integrate new innovations.	Mining supervisors or specialists responsible for implementing new technologies within specific operations.
Early Majority	Individuals who adopt innovations before the 'average person'. These individuals need to see evidence of the effectiveness of a particular innovation before they consider whether to adopt it.	Machine operators or maintenance staff adapting to the use of new equipment.
Late Majority	Individuals who, while initially sceptical of the adoption of innovations, eventually adopt the innovation due to widespread use of the innovation or due to peer influence.	Administrative staff or individuals in support roles who adopt the innovation because of widespread use.
Laggards	Individuals who are least likely to adopt innovations within the social system. These individuals often resist change, which poses challenges to the overall integration and adoption of innovations within a particular social system.	Traditionalists within the MMS, who view technology as more of a threat than an opportunity.

In addition to providing adopter categories, DOIT also provides factors that influence the adoption of an innovation. These factors are listed below (Boston University, 2022):

Factor	Description	Contextual Example
Relative Advantage	The notion that the greater the perceived benefits associated with a particular innovation, the more it will be adopted within a social system.	For example, if a particular piece of equipment shows benefits as it pertains to increasing efficiency, improving safety, and optimising the use of resources, the piece of equipment is more likely to be adopted within the MMS.
Compatibility	Considerations around how compatible the innovation is with the values, experiences, and needs of potential adopters.	For example, the extent to which a particular type of new technology fits in with established workflows within an organisation.
Complexity	The level of complexity associated with acquiring and applying innovations impacts the rate of adoption.	For example, the easier it is to acquire and integrate a piece of equipment within a mining operation, the more likely it is to be adopted across the whole sector.
Trialability	The extent to which a particular innovation can be tested or 'trialled' before a commitment to adoption is made.	The ability to test a piece of equipment before it is integrated into a mining operation is key to mitigating resistance and encouraging broader adoption.
Observability	The extent to which the innovation provides tangible, positive results.	For example, if employees are aware of positive outcomes associated with new equipment, the rate of adoption may be higher.

The application of the principles of the DOIT framework proved critical to the achievement of the overall aims of the research and provided key insights on the current level of adoption of technology within the MMS. However, to ensure robust findings the Grounded Theory framework was also used as a key theoretical paradigm, as it provided a guideline that allowed for the analysis of emergent themes from field research to be conducted in a structured and nuanced manner.

Grounded Theory

Grounded Theory is a framework that is focused on constructing theories from multiple data sources which have been obtained systematically and comparatively analysed. The framework enables the generation of theory that is 'grounded' in this data (Noble

& Mitchell, 2016). Grounded Theory provides a set of tools that assist researchers sort through data in a structured manner, in order to be able to develop key theories or identify key insights emerging from said data (Thornberg, Perhamus, & Charmaz, 2015). For this Project, Grounded Theory was a key framework that guided data analysis, and it provided a structured approach which allowed for the determination of key theories relating to the impact of the 4IR on the MMS, sourced directly from the insights of key MMS stakeholders. The framework provided by Grounded Theory prescribes how the theory should be applied in practice. Application of the Grounded Theory framework in this Project involved the following processes:

- **Initial coding**: Grounded Theory encourages the process of initial coding, which is the first step in data analysis when conducting a study through the lens of the framework. Initial coding is a method used to identify important concepts in the data and label these concepts accordingly (i.e., codes) (Thornberg, Perhamus, & Charmaz, 2015). Initial coding is often followed by focused and theoretical coding, which involves refining the codes developed initially (Birks & Mills, 2015). Within the context of this Project, a detailed examination of interview and focus group transcripts was conducted to identify initial themes and to formulate initial codes. Further coding analysis was conducted to formulate clearly defined themes (using constant comparative analysis techniques, as outlined below).
- **Concurrent data collection and analysis:** One of the key principles of Grounded Theory is collecting data with an initially purposive sample (Birks & Mills, 2015). The data from these initial consultations are coded before more data is collected. For this Project, initial consultations were conducted with several employers within the MMS as well as representatives from the CSIR, SATCAP and MCSA to help provide initial insights that helped to frame the data collection instruments, which provided a foundation for more comprehensive data collection to occur.
- **Theoretical sampling:** Conducting research through the lens of Grounded Theory lends itself to adopting theoretical sampling when selecting participants for the study (Birks & Mills, 2015). This means that study participants are chosen based on theoretical considerations emerging during the research process. To sample theoretically, the researcher must make strategic decisions regarding the study participants, with due consideration given to those individuals that will provide the most insightful information (Thornberg, Perhamus, & Charmaz, 2015). For this Project, careful consideration was given to the individuals who formed part of interviews, with participants being selected according to specific criteria, including organisation size, the position of the individual being interviewed, as well as the location of the organisation.
- **Constant comparative analysis:** A key part of applying Grounded Theory principles in a practical setting is comparative analysis of different data sources throughout the data collection process to continuously refine categories/themes

(Birks & Mills, 2015). For this Project, constant comparative analyses were conducted throughout the data collection process and involved the comparison of diverse data sources including survey, interview, and focus group data.

- **Saturation:** Grounded Theory is concerned, at a fundamental level, with obtaining a level of data saturation. Saturation is reached when new data gathered through the research process fails to provide new insights (Noble & Mitchell, 2016).
- **Emergent theory**: The final product of Grounded Theory is an integrated and comprehensive theory that explains a particular phenomenon (Birks & Mills, 2015). This final process is concerned with building theories from the data collected as part of the research, using the techniques and practices listed above.

The rationale for the adoption of the DOIT and Grounded Theory frameworks as key theoretical reference points for this Project was because of the nature of the research topic at hand. For this Project, DOIT served as the overarching framework, guiding the process of determining the impact of the 4IR on the MMS, the current level of adoption of 4IR-related technology within the MMS and associated challenges with technology adoption. This helped, from a conceptual perspective, to understand what adopter categories respondents fell into and to determine factors influencing the level of 4IR-related technology adoption, which was critical to framing the insights contained within this report. Concurrently, the framework prescribed by Grounded Theory was applied to allow for a comprehensive and nuanced exploration of specific themes and patterns relating to the impact of the 4IR on the MMS, for example, through the identification of specific 4IR occupation and skills related changes within specific sub-sectors, or providing insights into the reasons underpinning limited adoption of 4IR-related technologies within organisations of a specific size.

4 Literature Review

This section provides key insights from the desktop research undertaken as part the study. Consulting desk-based sources was a critical step in formulating a conceptual foundation for the Project.

The section demonstrates an understanding of the MMS in South Africa, including background context. The section further outlines the potential skills and occupational changes that may be experienced within the sector as a result of the 4IR. The impact of the 4IR on the MMS such as threats and challenges are outlined as well as benefits and challenges to be faced as a result of the 4IR in the MMS.

4.1 Overview of MMS

Mining involves the extraction and transformation of precious metals and minerals, as well as other geological materials (Corporate Finance Institute, 2022). Mining Companies can be categorised into artisanal and small-scale mining (“ASM”) and large-scale mining (“LSM”). Artisanal mining involves individuals using rudimentary methods and tools to access mineral ore, usually for subsistence, while small scale mining is conducted by smaller producers sanctioned by authorities with limited capital (Debrah, et al., 2014). In contrast, LSM focuses on accessing large high-grade mineral deposits, which are typically economically feasible for large companies (Rodríguez-Novoa & Holley, 2023).

4.1.1 Background to the 4IR in the MMS

The 4IR refers to the convergence of the physical, digital, and biological worlds and ultimately, the impact they will have on the changing way people live and work (Salesforce, 2020). While previous industrial revolutions transformed the way industries and broader society operated, the 4IR is unique in that the core disciplines or emerging technologies that are driving it have ultimately resulted in an unprecedented cross-pollination of the digital, physical and biological worlds (PwC, 2017). Some of the emerging technological domains include trends such as the IoT, robotics, VR and AI (Wigmore, 2020). Other emerging technologies include cloud computing, blockchain technology, and Big Data (Institute of Electrical and Electronics Engineers, 2020).

The 4IR represents a fundamental shift in the way that technology, communications, data, and analytics affect society and the economy. The same is the case within the context of the South African MMS, with the advent of 4IR ushering in a new era in which mining processes and activities are conducted in South Africa.

The readiness for the 4IR, as well as digital transformation, are some of the major trends that are currently impacting the mining sector in South Africa. Broadly speaking, technology is increasingly being applied in the areas where it has the greatest potential measurable benefit (CSIR, 2023). Furthermore, research indicates that the South African MMS is increasingly adopting technology as a result of the impact of the COVID-19 pandemic, which accelerated the digitisation of work processes, as well as the adoption of automation and other innovative tools in the mining sector (Mungadze, 2021). The new technologies being adopted within the MMS include robotics, smart sensors, 3D printing, and machine learning, which enable the South African mining sector to be more globally competitive with regard to costs and on environmental, social and governance issues (Mungadze, 2021).

4.1.2 The MMS Value Chains

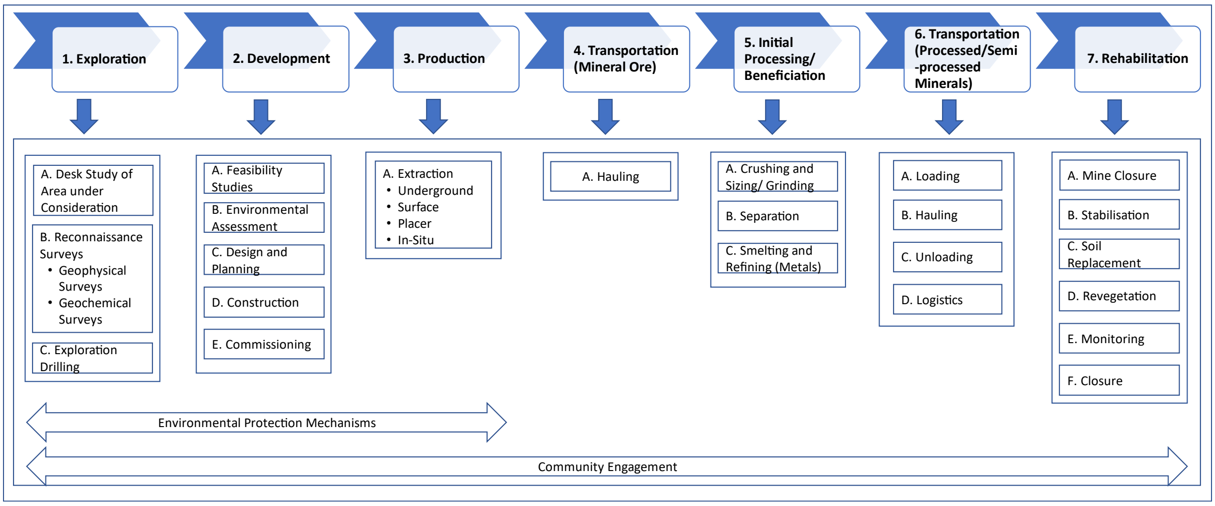
A value chain involves a broad spectrum of activities necessary for creating a product or service, which include research and development, product design, procurement of raw materials, production, marketing, distribution, and customer service. Essentially, the value chain encompasses every step taken to develop and deliver the product or service to the market, from its initial conception to its launch (University of Cambridge, 2011).

In order for the MMS value chain and organisations in the MMS sector to keep up with changing 4IR technology and the capabilities required as a result, organisations will need to undertake a process of ensuring that their organisation, operations and systems are adapted accordingly. By understanding where changes may occur in the value chain as a result of the 4IR, one can understand the changes that will be required within organisations, such as SMMEs, particularly in relation to the changing roles for employees, occupations and skills. This will enable the sector to consider and adapt to the new 4IR capabilities through skills development initiatives such as qualifications and training. Beyond this, employees will need to be upskilled in order to play a role in the new 4IR aligned organisation.

In order to understand the potential impact that the 4IR may have on organisations within the MMS it is important to get an understanding of the MMS value chain. The MMS value chain can be divided into two categories, the mineral extraction value chain, as well as the beneficiation value chain. The mining value chain has been divided in this manner given the differing nature of the processes in the value chains, including processes of extracting and processing minerals and metals, from exploration to production and distribution of manufactured jewellery (McKinsey & Company, 2020). While some activities are concerned with extracting and processing minerals, such as coal and PGMs, for market use, constituting the mineral extraction value chain, other activities are concerned with how additional value may be added to precious metals, such as gold, and used to produce jewellery for the market - constituting the beneficiation and manufacturing value chain. The value chains are discussed further below.

Mineral Extraction Value Chain:

Figure 4-1: MMS Value Chain



The phases of the above mineral extraction value chain are as follows:

- Exploration:

The exploration phase of the value chain entails the assessment of an area to determine whether economic minerals exist (Evolution Mining, 2022). Conducting reconnaissance surveys[8] is the next step that follows, which includes gathering various forms of geophysical and geochemical data on the piece of land (through surface sampling) to develop an initial understanding as to whether developing a mine on said land is feasible (NZ Petroleum and Minerals, 2017). Exploration drilling will then follow, should the analysis of collected data indicate evidence of the existence of economic minerals within the piece of land (Evolution Mining, 2022).

- Development:

The development component of the value chain succeeds the exploration phase once it has been confirmed that the specific piece of land contains mineral resources. In this phase, more technical studies including feasibility and environmental assessments are conducted to determine the economic viability of mining the land, as well as whether mining would be in line with environmental standards and regulations (Danthurebandara, 2015). The feasibility and environmental assessments are followed by the design and planning for the construction of the mine, which will be based on the specific mining method to be used, power and water supply economics, the extent of processing to be carried out onsite, and the proximity of the mine to existing transport infrastructure (Dymond & Burton, 2021). Regulatory requirements should also be adhered to in this phase, including applying for a mining permit from the Department of Mineral Resources ("DMRE"). Once regulatory and legislative requirements have been met and the design of the mine finalised, construction may

[8] Reconnaissance refers to the preliminary examination of the general geological features and characteristics of a specific region. Systematic investigation in reconnaissance involves geological mapping, outcrop sampling, wide-spaced geochemical sampling, and a preliminary geophysical survey (Gandhi & Sarkar, 2016).

commence (American Mine Services, 2019). This may involve various processes such as site preparation, drilling, blasting[9], excavation (i.e., removal of the broken rock), tunnelling[10] (for underground mines), reinforcement[11], infrastructure installation and mining equipment installation. Typically, once the tunnels and shafts have been reinforced, infrastructure such as electrical wiring, lighting, plumbing, ventilation systems as well as transportation infrastructure are installed (Dymond & Burton, 2021). This is followed by the installation of mining equipment such as drill rigs, loaders, and trucks which are installed to allow for actual mining operations to commence.

- Production:

The production phase of the mineral extraction value chain entails the extraction of the various mineral resources. The method used to extract the minerals is determined by multiple factors, including the ore's grade (i.e., the concentration of minerals in the ore), the ore deposit geometry (i.e., its shape and size), its depth (shallow or deep), the environmental impact, safety considerations, and cost implications of each extraction method (Balt & Goosen, 2020).

- Transportation of Ore Deposits:

Once the ore deposits have been extracted, the raw materials are transported to the surface (for underground mines) through conveyors, and then transported or hauled to a processing plant for further processing (Balt & Goosen, 2020). The complexity of the hauling process is largely dependent on the specific mining extraction technique used. For open pit mining, for example, ore deposits may be loaded onto haul trucks and transported to a designated area, which, depending on the way the mine was designed and constructed, may be a nearby processing plant or a temporary storage facility (Dotson & Hethmon, 2011). Transporting ore deposits from an underground mine, on the other hand, is a more intricate process, requiring movement of the minerals from the underground site to the surface and then onward to the processing plant or storage facility. This task necessitates the use of specialised infrastructure constructed during the mine development phase of the value chain, such as declines or ramps, shaft systems, rail systems, conveyor belts, and hoisting systems (Mining Technology, 2020). These systems facilitate the transport of ore deposits from the underground location to the surface. Subsequently, the deposits are conveyed to a nearby processing plant or temporary storage facility.

- Initial Processing/Beneficiation:

[9] Blasting refers to the controlled use of explosives to break rock for the purposes of excavation (Hustrulid, 2011)

[10] Tunnelling refers to the process of creating tunnels and shafts within a specific excavated area. These tunnels are utilised for the purposes of transportation of underground ores, ventilation for individuals working within mines, and to provide access to different areas of the mine (American Gem Society, 2023).

[11] Rock reinforcement involves the installation of support beams, rock bolts and anchors, and/or concrete to stabilise the rock and to strengthen the structural integrity of the mine tunnels and shafts (Mining Industry Human Resources Council, 2020).

Once the ore deposits have been transported to the processing plant, the deposits can be processed. The type of processing that a specific ore deposit will need to undergo is dependent on the nature of the mined mineral or metal. The different approaches are outlined below:

- Coal Mining: After being crushed and sized, raw coal is washed to separate the coal from impurities. This typically involves crushing the coal and then passing the crushed coal through a series of water-based separation processes, including gravity separation[12], centrifugation[13], and froth flotation[14]. The coal then undergoes thermal drying, which involves the use of heat to remove excess moisture from the coal. The result of this process is dry, high-quality coal that can be used for various purposes, such as electricity generation (RPM Solutions, 2023).
- Gold Mining: To process gold, crushed and ground gold ore is mixed with various chemicals such as sodium cyanide and water to dissolve the gold and create a gold containing solution (Youlton, et al., 2021). This solution is subsequently passed through activated carbon, which attracts the gold particles and separates the gold from the solution. The gold particles are then separated from the carbon by washing it with a solution of hot caustic cyanide, which dissolves the gold, creating a solution of gold cyanide (Natural Sapphire Company, 2023). The solution is then passed through an electrolytic cell, where the electrical current causes the gold particles to deposit onto a cathode (911Metallurgist, 2023). Finally, the gold containing cathodes are smelted, which involves the cathodes being melted down in a furnace to produce gold bars, which will be further refined and processed to produce jewellery or other gold products (i.e., beneficiation) (Natural Sapphire Company, 2023).
- Diamond Mining: The processing of diamond involves first scrubbing the diamond ore to remove clays and dirt and then crushing it with high pressure grinding rolls. The ore is then passed through coarse and fine scrubber screens and undergoes classification with the help of spray bars and nozzles. The screened ore is separated from waste using an Over Belt Magnet and undergoes dense medium classification through Cyclone Feed Distributors. Finer particles go through a Float Screen while higher-density particles go through a Sink Screen. Sizing Screens and X-ray screening are used to sort particles downstream, leaving behind rough diamonds (Multotec, 2019).

[12] Gravity separation refers to the separation of mineral particles weight by weight and density (Ambreen, Dhivylakshmi, Shuruti, Dhivya, & Danish, 2021).

[13] Centrifugation is the separation of molecular particles of different densities by rotating a solution containing these particles around an axis (or centrifuge) at high speeds (Stephenson, 2016).

[14] Froth flotation refers to separation of minerals by creating a collection of bubbles (or froth) on the surface of a slurry to capture the mineral particles and then removing the froth for further processing (Crawford & Quinn, 2017).

- PGM Mining: The beneficiation process for PGMs typically involves adding chemicals to the mineral ore slurry, formed by crushing the ore, to selectively separate the PGMs from the gangue minerals in a froth flotation process. The resulting concentrate is then filtered and dried to remove excess water. The dried PGM concentrate is smelted to produce a matte, which is a mixture of sulphide minerals containing the PGMs. The matte is further refined to separate the PGMs from other impurities, typically using a process called electrorefining that involves passing an electric current through the matte to selectively dissolve and recover the PGMs (Scholarly Commuity Encyclopaedia, 2023).
- CLAS Mining: The processing of lime is dependent on the intended use of the limestone, but typically involves further grinding to a fine powder or calcination[15] in a kiln to produce quicklime. Chemical additives may also be introduced at various stages to modify the properties of the limestone or improve its performance. The exact details of the beneficiation process can vary depending on the specific type of limestone being processed and the intended end use, but these stages are typical of the process for extracting and processing limestone (Jorge, 2022). In order to produce cement, the ground limestone, aggregates and sand, extracted from quarries, are blended in correct proportions to create a desired cement mix. The mixture is then ground to a fine powder and heated in a kiln to produce clinker, a substance that is then ground again with gypsum to produce the final cement product. During this process, various additives may be included to modify the properties of the cement or improve its performance. (Michaud 2016)
- Other Mining: The beneficiation processes for ‘other minerals, including copper and iron, typically involves either hydrometallurgy[16] or pyrometallurgy[17]. With regard to hydrometallurgy, the mineral ore, for example, copper, undergoes heap leaching, where chemical solutions are percolated through a heap of crushed ore, while solvent extraction involves separating copper from impurities in a solution by stirring it with an immiscible liquid and allowing them to separate based on solubility. In pyrometallurgy, the mineral ore is heated at high temperatures to extract the metal by roasting to remove impurities and smelting to produce a metal-rich product. The mineral concentrate is smelted in a furnace to produce a matte, which is further refined to produce metal, making it suitable for high-grade ores with

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[15] Calcination involves heating limestone rock to a high temperature in a kiln or furnace in the absence of air or with limited air supply. The heat causes the limestone to undergo a series of chemical reactions, resulting in the release of carbon dioxide gas (CO_2) and the formation of calcium oxide (CaO), also known as quicklime (Satyendra, 2013).

[16] Hydrometallurgy involves using chemical reactions in aqueous solutions to separate and purify metals from their ores (Hidayah & Abidin, 2017).

[17] Pyrometallurgy involves using high-temperature processes such as roasting, smelting, and refining, and chemical reactions to extract metals from their ores (Singh & Schwan, 2011).

sufficient metal concentrations to justify the high energy costs (Superfund Research Centre, 2023).

- Transportation of Processed Minerals:

Once the specific ore deposit has been processed, and the valuable components of the ore have been deemed to be of the desired grade (concentration), the specific minerals or metals are packaged and stored, and are then ready to be transported to a specific destination. This involves activities such as loading the materials onto cargo vehicles (e.g., trucks, trains, or ships), transporting the materials to its destination, and unloading the materials. This component of the value chain also involves logistical planning, such as the scheduling and coordinating of transportation routes, ensuring the availability of required equipment and personnel, and ensuring compliance with transportation regulations and safety standards (Mining Technology, 2023).

- Rehabilitation:

The rehabilitation component of the mineral extraction value chain is primarily focused on restoring the land and ecosystem that were impacted by the activities undertaken during the mining process (Allan, 2022). The specific steps taken as part of the rehabilitation process vary depending on the type of mining extraction technique used, the size and complexity of the mining site, as well as regulatory requirements.

Typically, the first step involves the decommission of the mine. This entails ceasing mining and mineral processing operations, and the subsequent dismantling and removal of mining equipment from the site (Kauppila, 2018). The next step in the process involves 'stabilising' the site to prevent further erosion, landslides, or other types of drainage. This may involve grading the site to create a stable surface, constructing retaining walls to prevent soil erosion or stabilising slopes with vegetation. Thereafter, once the site has been stabilised, topsoil that was removed during the mining process is replaced with healthy soil to restore the natural soil profile, which serves to restore the ecological function of the site. Once the soil has been restored, the next step relates to the revegetation of the site by planting native vegetation such as grass and other plants that were originally located within the site. Once the site has been revegetated, the site is monitored over a specific period of time to ensure that the ecological function of the site is maintained. This step involves key activities such as monitoring soil and water quality, vegetation growth, and wildlife populations. Finally, once the site has been fully rehabilitated and restored, and is considered stable and functional from an ecological perspective, the mining company may apply for a closure certificate.

- Environmental Protection:

Environmental protection in mining is the practice of ensuring that mining activities do not cause undue harm to the environment and the health and well-being of people and other living beings in surrounding areas. It involves applying reasonable legislative and other measures to prevent pollution and ecological degradation, promote conservation, and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development. Environmental protection in mining also requires implementing lower-impact mining techniques, reusing mining waste, using eco-friendly equipment, rehabilitating mining sites, and shutting down illegal mining (Nichols, 2020). Environmental protection is an on-going process throughout the value chain.

- Community Engagement:

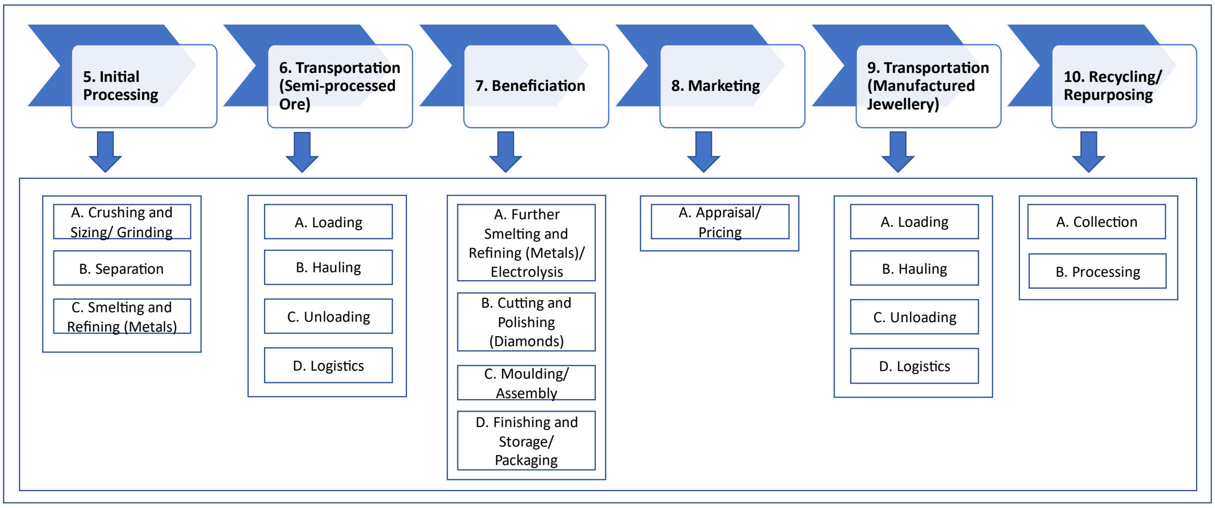
Community engagement is one of the most important aspects of the mining of minerals process, as it ensures that adequate engagement occurs between the mining organisation and the surrounding community. In this phase of the value chain, it is important for the organisation that wants to explore a specific piece of land to obtain community buy-in. Engaging with local communities allows the community members to be made aware of the potential impact the mines will have on their livelihoods, as well as an opportunity for them to have a say in how the project proceeds (Caripis, 2021). Community engagement is an on-going process throughout the value chain.

Beneficiation and Manufacturing Value Chain:

The beneficiation value chain involves various interconnected components that culminate in the production of manufactured jewellery to the market, including finished diamond. The first two phases of the below value chain, initial processing and transportation of mineral ore, overlap with phase 5 and phase 6 of the mineral extraction value chain (as described in the sections above), which is concerned with initial processing and transportation of the semi-processed ore, respectively. The remaining phases of the value chain are outlined below. The value chain is applicable to the diamond processing and jewellery manufacturing sub-sectors, as well as the services inherent to these sub-sectors.

The value chain is illustrated in the figure below:

Figure 4-2: Beneficiation Value Chain



*Sources: MQA **(2021)**; DMRE **(2017)**; McKinsey & Company **(2020)**; Glasgow **(2013)**; Siddiqui **(2016)***

The phases of the beneficiation value chain are as follows:

- Beneficiation:

The first phase begins with a number of key activities, as outlined below.

  - Further Smelting and Refining: Subsequent to the initial processing conducted in the mineral extraction value chain, the semi-processed gold and diamond bearing ores will be exposed to further processing techniques, aimed at adding value to the minerals. With regard to gold, the gold bars formed during the processing phase are melted into liquid form and then poured into a mould, which has a cavity in the shape of the desired jewellery design. Liquid hot wax is injected into the mould which then cools down and settles. This hardened wax is now separated from the mould and what remains is gold casted jewellery, which is then polished (Sourav, 2015).
  - Cutting and polishing: Rough diamonds, on the other hand, are analysed using computer imaging technology to determine where cuts will be made in order to obtain the necessary shape and minimise wastage. This is followed by cleaving or sawing, which involves the use of a diamond-edged saw or laser to cut the diamond into the specified pieces. It is necessary for the saw to be made out of diamond due to the hard nature of the rough diamonds, which can only be penetrated by other diamonds. The next step is bruting, where two diamonds are set on spinning axles and made to grind against each other, and the diamond is shaped into its destined round shape. This is followed by brillianteering, where the facets are placed and cut to determine the light performance and brilliance of the finished diamond. Finally, the diamond is polished to a mirror finish by cutting facets into the stone and polishing the cut surfaces (Isenberg, 2023).
  - Moulding or Assembly: Once the minerals have been polished, the diamond can then be set in the piece of jewellery being manufactured. The product is then ready for delivery to markets.
  - Finishing and Storage/ Packaging: The manufactured jewellery items are packaged and stored and are then ready to be transported to a specific destination (McKinsey & Company, 2020).

- Marketing:

Jewellery marketing is the process of promoting and selling jewellery products and services to potential customers. It involves creating a brand identity, developing a marketing plan, and implementing various marketing strategies to reach and attract the target audience (Marnewick, 2022). The marketing phase of this value chain involves conducting an appraisal of the jewellery by assessing its quality and in order to determine its value (Jewelers of America, 2023).

- Transportation:

This involves activities such as loading the materials onto cargo carriers and transporting these to their intended destinations. Similar to the mineral extraction value chain, this component of the value chain also involves extensive logistical planning, including coordination of routes, ensuring the availability of required equipment and personnel, and ensuring compliance with transportation regulations and safety standards (Mining Technology, 2023).

- Recycling/Repurposing:

The majority of the components used when manufacturing jewellery are recyclable, including precious metals such as gold, in addition to diamonds and gemstones which do not wear out (Harvey-Walker, 2019). Jewellery recycling is the process of reusing and transforming these recyclable components of old, unwanted, or broken jewellery into new and valuable products. It can involve melting down gold or other precious metals, resetting diamonds or gemstones, or redesigning jewellery pieces to suit a different style or purpose (Euro News, 2019).

4.2 Impact of the 4IR on MMS

While the current MMS context indicates that the sector is facing several challenges which are impacting its ability to contribute to GDP and remain competitive from a global perspective, the modernisation of mining operations, and by extension, the implementation of 4IR technologies, has the potential to address some of these challenges.

These advanced technologies such as artificial intelligence, automation and data analytics present a robust toolkit for the MMS to handle the multifaceted challenges faced in the sector. By embracing the capabilities of the 4IR, mining operations will be greatly enhanced and become much more efficient, optimise resource utilisation and respond with agility to the ever-changing demands of the industry. Although there are many positive advantages of the 4IR on the MMS, it is important to have a thorough understanding of the various factors that will change and affect the mining environment, both positive and negative, which will be discussed below.

4.2.1 Benefits of the 4IR for the Mining Sector

The 4IR has the potential to enhance the global competitiveness of the South African MMS and enable the sector to make greater contributions to the South African economy, given its potential effectiveness in mitigating rising operating costs and increasing productivity levels within mining operations. By integrating 4IR technologies, mining organisations can improve their efficiency in processes such as locating minerals for extraction, extracting the minerals, as well as processing ore deposits. The implementation of 4IR technologies may, as a result, enhance the global competitiveness of the South African mining sector, attract top talent, and ultimately contribute even more to the economy and society (Wadula, 2022). The modernisation of mining operations is seen as being key to ensuring the health and safety of miners, ensuring that the mining sector retains and continues to create jobs, and to ensure that the South African MMS continues to provide essential commodities to the global economy in a manner that is economically viable (Minerals Council, 2019).

Technological advancements and enhanced modernisation are acknowledged as direct contributors to long-term competitive advantages. Technological advancements are capable of assisting mining companies reduce costs, minimise environmental impact, boost production and enhance mineral recovery. For example, South Africa's production of diamonds is expected to increase at a compound annual growth rate ("CAGR") of 7% by 2026 (Mining Technology, 2023). This is as a result of digital technologies in the diamond mining process, resulting in improved efficiency (Fortune Business Insights, 2023). Similar trends are expected for gold production, which is expected to increase at a CAGR of 3% by 2025 (Global Data, 2021).

The importance of modernising the South African MMS is further highlighted by future projections which indicate that in terms of employment alone, 200 000 jobs may be lost in the next 10 years without modernising current mining operations. Contrastingly, incorporating modernised methods into mining operations has the potential to significantly extend the lifespan of South Africa's current gold and platinum group metal ("PGM") operations, and by extension, retain current jobs and create new employment opportunities (Minerals Council, 2019). Projections indicate that a low-grade mine with a current conventionally mined life expectancy of 4 years could potentially extend operations to 15 years using mechanised drilling and blasting methods.

Furthermore, if rolled out across the entire sector, modernisation could unlock the equivalent of 11 large gold mines and 8 platinum mines. In this sense, modernisation has the potential to contribute to job retention and the creation of new jobs, while simultaneously contributing to the profitability and economic viability of the MMS as a whole (Minerals Council, 2019). In addition to the impact on employment, and to further highlight the potential of the 4IR on the South African economy, analysis conducted by McKinsey (2019) indicates that 4IR related gains through productivity improvements, strategic infrastructure development, and technological evolution could triple South Africa's productivity growth, double growth in per capita income, and add a percentage point to its real GDP growth rate over the next decade.

4.2.2 Threats of the 4IR to the MMS

While there are numerous potential benefits associated with the implementation of 4IR technologies within the South African MMS, as outlined above, it is important to note that the phenomenon represents both an opportunity and a threat. Some of the identified threats include potential job losses due to automation, as well as an unskilled work force. Some of the threats and challenges to be considered are listed below:

Workforce Challenges

The first consideration for organisations within the MMS looking to implement 4IR technologies is the impact that enhanced digitisation may have on the MMS workforce. The implementation of 4IR technologies is anticipated to have a significant impact on the MMS workforce, in terms of employment as well as skills development. The challenge of reskilling and/or upskilling the MMS workforce is further highlighted by the fact that digital transformation in mining will require creating new occupational roles that may either require traditional mining skills to be supplemented or may not require traditional mining skills at all (PwC, 2023). The impact that the 4IR may have on the MMS workforce is therefore considered to be a major concern, with sector experts agreeing that the implementation of 4IR technology will greatly impact labour dynamics within the sub-sectors . As a result of these concerns, there is a risk that if the implementation of 4IR technologies is not managed carefully, it could potentially heighten tensions between organisations and the MMS workforce (Maswanganyi, 2021).

Research indicates that the implementation of 4IR technologies could result in the displacement of approximately 3.3 million existing jobs by 2030 (McKinsey & Company, 2019). However, in noting these displacements, it may also be noted that the introduction of 4IR technologies has the potential to create up to 4.5 million new jobs across all economic sectors, which represents a net gain of 1.2 million jobs (McKinsey & Company, 2019). These projections suggest that short term job losses as a result of 4IR technology implementation will be offset by the long-term employment created by the 4IR. The challenge regarding potential job losses is compounded when considering the traditional nature of the MMS workforce – with the sector being characterised by workers with low literacy levels and a lack of familiarity with digital tools such as computers and other electronic devices (PWC, 2021).

Another potential challenge to 4IR technology implementation as it pertains to the MMS workforce is the age of employees within the sector. According to the literature, young people are traditionally not attracted to the mining sector with young graduates preferring to live in cities as opposed to smaller mining towns (Stanz, et al., 2021). This is important to note because research indicates that while the aging MMS workforce may have deep sector knowledge, these individuals may struggle to work with digital tools once mechanised mines become more prevalent (Maswanganyi, 2021). Research indicates that mindset, culture, and behaviour is a key contributor to the successful implementation of innovative technologies (Maswanganyi, 2021). Employees need to have the willingness to adapt to change. Maswanganyi (2021) notes that MMS employees tend to possess 'traditional' attitudes towards change and are embedded in a culture of unwillingness to familiarise themselves with new and innovative technologies which may serve to be a barrier to 4IR technology implementation. This is exacerbated by the age profile of MMS employees, with research further indicating that older employees tend to face challenges with utilising innovative technologies due to technical and attitudinal barriers (Yang, 2019).

<u>Organisational, Infrastructure and Institutional Challenges</u>

There are specific organisational, infrastructure, and institutional challenges impacting the implementation of 4IR technologies. According to Zulu, et al. (2021), organisations face several challenges in the implementation of 4IR technologies such as a lack of impetus to implement 4IR technologies, challenges related to infrastructure constraints and institutional setups. Certain organisational barriers also impact on 4IR technology implementation, such as insufficient funding, the limitations of existing information technology ("IT") systems, unclear roles and responsibilities for mining employees, a lack of vision, an unclear business case, as well as instances of different business units within mining organisation operating in siloes .

The use of 4IR technologies may also result in increased cyber risk for organisations attempting to integrate said technologies into current operations. This is mainly because these technologies are dependent on the flow of data via a network connected to the internet, which is susceptible to various threats (Maswanganyi, 2021). Given that 'big data' databases typically contain large amounts of data, any breach of this data poses significant risks, and may result in a leak of confidential information regarding a particular mines' performance. Maswanganyi (2021) notes that, due to a lack of experience regarding the use of digital systems in the MMS, the extent of the potential cyber threats and the associated consequences is unknown. Furthermore, organisations within the MMS are still uncertain regarding the level of protection, as well as the expertise required, to guard against potential cyber threats (Maswanganyi, 2021).

The potential benefits and threats of the 4IR identified in the desk-based research were subjected to in-depth exploration through the fieldwork phase of the study. This investigation was key in gaining a comprehensive understanding of current employer perceptions within the MMS regarding the anticipated positive impact of advanced technologies on mining operations. Additionally, it shed light on the factors that either facilitate or impede the widespread adoption of the 4IR-related technologies. These insights are documented in Section 6 of this report.

4.3 Current Skills Development Landscape

While it is important to understand the 'as-is' situation regarding the current level of adoption of 4IR technology within the MMS, for the purposes of this study, it is equally important to understand what the implications of the uptake of the 4IR are or may be as it pertains to skills development and occupational profiling. However, in order to understand the impact of the 4IR on occupational profiling within the MMS it is important to first consider the current MMS skills development landscape.

The MMS is a dynamic sector that relies on a diverse range of skills and competencies to drive its operations and foster innovation. As such, by examining the skill sets, knowledge, and capabilities essential for different roles within the sector, this section provides a holistic understanding of the MMS's workforce requirements. Additionally, it sheds light on the skills gaps that need to be addressed to bridge the divide between the current workforce capabilities and the evolving demands of the MMS. The section also delves into the supply and demand for 4IR skills within the sector and provides an overview of the potential impact of the 4IR on occupational profiling, including the impact of changing technology on skills needs and occupations within the sector.

4.3.1 Overview of Sector Skills Gaps

In order to understand the nature of 4IR skills demand and supply, it is important to first consider the current skills gaps that exist within the MMS. Skills gaps, also referred to a “top-up skills”, arise when employees lack the necessary competencies and specific skills required by sector standards to effectively perform job tasks. These gaps can result from factors such as inadequate training, the introduction of new job tasks, technological advancements, or changes in production processes (MQA, 2021). Skills shortages remain a threat to the implementation of some of the advancements brought on by the 4IR (Odendaal, 2020). To address these skills shortages, employers have identified certain top-up skills that need to be filled. These skills include (MQA, 2021):

1. 4IReadiness - A term that has been recently coined and speaks to the fostering of data literacy of the workforce. As more technological advancements are introduced, there is a higher demand for a workforce that is digitally fit and have the necessary skills to leverage the advancements (PWC, 2019). This also entails possessing knowledge and proficiency in utilising computers and related technologies. It includes competencies in data entry, word processing, spreadsheets, and electronic communications using personal computers.

2. Cyber security and data custodianship - Lack of either one or a combination of these primary skills in the workforce has been identified as a challenge to the implementation of 4IR technologies. As the dependency on technologies increases in the mining sector, there is a requirement for data literate employees that are able to take full advantage of technologies and use all available digital tools. Additionally, since several emerging technologies make use of data portals and linked networks which are prone to hackers, there is an increased need for cyber security and data custodianship (PWC, 2021).

3. AI and “Cyber-Physical” systems - The assimilation of human intelligence by computers and some machines have several potential benefits in the mining sector which include resource estimation, troubleshooting and process optimisation across the value chain. While the automation of mines is now possible and has proven to be labour and time efficient, a number of skilled workers with knowledge of AI are crucial to the implementation and overseeing of some processes in the mines (Boliden Aitik, 2022).

4. Robotics - This engineering specialty focuses on creating, manufacturing, and using machinery. Robotics, particularly in mining, possesses several benefits such as improved conveyor maintenance which is typically a highly risky task (Rungasammy & Nembudani, 2021). Other benefits of using robotics in the mining sector could include improved safety, cost and time efficiencies and higher productivity since it relies less on human labour, but there would still be

a requirement that the end user fully comprehends the operation of the technology in underground or surface mining (African Mining, 2022).

5. AR and VR - The adoption of AR and VR in training by using simulations which allow workers to engage with real control panels in virtual environments could aid the better comprehension of machinery, potential high-risk situations, calculating safety distances and potential high-risk scenarios. There is a demand for the understanding of such technologies and how they could be applied in ensuring preparedness and safety in mining (Minerals Council, 2021).
6. Environmental expertise - While some studies have established the environmental friendliness of 4IR infrastructure as well as some of the risks associated with the 4IR, it is not yet well understood what some of the long-term negative impacts may be (Alexander, 2021). There is a growing need for environmental expertise that will conduct studies aimed at understanding the sustainability of the 4IR.
7. Leadership skills: This skill involves the ability to influence others, ensuring that they understand and agree on what needs to be done. It also entails the facilitation of individual and collective efforts to achieve shared objectives.
8. Management skills: These skills encompass five key functions, namely planning, organising, coordinating, directing, and oversight. They are crucial for effective management in various occupational roles.
9. Technical (job-specific) skills: This refers to the application of principles, techniques, procedures, and equipment that are specific to a particular job. Possessing these skills ensures proficiency and expertise in performing job-related tasks.
10. Mine production process skills: This skill set involves understanding, informing, and supporting production processes related to mining. It is vital for individuals working in the mining sector to have a comprehensive grasp of these processes.
11. Advanced IT and software skills: This entails possessing knowledge and proficiency in utilising computers and related technologies. It includes competencies in data entry, word processing, spreadsheets, and electronic communications using personal computers.
12. Supervisory skills: This skill set involves monitoring and regulating processes and employees in the performance of assigned or delegated tasks. Effective supervision ensures that tasks are carried out efficiently and in accordance with established standards (Health and Care Professions Council, 2021).

The types of emerging skills and jobs, the types of redundant jobs, and the focus of current reskilling and upskilling programs remain similar across the mining sector (World Economic Forum, 2020). Research indicates commonalities in the challenges faced by sub-sectors in terms of workforce development and skill requirements.

While the literature provides a solid knowledge base regarding the specific skills that may be required by employees within the MMS considering the changing technology within the sector, the fieldwork conducted as part of this Project identified specific MMS sub-sector skills gaps, as well as the specific soft and technical skills that will be in demand in the short-term future. A detailed discussion on MMS skills gaps is included in Section 6.3 of this report.

4.3.2 4IR Skills Supply and Demand

Following the high-level view of the skills gaps within the MMS, this sub-section gives an overview of some of the current training interventions and adaptations to curricula being implemented to support the 4IR.

4.3.2.1 Current Training Interventions and Collaborations that Support 4IR Implementation in the MMS (Skills Supply)

The following are some training interventions and collaborations that are currently in place and are aimed at the advancement of the 4IR in the MMS:

- Technology Integration: Learning institutions are partnering with organisations to incorporate more technology into their training programmes and educating both semi-skilled and skilled mining professionals about new machinery and automation of processes such as exploration, ore sorting and transportation. University courses on mining-related technologies such as robotics are used in underground mineral hauling, machine learning and autonomous systems – used in the transportation of minerals are also being introduced across the value chain as the 4IR becomes more prevalent. An example of this is the partnership between Sibanye-Stillwater and Simulacrum, a state-of-the-art training facility within the mining faculty at the University of Johannesburg ("UJ"). The collaboration entails a full-scale mine excavation via simulation in order for students to experience mining processes such as mine wall blasting, identification of geological hazards, reading temperature, pressure and gas, barring and watering down of excavations and working at elevated heights (UJ, 2023).
- Upskilling and Reskilling: There is a high potential that low-skilled or unskilled workers could end up losing their livelihoods as mechanisation and digitisation of the sector grows and could possibly eradicate the need for manual labour (Moses, 2023). There is, thus, a need to equip these employees with new skills in order to address arising skills gaps as a result of the emerging occupations within the MMS. As such, a number of upskilling and reskilling programmes are being developed by mining organisations and bodies in order to provide the current workforce in the MMS with information and skills needed to adapt to a digital mining environment (van der Woude & Ally, 2022).

4.3.2.2 Adapting Training Curricula for 4IR Implementation in the MMS

To address some of the skills gaps that result from the 4IR, the current training curricula in the mining sector has had to undergo revision in order to better equip the mining workforce in South Africa with the skills and knowledge necessary to thrive in a 4IR-driven mining sector. There are a few examples listed below of the interventions that have been in place to adapt the curricula according to sectoral needs:

- An online training course to demystify the 4IR was launched in 2020 by Via Afrika, a digital and printed educational content producer in South Africa. The course is aimed at providing participants with accurate information about the 4IR, and explaining how living and working in this new era of technological innovation and disruption might look like in the near future. Each consecutive session broadens users' knowledge bases and gives teachers insight into crucial 4IR theory and subject matter components for preparing their students for an unforeseen future.
- The University of Pretoria (“UP") in collaboration with the Exxaro Chair launched a virtual course in Extended Reality (“XR”) Technology in September 2021. The collaboration between the Chair and the Virtual Reality and Interaction (“VRI”) lab at UP is aimed at identifying some of the leading available technologies that can mitigate safer, economical, and more environmentally sensitive forms of mining. Additionally, it is also aimed at educating and training the upcoming generation of researchers and developers about the application of XR technologies to real-world initiatives.
- A modern training programme called Artisan 4.0 was launched in 2021 by the Artisan and mining skills training college Colliery Training College (“CTC”) in response to the 4IR. The programme is aimed at aligning artisan training with the requirements of the 4IR in the mining sector, and will consist of four phases of training.

The demand and supply of 4IR-related skills was also investigated further through fieldwork. This was key to understanding the current perspectives of MMS Employers with regard to the need for, and availability of 4IR-related skills. The study explored the factors influencing the demand for these skills, as well as the challenges and opportunities associated with their supply. Section 7 of this report outlines the findings related to this gathered during this fieldwork.

4.4 Policy and Legislation

Various policies currently exist that are intended to promote skills development in South Africa. These include the National Development Plan (“NDP”) 2030, National Skills Development Plan (“NSDP“), the Human Resource Development (“HRD”) Strategy for South Africa and Economic Reconstruction and Recovery Plan Skills Strategy (“ERRS”). The following paragraphs provide further detail regarding these policies.

The NDP, published in 2012 as part of the country's efforts to reduce inequality and eliminate poverty by 2030, serves as a long-term vision and strategic framework for the country's development, outlining goals and targets across various sectors to address socio-economic challenges and promote inclusive growth. The plan emphasises sustainable development, job creation, education, and improved infrastructure to build a more prosperous and equitable nation (South African Government, 2023). Furthermore, the plan places a strong emphasis on the need for innovation in both emerging and established sectors, such as mining. In line with this, the plan aims to improve education, training and innovation through a number of initiatives including; the production of 30 000 artisans per year, increasing the enrolment at universities by 70% by 2030 and improving the throughput rate to 80% by 2030.

In addition to the NDP, the NSDP is a key policy framework that outlines South Africa's approach to skills development. The policy aims to create a highly skilled and competent workforce that will advance both the social and economic growth of the country. The NSDP aims to enable both government and social partners to contribute towards economic growth by enhancing the standard of education and training, increasing access to educational and training opportunities, encouraging innovation and entrepreneurship, and developing skills in growing economic sectors. While not exclusively focused on 4IR-related skills, the NSDP recognises the importance of adapting to technological changes as it seeks to: “Harness the use of technology, where possible and relevant, standardise processes across all skills levy institutions, improve efficiencies and increase stakeholder involvement through online portals and accurate data analysis for improved decision making” (Department of Higher Education and Training, 2019).

The HRD Strategy for South Africa was developed in 2001 as a comprehensive strategy that addresses the development of a country’s human capital and sustainable economic growth. The NSDP, Sector Education and Training Authorities (SETAs), and National Qualification Frameworks (NQFs) are some of the tools used to implement the HRD Strategy and encourage the formation of an educated workforce that will contribute to the economic development and growth of the country. While the HRD strategy has been reviewed several times since its introduction, some of the goals of the HRD strategy as defined by the National Integrated Human Resource Development include; strengthening basic education and foundation programmes, expanding access to quality post-schooling education and training, improving research and technological innovation outcomes and producing appropriately skilled people for the economy.

The ERRS, on the other hand, is a developing strategy which aims to ensure that implementation of the Economic Reconstruction and Recovery Plan (“ERRP”) will be supported by skills that are readily available. It recognises that the implementation of the key components as outlined in the ERRP requires certain skills, which include a mix of technical, managerial, and leadership skills across various sectors, and will fail if these skills are not available. The interventions set out in the ERRS include but are not limited to the expansion in the provisioning of short skills programmes and the enablement of the provision of targeted skills programmes which both seek to enable the development and provision of skills training that is responsive to the industry that can be implemented promptly by training providers (Department of Higher Education and Training, 2022).

While the above policies consider ways in which skills development can be supported in the context of changing technology, the South African educational system has not accommodated or kept pace with technological changes (Mendy & Madlope, 2020). This is, in part, as a result of a lack of agility in educational institutions and slow curriculum development and review processes (MoonasamyI & Naidoo, 2022). It has been argued that there is a need for flexible educational programmes, systems, and curricula in order to provide skills for the 4IR and future industrial revolutions (Chetty, 2019). Efforts toward skilling for the future have been stifled by long processes in the development of qualifications and accreditation of training providers through the Quality Council for Trades and Occupations ("QCTO") and the South African Qualifications Authority ("SAQA"). According to the ERRS, stakeholders in the sector have noted the following challenges in relation to the disbursement of the Discretionary Grant (Department of Higher Education and Training, 2022):

- The QCTO qualification development process is drawn out by the dependency on external consultants.
- The demands of SETA processes for accessing the Discretionary Grant and South Africa's education and training quality assurance system have created obstacles for employers and training providers in their efforts to provide accredited and non-accredited skills programmes.
- Accreditation is only granted to Skills Development Providers who offer programs that are linked to qualification pathways. In cases when adequate registered qualifications do not yet exist, such a requirement is ineffective.

In order to ensure that sectors including the MMS respond timeously and adequately to the impact of the 4IR, it is necessary to ensure that skills and qualification accreditation bodies such as the QCTO and SAQA are prompt in accrediting relevant programmes.

4.4.1 4IR-Related Policy Frameworks

In addition to the national skills development policies outlined above, there are a number of 4IR and technology-related policy frameworks that have been developed by various government entities and departments. The following table identifies and highlights the various 4IR policies that have been implemented in South Africa in order to aid the implementation of the 4IR in the country overall, as well as within the MMS specifically. Furthermore, an overview of their implementation to-date is provided.

Table 4-1: 4IR Policies in South Africa

#	Policy	Description	Effectiveness of Implementation
1	**Presidential Commission on the Fourth Industrial Revolution Strategic Implementation Plan ("PC4IR SIP")**	• The goal of the PC4IR SIP is to ensure that the country can fully participate in and benefit from the 4IR by developing a comprehensive strategy for implementing new technologies and digital advancements in key areas such as education, healthcare, transportation, and infrastructure (Department of Communications and Digital Technologies, 2020). • The plan aims to promote economic growth, create jobs, and improve the standard of living for all citizens by leveraging the opportunities presented by the 4IR (Department of Communications and Digital Technologies, 2020). • Additionally, the plan aims to address the challenges that may arise from the rapid pace of technological change, such as inequality, unemployment, and social dislocation (Department of Communications and Digital Technologies, 2020). • The key recommendations on how to achieve the PC4IR SIP goals include (Department of	In line with the PC4IR SIP goals, the following has been achieved to-date: • Adoption of the e-government strategy and roadmap to guide digital transformation of public service (Department of Communications and Digital Technologies, 2023). • Launched AI Hubs at the University of Johannesburg and the Tshwane University of Technology with the aim of providing training and creating a positive social impact around the involvement of AI in key sectors of the economy (Department of Communications and Digital Technologies, 2023). • Completion of the high-demand radio frequency spectrum auction which set out to allocate high-demand spectrum bands (e.g., 700MHz, 800MHz, 2 300MHz, 2 600MHz, and 3 500MHz, which are needed for high-speed broadband and 5G) to telecommunications operators within the country, to ultimately transform and create competition in the telecommunications sector with respect to the reduction

#	Policy	Description	Effectiveness of Implementation
		Communications and Digital Technologies, 2021): ○ Investment in human capital; ○ The establishment of an AI Institute; ○ The establishment of a platform for advanced manufacturing; ○ Securing and availing data to enable innovation; ○ Incentivising future industries, platforms and applications of 4IR technologies; ○ Building 4IR infrastructure; ○ Reviewing and amending (or creating) policy and legislation; ○ Establishment of a 4IR Strategic Implementation Coordination Council Th above recommendations will be implemented through the development of a strategic implementation plan which includes cross-sectorial 4IR programmes and institutional establishments highlighting the potential for the development of 4IR infrastructure within the MMS at a national level.	of costs to communicate. This initiative aims to improve digital infrastructure and enable the deployment of new technologies in public schools, public clinics and hospitals, and police stations (Department of Communications and Digital Technologies, 2023). While there are no sectorial-specific initiatives that form part of the PC4IR SIP, access to broadband connectivity, improved digital infrastructure and introduction of new technologies for public institutions such as schools as well as the increased focus of research and development in the field of AI will broadly impact the level of skills and knowledge of the 4IR and innovative technologies amongst the population, which may, in turn, facilitate the implementation of the 4IR across various sectors, including the MMS.

#	Policy	Description	Effectiveness of Implementation
2	**Department of Science and Technology ("DST") Ten-Year Innovation Plan**	• The strategy outlines a medium-to-long-term policy direction for the transformation towards a knowledge-based economy, with a focus on where the country should be in ten years (Alexander, 2021) • The policy is driven by four key elements namely, human capital development, knowledge generation and exploitation, knowledge infrastructure and enablers to addressing the innovation gap between research results and socioeconomic outcomes (Alexander, 2021) • The first of the plans, related to science, technology and innovation, was approved in March 2021 (Alexander, 2021)	The DST Ten-Year Innovation plan has developed a number of indicators related to strategic priorities that the plan will focus on. The plan has identified the following as tentative indicators for the mining sector (Department of Science and Innovation, 2023): • Improved mining sector factor productivity • Increased R&D intensity of sector • Improved effectiveness and efficiency in mining sector operations for developing and adapting high-tech applications for sustainability • Increased R&D intensities and competitiveness of the mining sector • Strengthen the integration of key enabling high-technology and mining equipment to improve accuracy and extraction levels • Increased use of high-tech equipment, services and processes in mining to drive the sector's sustainability and competitiveness • Increased use of high-tech to enable mining equipment tracking, usage and proactive failure warning

#	Policy	Description	Effectiveness of Implementation
			In order to meet the objectives of the mining sector indicators, the Ten-Year Plan envisages modernising mining through Science, Technology and Innovation ("STI") by leveraging and improving the coordination of existing STI programmes such as those with the Mining Equipment Manufacturers of South Africa to create innovation and product opportunities for locally developed mining equipment. These indicators will assist in the development of the 4IR within the mining sector by providing key policies and strategies to guide the changes that will arise as a result of the 4IR.
3	**Industrial Policy Action Plan ("IPAP")**	• IPAP aims to promote industrial development and competitiveness in South Africa, with a specific focus on 4IR technologies such as advanced manufacturing and digital industries (Department of Trade Industry and Competition, 2019). • The plan also focuses on increasing investment in research and development and improving the country's innovation ecosystem (Department of Trade Industry and Competition, 2019). • IPAP addresses the 4IR by focusing on building the	The IPAP has implemented a number of Key Action Programmes specific to the minerals beneficiation sector aimed at promoting the long-term growth and sustainability of the sector. These Programmes have been detailed as part of the IPAP and include the nature and purpose of the intervention, targeted outcomes, key milestones and specific projects to be implemented as part of the Programmes. These Programmes include (The Department of Trade, Industry and Competition, 2019): • Interventions for a sustainable steel industry

#	Policy	Description	Effectiveness of Implementation
		necessary enablers for Industry 4.0 such as (Department of Trade Industry and Competition, 2019): ○ Developing a skilled workforce and support for worker retraining ○ Improving access to finance for small and medium-sized enterprises ("SMEs") ○ Improving the country's infrastructure to support the growth of the manufacturing sector ○ Encouraging investment in research and development, including in advanced technologies such as artificial intelligence, the IoT, and big data analytics.	including targeting investment growth within the steel value chain and technological upgrades in the short-to-medium term. • Expansion of the PGM beneficiation industries through the development of the Fuel Cell industry. Fuel cells offer health and safety benefits to conventional diesel as well as electric mining equipment in underground applications as an integrated technology solution, making this a key Programme to take note of within the MMS. • The development of energy storage technology in South Africa to meet the projected global up-take of vanadium energy storage solutions. This Programme will require South Africa to demonstrate its ability to implement innovative technologies in line with global standards. • Growing the market share of domestic manufacturers of mining equipment and components by identifying opportunities for localisation, supplier development and export growth. This Programme, spearheaded by the Mandela Mining Precinct will include projects such as:

#	Policy	Description	Effectiveness of Implementation
			○ Modernisation of current operational mines. ○ Mechanised mining for gold and platinum. ○ Non-explosive rock breaking. ○ Advanced ore-body knowledge. ○ Real-time information management systems and Mining 4.0. ○ Optimisation of the mining supply chain. The abovementioned Programmes, along with growing the sector as a whole, aim to enhance innovation and the technological capacity of the sector to ensure global competitiveness and build the necessary capacity to enable the adoption of the 4IR.

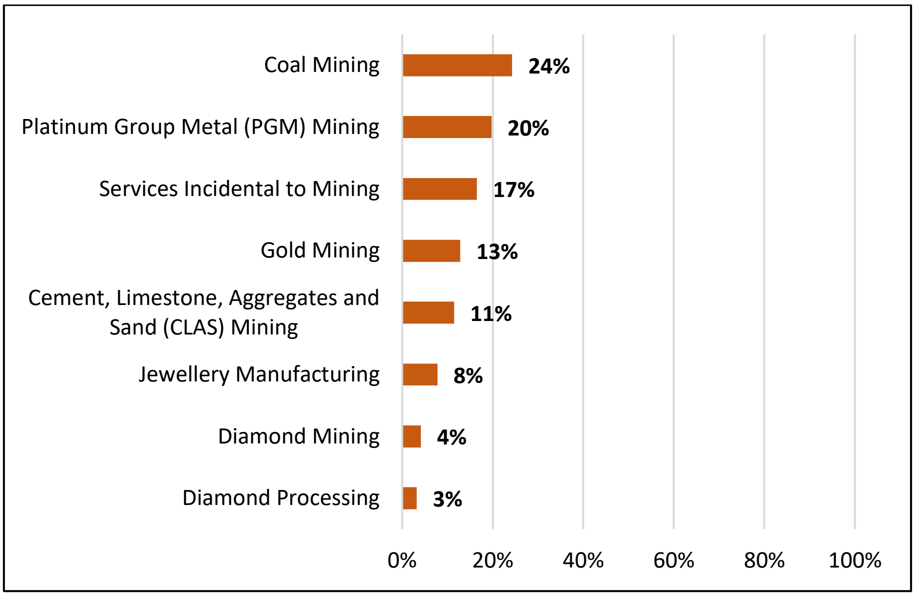
5 Demographic Details of Respondents

In order to provide context to the research findings detailed in the sections that follow, this section provides an overview of the provinces in which organisations that responded to the survey were located, insight into the mining techniques currently being adopted as well as the average education level of employees within these organisations.

5.1 Mining Extraction Techniques and Sub-sector

The following figure highlights the mining sub-sector of the organisations who responded to the survey.

Figure 5-1: Sub-sector Representation of Respondents



Source: MQA Impact of 4IR Survey, 2023

As seen in the figure above, the majority (24%) of survey respondents represented the Coal mining sector, followed by PGM mining (20%), and Services incidental to Mining (17%). The Diamond processing sub-sector had the fewest respondents at 3%.

Beyond the above, the following table provides further detail regarding the sub-sector demographics of the individuals who participated in the interviews.

Table 5-1: Employer Interview Sub-Sector Representation

Sub-sector	Conducted
Gold Mining	4
Coal Mining	5
Diamond Mining	2
PGM Mining	6
CLAS Mining	1
Other Mining	3
Diamond Processing	2

Jewellery Manufacturing	2
Services Incidental to Mining	8
Total	**33**

Additionally, the sub-sector details of the Training Providers who participated in the interviews is indicated below.

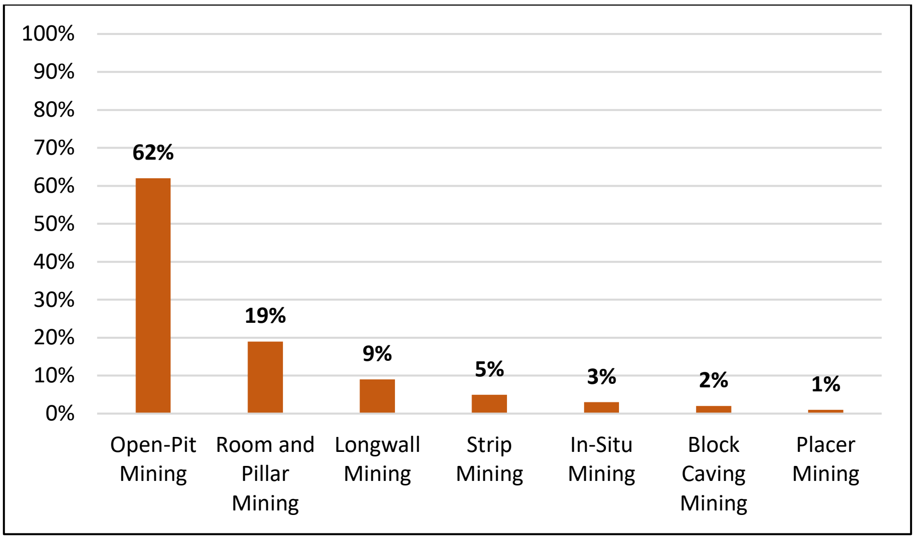
Table 5-2: Training Provider Interview Sub-Sector Representation

Sub-sector	Target	Conducted
Gold Mining	2	1
Coal Mining	2	3
Diamond Mining	2	1
PGM Mining	2	1
CLAS Mining	2	0
Other Mining	2	3
Diamond Processing	2	1
Jewellery Manufacturing	2	4
Services Incidental to Mining	2	1
No specific sub-sector[18]	-	7
Total	**18**	**22**

The following figure highlights the mining extraction techniques of the organisations who responded to the survey.

[18] Training Provider representatives who participated in the research but indicated that they did not align to a specific sub-sector were included within this category, this included, for example Training Providers who provide training across multiple sub-sectors.

Figure 5-2: Mining Extraction Techniques of Organisations[19]



Source: MQA Impact of 4IR Survey, 2023

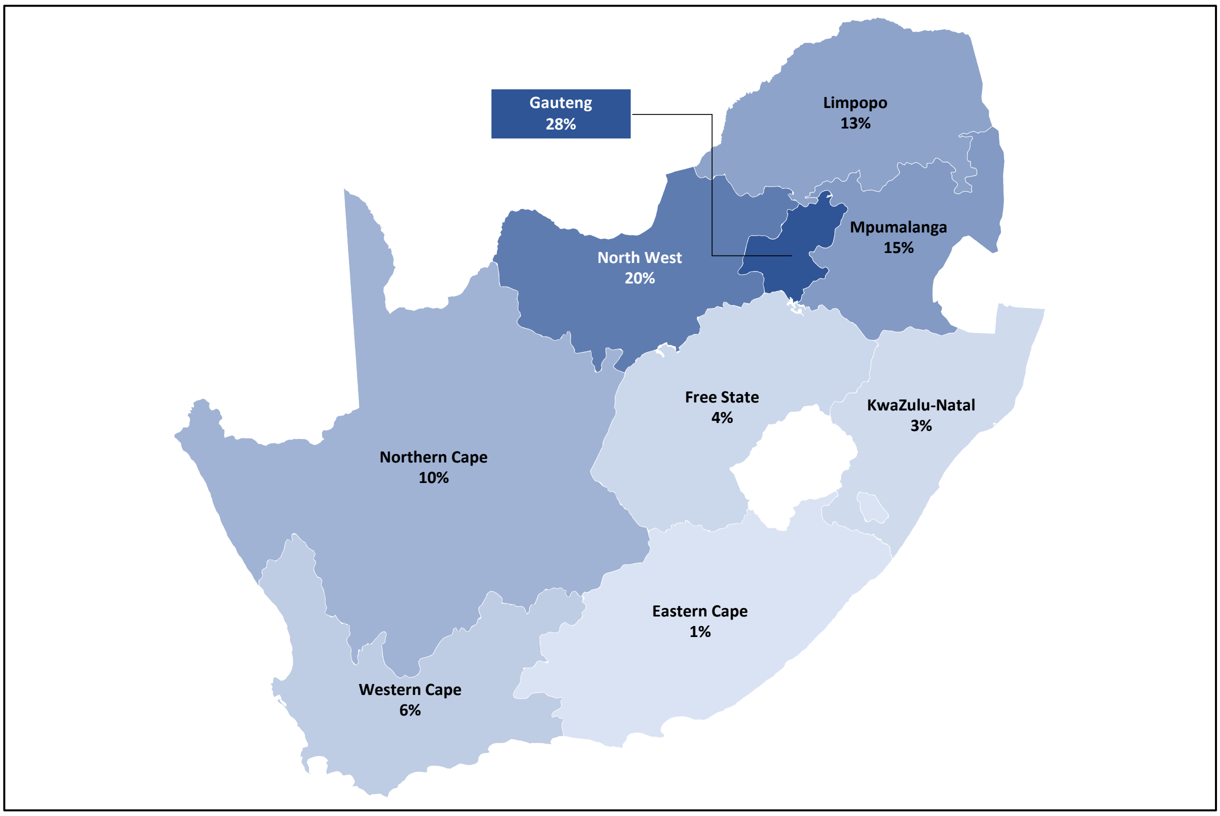
As seen above, the majority of organisations (62%) indicated that they are currently mining through Open-Pit Mining. This is followed by 19% of respondents who utilise Room and Pillar Mining techniques. Only 1% of respondents to the survey represent Placer Mining.

5.2 Provincial Representation

The following figure highlights the provincial location of the organisations who responded to the survey.

[19] Figures in the graph may not add up to 100% due to rounding off.

Figure 5-3: Provincial Representation of Respondents



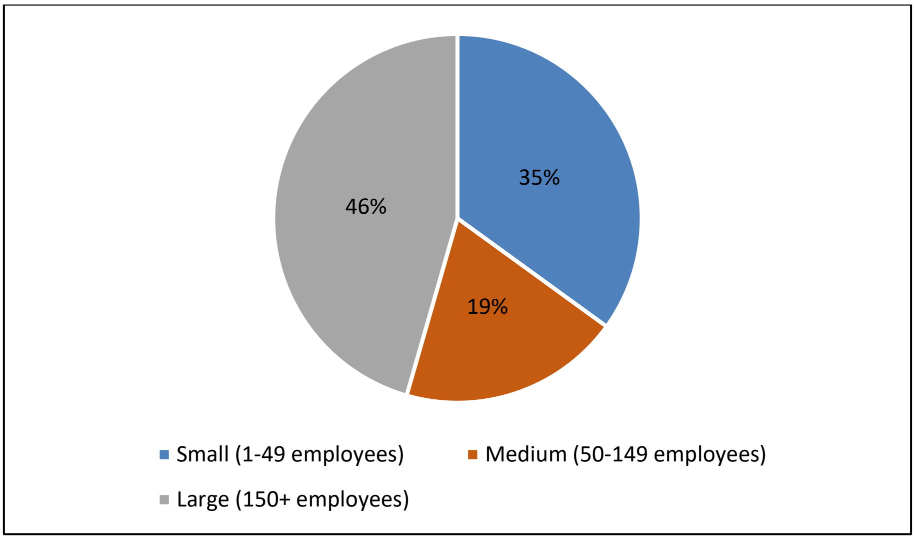
Source: MQA Impact of 4IR Survey, 2023

The figure above indicates that 28% of respondents are based in the Gauteng province, followed by 20% from the North-West, 15% from Mpumalanga and 13% from Limpopo. Only 1% of respondents were from the Eastern Cape.

5.3 Company Size

The following figure highlights the size of the organisations that participated in the survey.

Figure 5-4: Representation of Respondents by Company Size



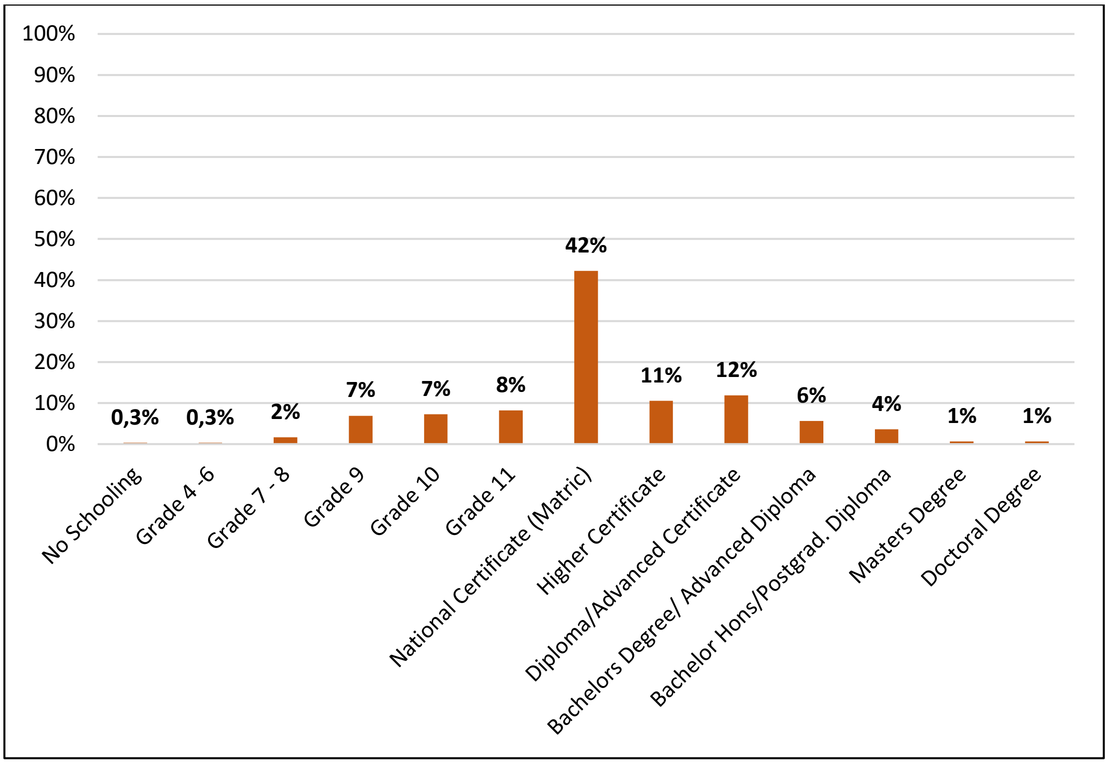
Source: MQA Impact of 4IR Survey, 2023

The figure above indicates that of the respondents to the survey, 46% represent large organisations, 35% represent small organisations and 19% represent medium sized organisations.

5.4 Average level of Education of MMS Employees

In order to determine how occupational and skills related changes as a result of the 4IR may impact the MMS workforce, it is important to understand the average levels of education of employees. The following figure illustrates the average level of education that employees of mining organisations possess.

Figure 5-5: Average Level of Education Amongst MMS Organisation Employees



Source: MQA Impact of 4IR Survey, 2023

As seen in the figure above, 0,3% of respondents noted that, on average, their employees do not have any schooling or have between a grade 4 and 6 education. The majority (42%) of respondents noted that on average, their employees possess a National/Matric Certificate.

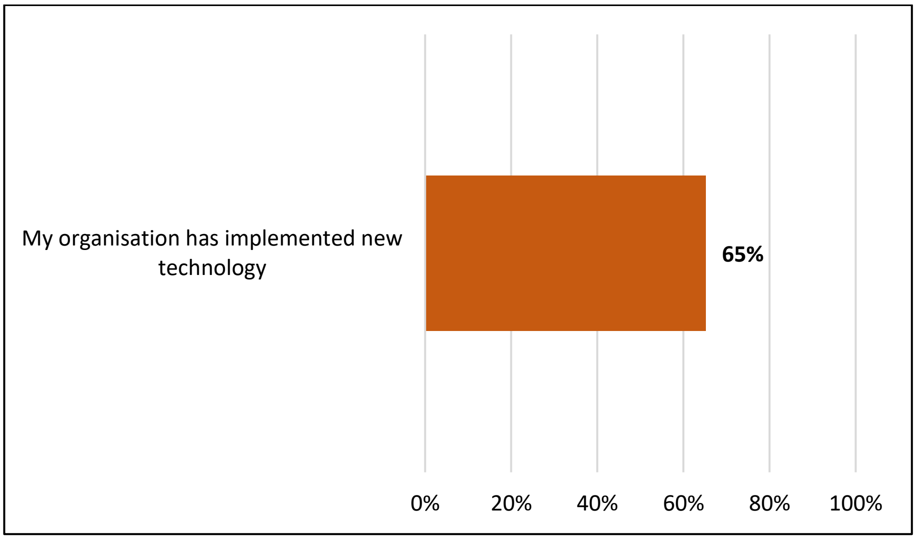
6 Adoption of the 4IR in the MMS

In order to understand the "As-Is situation", the current adoption of 4IR-related technologies amongst organisations was assessed. This section provides an overview of the level of innovation and application of the 4IR within the MMS. This includes a view of the current adoption of 4IR-related technologies amongst MMS organisations and plans to adopt 4IR-related technologies. Furthermore, the section provides an overview of the areas in the MMS Value Chain where 4IR technologies are likely to be implemented.

6.1 Current Adoption of 4IR Technologies Amongst MMS Organisations

The current level of adoption of 4IR technologies within the MMS is a key factor to consider as it allows for a comparison between the "current" and "future" state of the 4IR adoption in the sector and the implications on skills development as a result. The following figure provides an overview of the adoption of 4IR technologies by organisations within the MMS.

Figure 6-1: Current 4IR Adoption Within the MMS

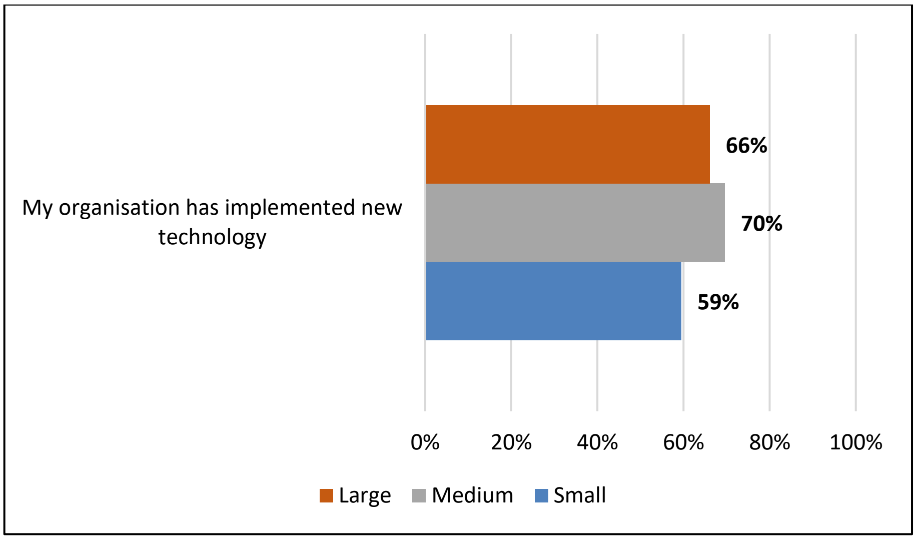


Source: MQA Impact of 4IR Survey, 2023

As seen in the above figure, overall, 65% of organisations have implemented new technologies within the past year and have made changes to their operations as a result.

In addition, the following figure provides an overview of the adoption of 4IR technologies within small, medium and large organisations.

Figure 6-2: Current 4IR Adoption Within Organisations [20]



Source: MQA Impact of 4IR Survey, 2023

As can be seen in the figure above, 66% of large, 70% of medium and 59% of small organisations agreed that they have implemented new technology in the past year and have made changes to the operations as a result.

It is interesting to note that slightly fewer large companies have implemented new technology compared to that of medium sized organisations. This may be attributed to the often complex processes and strategies within large and more established companies. This is supported by an opinion piece by the General Manager of Dell Technologies, South Africa, in which it is stated that medium sized-companies possess the flexibility to adapt quicker in an evolving technological environment and are able to respond to the market a lot faster (Biz Community, 2020). It was further noted during interviews that decision-makers in large organisations still appear to believe in the conventional way of mining and do not currently see the need to change the way things are done.

> "It [limitations to the adoption of 4IR] is not because of lack of skills, that's for sure… I would say it's because we still believe in the current way of doing things. I think it's because change needs to happen in our processes and how we inform our strategies… The commodities have gone down, you look at where you spent and you don't want to interrupt your current system, especially if it still allows you to be able to perform and produce as you're supposed to. I think it's just a matter of us opening up to change more than anything."
>
> *Respondent 7, Employer Interview, PGM Mining, 2023*

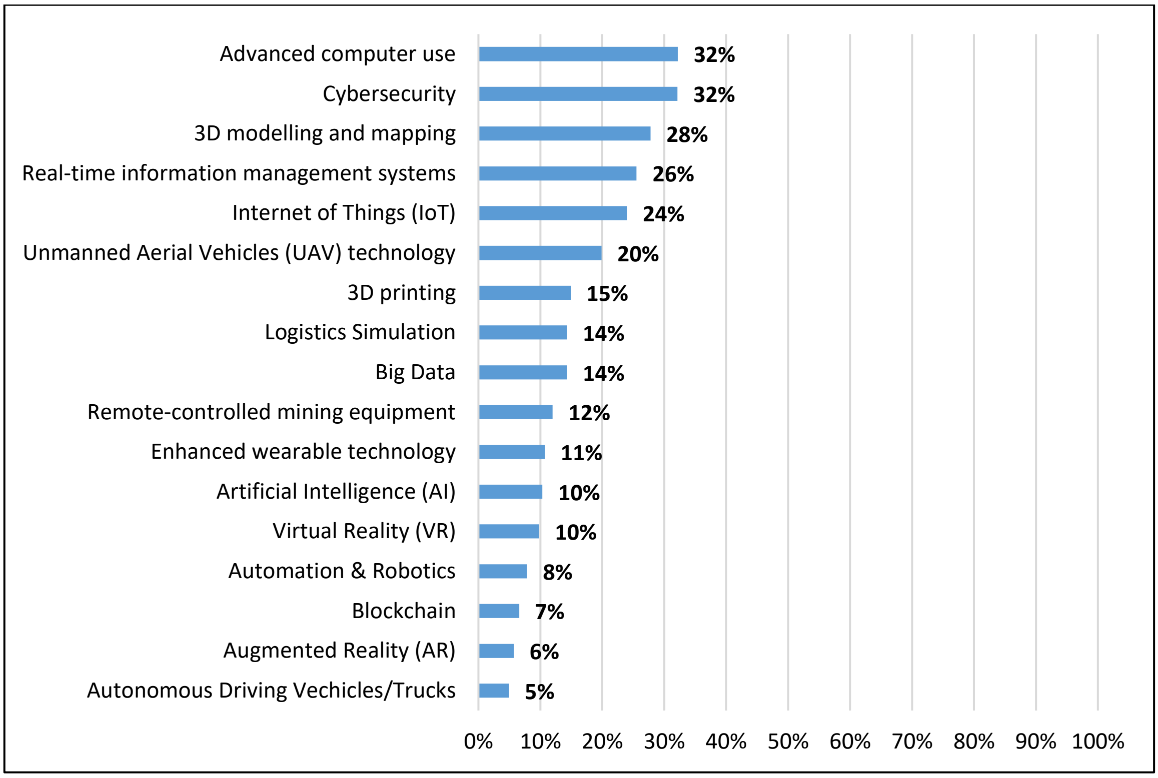
Further to the above, interviews with various organisations highlighted that innovation and the use of 4IR-related technologies is, at times, determined by the financial capacity of the organisation and whether the implementation of technology will have a measurable impact on areas such as worker health and safety and financial

[20] The percentages in the graph represent the percentage of stakeholders who responded positively to the statement assessed

productivity. This finding is supported by the CSIR, which found that, broadly speaking, technology is increasingly being applied in the areas where it has the greatest potential measurable benefit (CSIR, 2023).

The above finding regarding the limitations faced by organisations in the adoption of 4IR-related technologies should be taken into account when considering the current level of adoption of 4IR-related technologies by organisations within the MMS, analysed in the figure below.

Figure 6-3: Current Adoption of 4IR-Related Technologies[21]



Source: MQA Impact of 4IR Survey, 2023

As can be seen in the figure above, the 4IR-related technology that has been adopted by most organisations include advanced computer use[22] (32%), cybersecurity (32%), 3D modelling and mapping (28%), real-time information management systems (26%) and IoT[23] (24%). Stakeholders also noted the use of unmanned aerial vehicles/ drones (20%) within their operations.

[21] Respondents were allowed to select multiple options according to what was most relevant. Each category is to be assessed separately and totals may not add up to 100%

[22] Specialised computer skills related to programming, web development, data analysis and network administration. In the mining sector, advanced computer use may be employed by engineers to design and simulate complex systems, analyse data, and develop software applications for engineering projects (Simpli Learn, 2023).

[23] The embedding of everyday objects with sensors, software or other technologies to allow objects to connect and exchange data over the internet.

> "We have been using drone technology – this is a recent development. In terms of the drawing side, we have been using more advanced tools to do drawing. There are 2D and 3D tools, and so on. Before, they used to do manual checks on drawings, now they are using an online tool, a specific tool that makes sure that things like dimensions are on point."
>
> *Respondent 2, Employer Interview, Services Incidental to Mining, 2023*

While some organisations seem to have adopted specific 4IR related technologies, the overall adoption appears to be relatively low with only less than a third (32%) of organisations having adopted these. The lack of adoption of 4IR-related technologies or innovation within organisations may be attributed to the lack of financial capacity of organisations, as mentioned above. During interviews, stakeholders noted that while there may be a willingness to innovate, the current availability of resources and financial capacity is a challenge.

> "No I think the biggest thing is the cost of everything. It's easy to say let's automate but everything comes with a price. If we had the resources to bring in all this new technology we would not have an issue."
>
> *Respondent 17, Employer Interview, Diamond Mining, 2023*

In addition to the overall level of adoption of 4IR-related technologies by organisation within the MMS, the table below illustrates the level of adoption of 4IR-related technologies within each of the sub-sectors. By understanding the level of adoption within the various sub-sectors, the MQA may be able to determine where focus may be placed in terms of developing the required skills. The areas shaded in light green serve as a visual indicator of the top three 4IR technologies currently adopted per sub-sector.

Table 6-1: 4IR Technology in Use by Sub-Sectors

	Coal Mining	Gold Mining	Diamond Mining	PGM Mining	CLAS Mining	Other Mining	Services Incidental to Mining	Diamond Processin	Jewellery Manufactu
Advanced computer use	36%	33%	0%	38%	31%	30%	27%	25%	60%
Cybersecurity	33%	38%	0%	56%	50%	32%	31%	0%	0%
Unmanned Aerial Vehicles (UAV) technology	29%	25%	0%	25%	38%	22%	12%	0%	0%
3D modelling and mapping	27%	38%	0%	44%	33%	19%	19%	25%	58%
Real-time information management systems	25%	33%	0%	44%	33%	17%	27%	0%	40%
Internet of Things (IoT)	23%	0%	0%	56%	23%	24%	27%	20%	9%

	Coal Mining	Gold Mining	Diamond Mining	PGM Mining	CLAS Mining	Other Mining	Services Incidental to Mining	Diamond Processing	Jewellery Manufacturing
Virtual Reality (VR)	22%	22%	0%	19%	0%	8%	4%	0%	0%
Big Data	17%	25%	0%	25%	25%	8%	20%	0%	0%
Artificial Intelligence (AI)	13%	22%	0%	19%	8%	5%	8%	0%	17%
Automation & Robotics	13%	0%	0%	20%	23%	5%	0%	0%	11%
Remote-controlled mining equipment	13%	22%	0%	31%	8%	11%	4%	0%	10%
3D printing	12%	0%	0%	25%	9%	8%	4%	0%	75%
Logistics Simulation	12%	25%	0%	25%	25%	8%	15%	0%	20%
Augmented Reality (AR)	8%	11%	0%	20%	0%	3%	4%	0%	0%
Blockchain	8%	13%	0%	7%	8%	5%	4%	20%	0%
Autonomous Driving Vehicles/Trucks	8%	22%	0%	0%	0%	8%	0%	0%	0%
Enhanced wearable technology	4%	11%	0%	27%	17%	8%	12%	25%	0%

Source: MQA Impact of 4IR Survey, 2023

Supporting the overall view regarding the adoption of the individual technologies illustrated in Figure 6-3, it can be seen that advanced computer use and 3D modelling and mapping has already been implemented across the majority of the sub-sectors, with the exception of Diamond mining, highlighting the importance of these technologies to the future of work in the sector. While the Diamond mining sub-sector respondents indicate plans to adopt 4IR-related technologies within the next 1 to 2 years and 2 to 5 years, it was also noted that a large portion of Diamond mining respondents are not likely to adopt 4IR-related technologies. This may be due to certain technologies being unsuitable for adoption in the sub-sector. Furthermore, it may be noted from the data above that PGM mining organisations appear to have implemented the greatest proportion of 4IR-related technologies, compared to that of the other sub-sectors.

One of the key findings from interviews was that smaller organisations within the MMS may struggle to keep up with the technological advancements within the sector due to the high cost of 4IR-related technologies. Based on this perspective, it is, therefore, important to understand the current level of technology use by company size. The areas shaded in light green serve as a visual indicator of the top three 4IR technologies currently in use by organisations according to the company size.

Table 6-2: 4IR Technology in Use by Organisations by Company Size

	Small	Medium	Large
Advanced computer use	30%	27%	38%
3D modelling and mapping	28%	23%	31%
3D printing	20%	3%	16%
Internet of Things (IoT)	18%	16%	36%
Real-time information management systems	17%	19%	39%
Cybersecurity	13%	37%	48%
Logistics Simulation	13%	7%	21%
Unmanned Aerial Vehicles (UAV) technology	11%	20%	29%
Artificial Intelligence (AI)	11%	3%	14%
Big Data	9%	13%	22%
Automation & Robotics	8%	6%	11%
Enhanced wearable technology	7%	7%	16%
Remote-controlled mining equipment	6%	3%	22%
Blockchain	4%	7%	9%
Autonomous Driving Vehicles/Trucks	4%	3%	7%
Virtual Reality (VR)	2%	7%	18%
Augmented Reality (AR)	0%	3%	12%

Source: MQA Impact of 4IR Survey, 2023

As can be seen in the table above, the technology largely being used by organisations of all sizes is advanced computer use. Overall, it appears that smaller organisations have not adopted as much 4IR-related technologies, with employers noting that smaller organisations do not have the financial capacity required to adopt 4IR technologies due to the high cost of the machinery and assets.

> "Yes, in addition to that, for us it is expensive to adopt new technologies – the expense, lack of skills, and lack of knowledge do not weigh up to the benefit gained, especially for us because we are so small, we won't really gain much, but it would cost us a lot."
>
> *Respondent 18, Employer Interview, Diamond Mining, 2023*

Inferential Analysis

Chi-Square tests, using a significance level of 0.05, were conducted to understand the relationship between the size of the organisation and the current adoption of 4IR-related technologies, sub-sector and current adoption of 4IR-related technologies and the mineral extraction technique adopted and current adoption of 4IR-related technologies. This analysis reveals no significant relationship between the size of the organisation, the sub-sector or the mineral extraction technique and the current adoption of 4IR-related technologies.

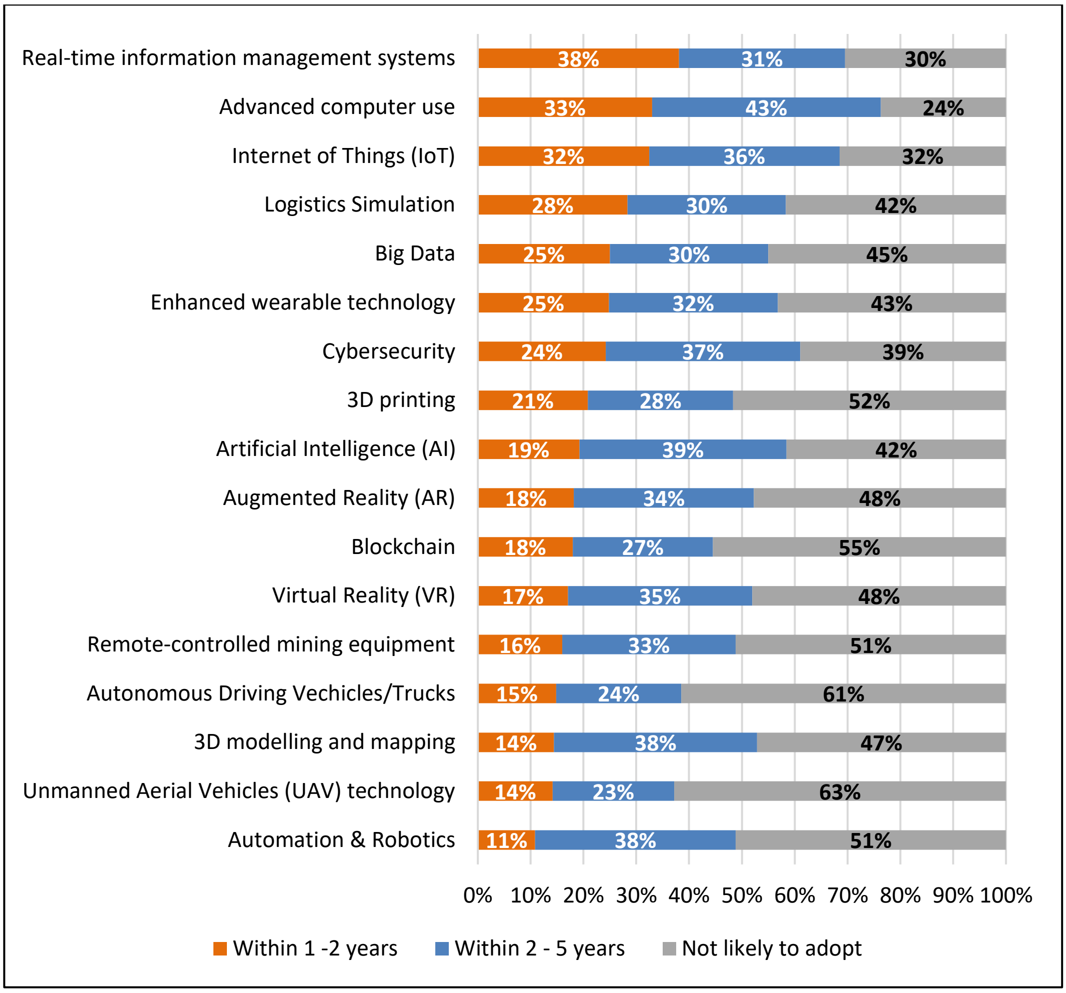
Key Findings

- The top three technologies that have already been adopted by organisations include advanced computer use, cybersecurity, and 3D modelling and mapping. However, the adoption of 4IR technologies still appears to be relatively low, overall.
- A higher number of organisations in the PGM mining sub-sectors appear to have adopted the use of 4IR technologies when compared to the other sub-sectors. Additionally, the adoption of technology appears to be lower amongst smaller organisations.

6.2 Future Adoption of 4IR-related Technologies Amongst MMS Organisations

To understand the extent to which 4IR related skills will be required in the sector in the next 5 years it is important to understand organisations' plans to adopt 4IR technologies within the next 1 to 2 years and 2 to 5 years. The analysis in this section, therefore, includes a view of organisations who plan to adopt 4IR-related technologies, as well as those organisations that are not likely to adopt these technologies. Beyond the overall analysis provided below, an analysis based on sub-sector and company size is also included.

Figure 6-4: Future Adoption of the 4IR Amongst Organisations



Source: MQA Impact of 4IR Survey, 2023

As can be seen in the figure above, within the next 1 to 2 years, the top three technologies that will be adopted by organisations include real-time information management systems (38%), advanced computer use (33%) and IoT (32%). Further to this, within the next 2 to 5 years, the top technologies that will be adopted advanced computer use (43%), AI (39%), as well as 3D modelling and mapping and automation and robotics (38% each). MMS organisations noted during the interview process that while they may not have implemented 4IR technologies yet, their organisations are taking steps and progressing towards the implementation of technologies in line with the 4IR.

> "In terms of 4IR, we might not be there yet, but progressively we are getting there because, there's a whole number of things that are happening at their own pace, which are driving us and getting us into that platform."
>
> *Respondent 7, Employer Interview, PGM Mining, 2023*

Further to the above, it may be noted that the majority of the organisations that responded to the survey indicated that they are unlikely to adopt autonomous driving vehicles/ trucks (58%), blockchain (52%) and unmanned aerial vehicle technology

(50%). As mentioned previously, the lack of financial capital is a key consideration for many organisations when deciding whether to adopt 4IR-related technologies or not.

> "We will move with the times, but unfortunately, gold mining is very marginal in terms of profit. We are not going to spend too much money on new technology, unless we can see a very good return. In that way, the barrier on the uptake of technology is more financial implications, we can get around with skills. What we are doing works; it does not make sense to change what is working."
>
> *Respondent 1, Employer Interview, Gold Mining, 2023*

Furthermore, the plans to adopt 4IR-related technologies according to company size has been analysed. The areas shaded in light green serve in the table below serve as a visual indicator of the top three 4IR technologies that will be adopted by organisations within the next 1 to 2 and 2 to 5 years according to the company size.

Table 6-3: Future Adoption of the 4IR Amongst Organisations by Company Size

	Small		Medium		Large	
	Within 1 -2	Within 2 - 5	Within 1 -2	Within 2 - 5	Within 1 -2	Within 2 - 5
Real-time information management systems	28 %	22 %	42 %	16 %	21 %	28 %
Big Data	27 %	11 %	16 %	42 %	18 %	31 %
Internet of Things (IoT)	27 %	23 %	25 %	34 %	22 %	27 %
Logistics Simulation	26 %	13 %	20 %	33 %	25 %	33 %
Artificial Intelligence (AI)	23 %	25 %	16 %	45 %	12 %	41 %
Augmented Reality (AR)	22 %	17 %	10 %	52 %	17 %	36 %
Enhanced wearable technology	22 %	24 %	23 %	40 %	23 %	26 %
3D printing	22 %	15 %	17 %	24 %	14 %	31 %
Advanced computer use	21 %	21 %	20 %	43 %	25 %	30 %
Cybersecurity	21 %	25 %	20 %	27 %	10 %	24 %
Blockchain	17 %	21 %	17 %	37 %	16 %	22 %
Remote-controlled mining equipment	15 %	22 %	20 %	30 %	10 %	34 %

	Small		Medium		Large	
	Within 1 -2	Within 2 - 5	Within 1 -2	Within 2 - 5	Within 1 -2	Within 2 - 5
Autonomous Driving Vehicles/Trucks	13%	17%	3%	27%	20%	27%
Unmanned Aerial Vehicles (UAV) technology	13%	13%	3%	20%	14%	22%
3D modelling and mapping	12%	18%	7%	33%	10%	34%
Automation & Robotics	11%	25%	6%	45%	11%	39%
Virtual Reality (VR)	11%	37%	17%	30%	18%	28%

Source: MQA Impact of 4IR Survey, *2023*

Within the next 1 to 2 years, small organisations appear to be planning to adopt real-time information systems (28%), big data (27%) and IoT (27%). Within the next 2 to 5 years, more medium sized organisations are likely to adopt additional technologies, compared to that of small and large organisations.

Similar to the above, the table below highlights the technologies that organisations within the MMS plan to adopt within the next 1 to 2 and 2 to 5 years according to sub-sector. The cells highlighted in light green in the table below signify the top three 4IR technologies that organisations are anticipated to adopt within the next 1 to 2 and 2 to 5 years.

Table 6-4: Adoption of the 4IR within 1-2 and 2-5 Years by Sub-Sector

	Coal Mining		Gold Mining		Diamond Mining		PGM Mining		CLAS Mining		Other Mining		Services Incide		Diamond Pro-		Jewellery Manu-	
	1 to 2	2 to 5	1 to	2 to	1 to 2	2 to 5	1 to 2	2 to 5	1 to 2	2 to 5	1 to 2	2 to 5	1 to 2	2 to 5	1 to 2	2 to 5	1 to 2	2 to 5
3D modelling and mapping	8%	42%	25%	13%	13%	25%	13%	25%	0%	17%	8%	35%	12%	31%	25%	0%	17%	0%
3D printing	28%	28%	25%	13%	31%	25%	31%	19%	9%	0%	8%	35%	16%	28%	0%	25%	25%	0%
Advanced computer use	36%	20%	22%	22%	25%	75%	25%	19%	23%	38%	22%	27%	15%	42%	0%	25%	20%	20%
Artificial Intelligence (AI)	13%	50%	22%	11%	31%	25%	31%	31%	23%	31%	11%	39%	19%	35%	0%	25%	25%	33%

	Coal Mining		Gold Mining		Diamond Mining		PGM Mining		CLAS Mining		Other Mining		Services Incide		Diamond Pro-		Jewellery Manu-	
	1 to 2	2 to 5	1 to	2 to	1 to 2	2 to 5	1 to 2	2 to 5	1 to 2	2 to 5	1 to 2	2 to 5	1 to 2	2 to 5	1 to 2	2 to 5	1 to 2	2 to 5
Augmented Reality (AR)	8%	46%	22%	11%	33%	25%	33%	27%	15%	23%	17%	36%	19%	35%	0%	25%	30%	20%
Automation & Robotics	4%	33%	25%	25%	20%	25%	20%	20%	8%	31%	8%	35%	12%	42%	0%	40%	11%	56%
Autonomous Driving Vehicles/Trucks	12%	36%	22%	0%	38%	25%	38%	31%	0%	33%	13%	18%	12%	15%	25%	25%	0%	22%
Big Data	26%	30%	13%	13%	25%	50%	25%	19%	0%	33%	24%	22%	20%	28%	20%	40%	36%	18%
Blockchain	25%	21%	13%	13%	21%	25%	21%	21%	0%	25%	16%	22%	24%	28%	20%	20%	0%	56%
Cybersecurity	21%	29%	25%	13%	25%	25%	25%	0%	17%	33%	13%	21%	15%	23%	0%	50%	11%	67%
Enhanced wearable technology	38%	42%	22%	22%	33%	25%	33%	20%	25%	8%	19%	30%	15%	31%	0%	25%	20%	30%
Internet of Things (IoT)	35%	27%	50%	25%	25%	75%	25%	6%	23%	38%	18%	26%	19%	23%	20%	40%	27%	36%
Logistics Simulation	32%	40%	25%	0%	56%	50%	56%	0%	0%	33%	25%	28%	8%	35%	25%	25%	30%	0%
Real-time information management systems	42%	17%	22%	11%	19%	50%	19%	13%	33%	33%	25%	22%	27%	31%	40%	60%	30%	10%
Remote-controlled mining equipment	25%	38%	22%	11%	13%	25%	13%	25%	8%	17%	5%	32%	19%	35%	0%	50%	20%	10%
Unmanned Aerial Vehicles (UAV) technology	17%	21%	13%	0%	25%	25%	25%	19%	8%	8%	5%	19%	4%	27%	25%	25%	20%	10%
Virtual Reality (VR)	13%	39%	22%	33%	25%	25%	25%	31%	8%	46%	18%	21%	16%	24%	0%	40%	9%	55%

Source: MQA Impact of 4IR Survey, *2023*

Within the next 1 to 2 years, real-time information management systems appear to be the 4IR technology most likely to be adopted across all sub-sectors. The growing popularity of real-time information management systems may be attributed to its ability to gather, record, and transmit data between underground and surface environments in real-time, or as needed, with the aim of enabling more informed decision-making, enhancing operational efficiency, and ensuring the safety of mining operations (Mandela Mining Precinct, 2023). Additionally, it is worth noting that the Diamond mining sub-sector organisations, which has currently not adopted any of the listed 4IR-technologies, has plans to adopt 4IR-related technologies within the next 1 to 2 years, the most notable being logistics simulation, autonomous driving vehicles, AR, and enhanced wearable technology.

Within the next 2 to 5 years, VR appears to be the 4IR technology most likely to be implemented across the sub-sectors. The use of VR, particularly in the use of training through simulators, has been noted by several stakeholders as an increasingly important form of technology within the MMS. VR is being used to train employees by exposing them to simulations of the working environment and the machinery being used. This allows employees to gain practical exposure before entering the real-world mining environment with the added advantage of operating in a safe environment.

> "Looking to also do Barring with virtual reality without exposing the people to the real danger. It's just a method which the people use to remove loose rocks from the hanging wall. It's a dangerous type of work that the people perform and there's always a possibility of a rock that can dislodge from the hanging wall and hit people on the head or injure them severely. And that is why we want to use virtual reality so that we can do this in the classroom with virtual reality units without exposing them to the real danger."
>
> *Respondent 12, Training Provider Interview, Other Mining, 2023*

> "… we are going to make use of the 360° virtual reality where we're going to teach people before they even enter the workplace in that dangerous mining environment, they will have already been exposed through the capability part that they've seen where they're going to work and on what machines and equipment they will be worked and trained on."
>
> *Respondent 5, Employer Interview, PGM Mining, 2023*

Inferential Analysis

Chi-Square tests, using a significance level of 0.05, reveal no significant relationship between the sub-sector in which an organisation operates and the planned adoption of 4IR-related technologies, implying that the adoption of 4IR technologies is unlikely to differ significantly per sub-sector.

6.2.1 Adoption of 4IR Technologies within the MMS Value Chain

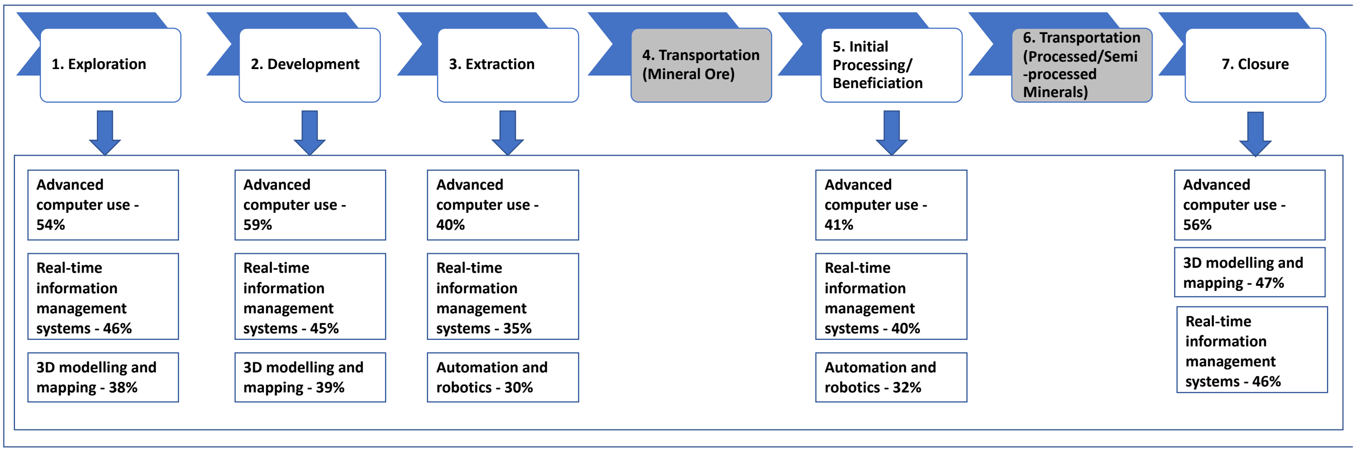
Key to understanding where developmental support may be required is to look at the specific phases within the MMS value chain to identify potential 4IR-related technologies that may be adopted and the changes that may occur in light of this. The following sections illustrate the likely adoption of 4IR technologies within the mineral extraction and beneficiation and manufacturing value chains.

6.2.1.1 Mineral Extraction

The process of mining involves various interconnected components that culminate in the supply of a specific mineral or product to the market (McKinsey & Company, 2020). This sequence of components, collectively known as the mineral extraction value chain, comprises several key phases including exploration, development, production (or mineral extraction), processing, beneficiation, transportation, and rehabilitation. This value chain is applicable to sub-sectors including gold, coal, diamond, PGM, CLAS and Other mining, as well as, in some instances, Services incidental to mining.

The following figure outlines the top three 4IR-related technologies that are likely to be adopted within each phase of the mineral extraction value chain. Blocks highlighted in grey represent those areas in which the adoption of 4IR technologies was anticipated to be limited due the nature of activities within these areas, for example, activities within the Transportation phase are unlikely to undergo automation as this includes the transportation of mineral ore from the mine site to a processing and manufacturing plant using trucks that are not susceptible to automation (Bhoopalam et al,2023).

Figure 6-5: Adoption of the 4IR in the Mineral Extraction Value Chain



Source: MQA Impact of 4IR Survey, 2023

As seen in the above figure, advanced computer use and real-time information systems may see adoption across all phases of the value chain. This is followed by the adoption of 3D modelling and mapping in the exploration, mine development and mine closure phases. Automation and robotics will likely see adoption within the Extraction and Initial Processing/ Beneficiation phases.

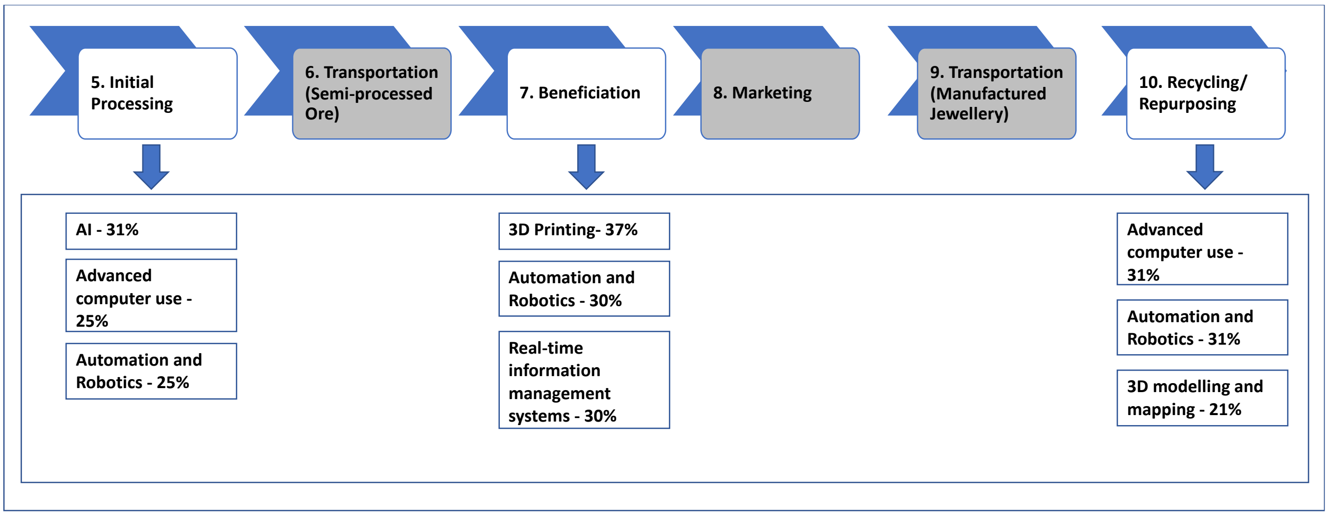
In addition to the technologies that are likely to be adopted within each phase of the mineral extraction value chain, the current adoption of 4IR-technologies within the value chain includes technologies such as AI, automation, and big data in the production processes within the mineral extraction value chain, allowing mining companies to mitigate rising operating costs as well as increase productivity (Mungadze, 2021).

6.2.1.2 Beneficiation and Manufacturing

The beneficiation value chain involves various interconnected components that culminate in the production of manufactured jewellery to the market, including finished diamond. The value chain comprises several key phases including transportation, beneficiation, marketing, and recycling and repurposing. The value chain is applicable to the diamond processing and jewellery manufacturing sub-sectors, as well as the services incidental to these sub-sectors. The activities conducted within this value chain are external to mining operations.

The following figure outlines the top three 4IR-related technologies that are likely to be adopted within each phase of the beneficiation and manufacturing value chain. Blocks highlighted in grey represent those areas in which the adoption of 4IR technologies was anticipated to be limited due the nature of activities within these areas, for example, the Marketing phase, which comprise of activities that may not be susceptible to automation or fall outside the scope of the MQA such as promoting and selling jewellery products and services to potential customers.

Figure 6-6: Adoption of the 4IR in the Beneficiation and Manufacturing Value Chain



Source: MQA Impact of 4IR Survey, 2023

As seen in the figure above, automation and robotics may be adopted across all phases assessed within the beneficiation and manufacturing value chain. This is followed by advanced computer use within the Initial Processing and Recycling/ Repurposing Phases.

Key Findings

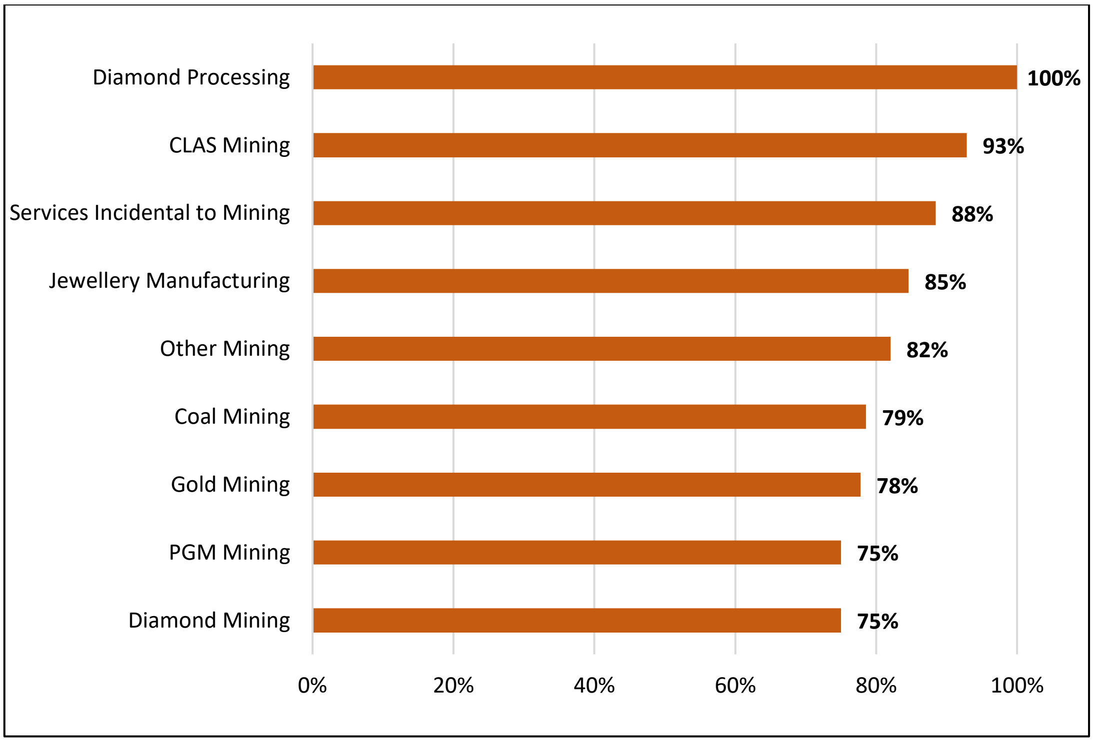
- The top three technologies organisations plan to adopt within the next 1 to 2 years include real-time information systems, advanced computer use, and IoT. Within the next 2 to 5 years, the top three technologies that will be adopted include advanced computer use, AI as well as 3D modelling and mapping and automation and robotics.
- Within the next 1 to 2 years, small organisations appear to be planning to adopt more 4IR-related technologies compared to that of medium and large organisations, whilst more medium sized organisations are likely to adopt 4IR-related technologies, compared to that of small and large organisations within the next 2 to 5 years. This may be a result of medium and large sized organisations already having implemented more 4IR-related technologies compared to that of small organisations.

6.3 Limitation to the Adoption of 4IR-Related Technologies

In order to assist organisations adopt 4IR-related technologies, it is important to understand the challenges that organisations are currently facing and how these challenges may be overcome. This section, therefore, outlines the factors that are limiting the adoption of 4IR-related technologies and highlights some of the support that organisations think will be required in order to adopt 4IR-related technologies.

The following illustrates the extent to which organisations within the MMS agree that the adoption of the 4IR is being limited by a lack of skills within the industry. These results have been presented per sub-sector to allow for focused follow up interventions.

Figure 6-7: Extent to Which the 4IR Adoption is Being Limited by a Lack of Skills per Sub-Sector



Source: MQA Impact of 4IR Survey, 2023

As illustrated in the figure above, 100% of respondents representing the Diamond Processing sub-sector agree that the adoption of the 4IR is being limited by the lack of relevant skills. This is followed closely by CLAS mining (93%), Services Incidental to Mining (88%), Jewellery Manufacturing (85%), and Other mining (82%).

Interviews with stakeholders in the Jewellery Manufacturing sub-sector revealed a lack of opportunities for people to gain the necessary skills, such as jewellery design related skills and qualifications, often having to study abroad to receive workplace exposure and qualifications.

> "I think so, yes. Some of the jewellery designers went overseas to get their qualifications abroad and then they got their exposure and training abroad as well."
>
> *Respondent 3, Training Provider Interview, Jewellery Manufacturing, 2023*

In addition to the lack of training and workplace exposure, i.e., opportunities for learners undergoing training to gain practical experience and training/ on the job learning, a lack of basic skills, such as reading and writing, in the sector has been highlighted as a key challenge hindering the adoption of technology. It was noted that this is due to 4IR-related technologies requiring a higher level of skills compared to traditional mining.

> "A lot of technology requires you to know how to read and write in English. Most employees in the mine are old people, they didn't go to school. That is why we implemented a programme to assist employees in the gap of reading and writing English. I think that is where the gap is."
>
> *Respondent 3, Employer Interview, Gold Mining, 2023*

Inferential Analysis

Chi-Square tests, using a significance level of 0.05, reveal no significant relationship between the size of the organisation and the extent to which the adoption of 4IR is being limited by a lack relevant skills nor between the sub-sector and the extent to which 4IR is being limited by a lack of relevant skills, implying a certain shortage of relevant skills across the market.

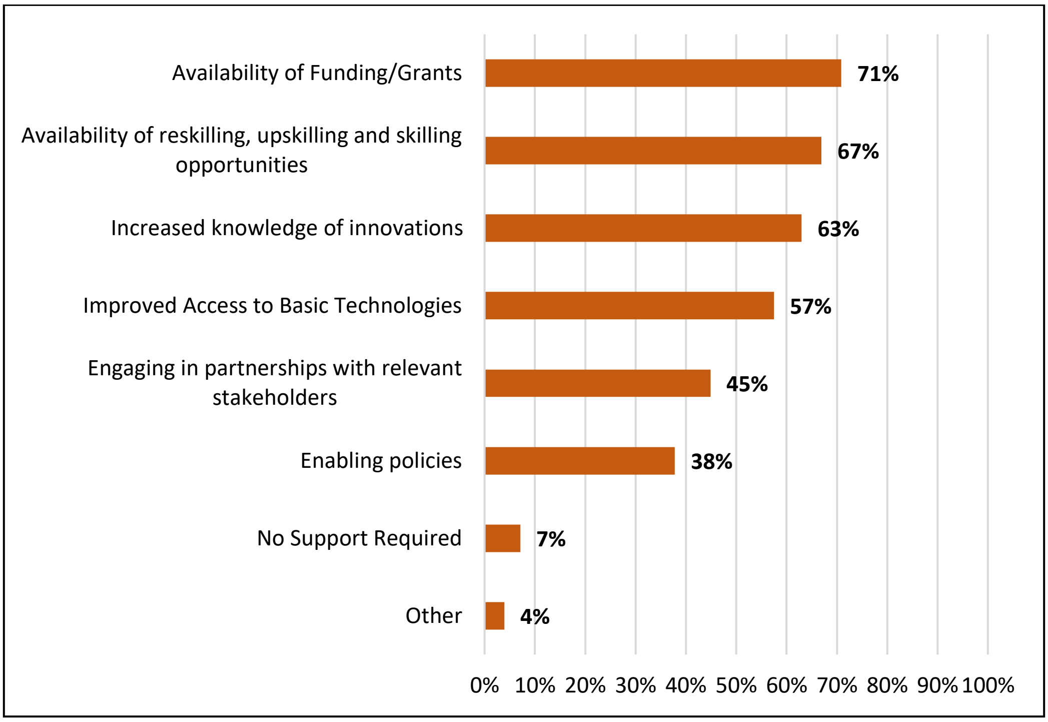
Key Finding

The majority of respondents agree that the adoption of the 4IR is being limited by a lack of relevant skills within the sector, particularly within the Diamond Processing and CLAS mining sub-sectors. It was noted that there appears to be lack of training and workplace opportunities for people to gain the necessary skills, often having to study abroad to receive training and qualifications. Furthermore, a lack of basic skills, such as reading and writing, was highlighted as a key challenge for organisations.

6.4 Support Required by Organisations to Adopt 4IR-related Technologies

The figure below details the support that organisations within the MMS believe they will require now or in the next 5 years in order to be able to adopt 4IR innovations.

Figure 6-8: Support Needed by Organisations to Adopt 4IR-related Technologies[24]



Source: MQA Impact of 4IR Survey, 2023

As noted above, the majority of stakeholders (71%) flagged the availability of funding/grants as a key form of support required, while 67% of stakeholders noted that skilling, reskilling, and upskilling opportunities are required and have been identified as crucial as they empower the workforce to harness new technologies effectively. The provision of relevant skilling, reskilling and upskilling opportunities as a form of support would relate to ensuring that the necessary training is available and accessible that will assist in providing the new skills required by employees as a result of the 4IR. For example, this may include the provision of skills such as Digital skills which may be incorporated into training programmes by introducing basic and advanced level computer courses as a requirement for the completion of a mining-related qualifications, which may be driven by the MQA.

Engaging in partnerships with relevant stakeholders, such as larger organisations in the sector, QCTO and training providers (45%) is another area that was identified by stakeholders. It was noted in particular that partnerships with OEMs (e.g., Osborn Engineered Products, a mining and quarrying equipment manufacturer), who are key to the development and transfer of skills to mining organisations and workers, were key.

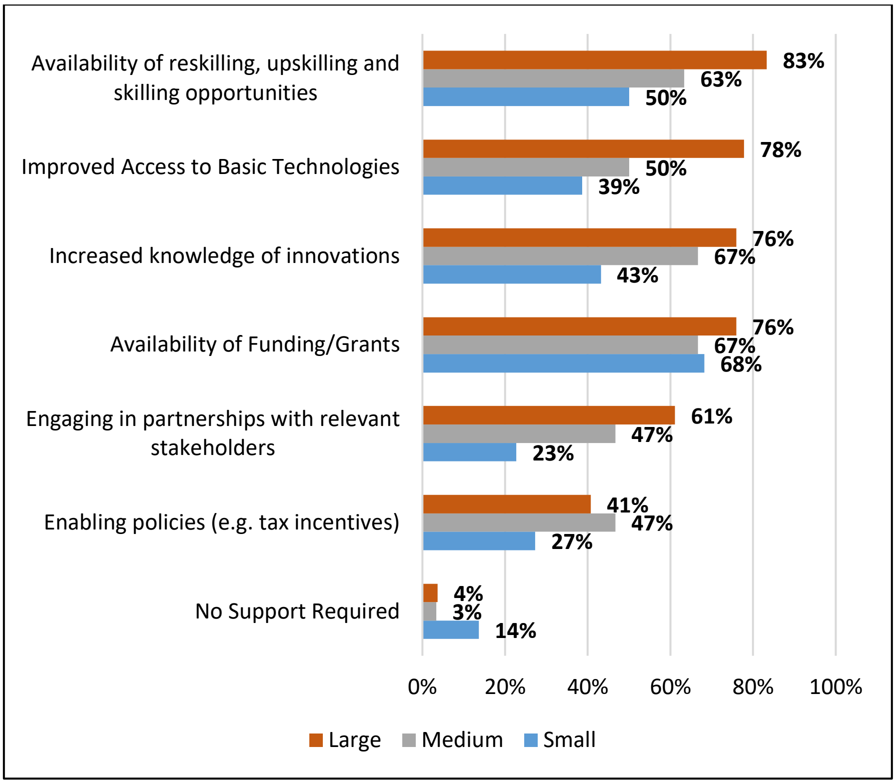
[24] Respondents were allowed to select multiple options according to what was most relevant. Each category is to be assessed separately and totals may not add up to 100%

"...we are doing the transfer of skills through the OEMs. The OEMs are the start of the whole process. Where they are supplying us with the machine, they will do the transfer of skills towards our own trainers which are registered assessors at MQA."

Respondent 5, Employer Interview, PGM Mining, 2023

In addition to the above, the graph below provides further analysis in terms of the support organisations require, per organisation size.

Figure 6-9: Support Needed by Organisations to Adopt 4IR-related Technologies by Company Size[25]



Source: MQA Impact of 4IR Survey, 2023

From the figure above, the topmost form of support required by large organisations is the availability of reskilling, upskilling and skilling opportunities (83%). Stakeholders noted that more in-depth practical training will be needed to support their employees in the transition to the 4IR.

"The sector must support employees through training, not theoretical training, but how to operate machines... They must know where to look when a machine fails, how to rectify that problem, not just to operate the machine."

Respondent 14, Employer Interview, Coal Mining, 2023

[25] Stakeholders were allowed to select multiple options. Each category is to be assessed separately and the maximum achievable percentage for each category is 100%.

Additionally, the topmost form of support required by small and medium sized organisations is the availability of funding/ grants (68% and 67%, respectively) as well as increased knowledge of innovations (67%) for medium sized organisations. The increased knowledge of innovations as a form of support refers to enhancing the knowledge of organisations regarding available technologies, the potential of the adoption of 4IR-related technologies within the MMS and the opportunities available to them should they adopt 4IR-related technologies. Stakeholders noted that the MQA may consider implementing a strategy whereby they fund a few companies to implement technology and in return these organisations should then assist with training and creating awareness of the 4IR within the sector.

"I think going forward the MQA will have to come to the party with grants and bursaries. I think with discretionary grants, instead of saying they give it to Health and Safety, they should give the grants to 2 or 3 companies and get them going, because once we get them going, they can assist other companies. Let's get this technology on a very small scale, let's show them what the future looks like, and they can spread the word gradually and slowly, and host workshops. They have been funded for that, not for their own good, but for the good of the industry. At this stage, they must look at their bursary and grant structure."

Respondent 33, Employer Interview, Diamond Processing, 2023

Key Findings

- The main forms of support required by all organisations to adopt 4IR-related technologies include additional funding and grants, availability of reskilling upskilling and skilling/ training opportunities and an increased knowledge of innovations.
- Partnerships and engagement with OEM's have been highlighted as key to the development of 4IR-related skills within MMS organisations.

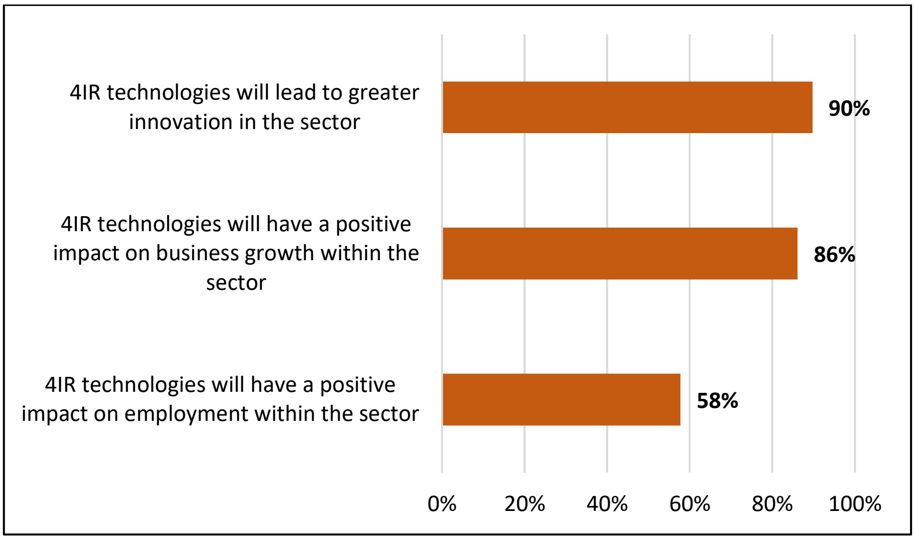
7 Impact of the 4IR on the MMS

A key consideration when conducting research on the 4IR is to understand the potential impact that the 4IR may have, particularly in terms of the impact on occupations and skills in a sector. This section, therefore, outlines the anticipated nature of the impact of the 4IR on the MMS, based on input provided by stakeholders, including impact on macroeconomic areas, impact of the 4IR on the nature of work, including occupational structures, and the impact on skills.

7.1 Impact of the 4IR on Macroeconomic Areas

Key to understanding the nature of the impact of the 4IR on the MMS is the assessment of the impact on macroeconomic areas within the sector. As such, this study sought to assess and determine the impact of the 4IR on as areas such as innovation, business growth and employment, within the sector. Figure 7-1 below outlines the results.

Figure 7-1: Impact of the 4IR on Mining and Minerals Sub-sectors[26]



Source: MQA Impact of 4IR Survey, 2023

As can be seen above, the majority of stakeholders agreed that the adoption of 4IR-related technologies may result in greater innovation (with 90% of stakeholders indicating this) and may have a positive impact on business growth (86%). A review of literature indicated that the adoption of the various technological advancements and the accompanying enhanced modernisation are further acknowledged as direct contributors to long-term competitive advantages as these assist mining companies reduce costs, minimise environmental impact, boost production and enhance mineral recovery (Mining Technology, 2023). These sentiments were echoed by stakeholders during interviews, where it was noted that 4IR-related technologies provide

[26] Stakeholders were allowed to select multiple options. Each statement is to be assessed separately and the maximum achievable percentage for each statement is 100%

organisations with an opportunity to enhance their operations and increase business growth.

> "As far as adopting 4IR is concerned, it is good and gives a competitive advantage, it gives an opportunity to scale up business. If what used to take 1 person 2 days to complete can now take 2 hours, you are able to scale up business and compete in the market and also reduce costs."
>
> *Respondent 20, Employer Interview, Diamond Processing, 2023*

It was noted that the integration of advanced technologies may lead to some processes being streamlined, resulting in more efficient operations, reduced time expenditures, and increasing overall productivity.

> "Technology is not all bad, it is more efficient, something that will take us 3 months can take us 2 weeks. That will allow us to do multiple projects at the same time..."
>
> *Respondent 24, Employer Interview, Services Incidental to Mining, 2023*

Furthermore, it was noted that the implementation of 4IR-related technologies may result in cost savings for organisations in the mining sector in the long term, thus contributing to business growth, despite requiring substantive investment initially.

> "From a business perspective, the input cost will definitely be much higher when implementing 4IR, but in the long run companies will make hefty profit..."
>
> *Respondent 11, Employer Interview, Coal Mining, 2023*

> "You're going to have a much-streamlined system and it's going to be more expensive in the beginning, but your cost, operational cost will be decreased to an extent."
>
> *Respondent 19, Employer Interview, Diamond Processing, 2023*

In addition to the above, stakeholders noted some further positive impacts of the 4IR, such as the potential health and safety benefits for employees of mining organisations. PWC found that the implementation of 4IR-related technologies may result in improved safety and working conditions as well as lead to mining operations being conducted in safer environments. Stakeholders echoed these sentiments, noting that the incorporation of smart technologies and automation may play a pivotal role in elevating and improving safety standards on the mines by minimising human exposure to hazardous environments and optimising risk management protocols.

> "…machines will significantly reduce many of the health and safety concerns currently present, leading to fewer losses in terms of life and incidents…"
>
> *Respondent 2, Labour/Union Representative Interview, 2023*

Fewer stakeholders (58%) within the MMS were of the view that the 4IR will have a positive impact on employment within the sector. This was also highlighted through a review of existing literature, which indicated that the implementation of the 4IR is anticipated to have a significant impact on the MMS workforce, both in terms of employment as well as skills development. The use of 4IR-related technologies such as automation and robotics, as an example, may potentially lead to job losses if repetitive and manual tasks become automated (PwC, 2023). This was further highlighted through interviews, where stakeholders were of the view that new technologies may potentially replace the human workforce within mining organisations, where one machine can perform the tasks of multiple employees, thus creating a fear of potential job losses.

> "…there will be a lot of negatives as too many people will lose their jobs. What used to take 10 people to do, like digging can be accomplished by 1 operator using machines."
>
> *Respondent 11, Employer Interview, Coal Mining, 2023*

> "We also know that job losses will take place, but we will need to get in more people with new skills suited for modern mines. Most of the people will end up losing jobs. I think that is currently the fear around our organisation, that if we transform fully, then people will lose their jobs."
>
> *Respondent 6, Employer Interview, PGM Mining, 2023*

While the fear of job losses was a key point highlighted, stakeholders also noted that the adoption of 4IR-related technologies presented employees with the opportunity to upskill and/or reskill themselves, which may assist with countering the potential job losses.

> "We know that 4IR might create job losses, but I think there is also room for growth opportunities as well if we continuously upskill employees as technology improves."
>
> *Respondent 24, Employer Interview, Services Incidental to Mining, 2023*

Key Finding

Stakeholders were of the view that the 4IR and the adoption of 4IR-related technologies presents several potential benefits to organisations within the MMS, including business growth, improved competitive advantage, cost savings, improved efficiency and improved safety standards. It was found, however, that there were concerns that the adoption of 4IR-related technologies and the automation of activities may potentially result in job losses for the mining sector.

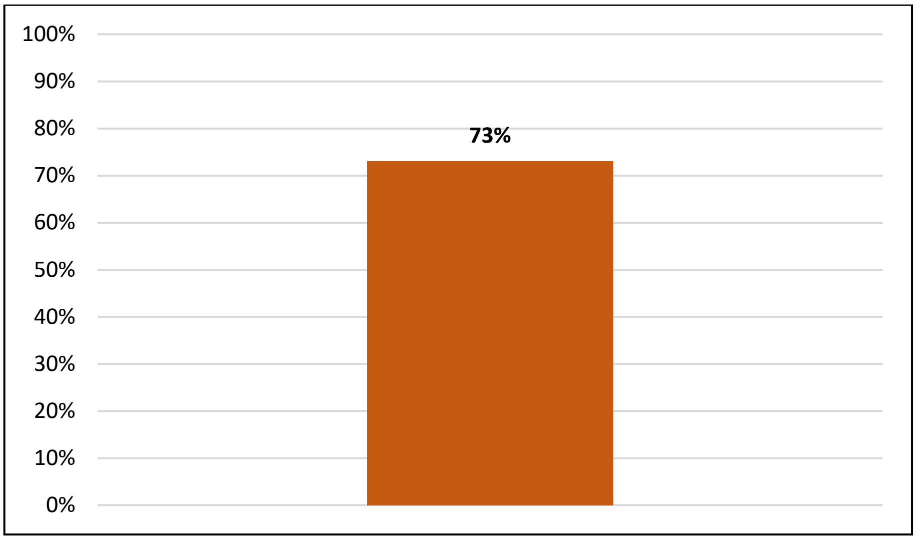
7.2 Impact of Emerging Technologies on Occupations and Skills within the MMS

This section outlines the impact of emerging and 4IR-related technologies on occupations and skills in the MMS. In particular, the section explores the changing nature of work within the MMS, including jobs that may potentially emerge or become redundant as a result of the adoption of 4IR technologies. The section further explores the 4IR skills landscape, with a focus on the changing nature of skills in the sector, the skills that may either emerge or become redundant as well as the occupational levels most likely to be impacted by 4IR technologies. Lastly, the sections outlines the key workforce changes arising from the adoption of 4IR technologies, including possible retrenchments within the sector, the extent to which employees will require upskilling/reskilling and whether there is an increase in demand for new employees.

7.2.1 Changes to the Nature of Work in the MMS as a Result of the 4IR

In order to understand how emerging technologies and the 4IR are reshaping job roles and skills demands within the MMS, an assessment of the extent to which the nature of work was changing was conducted. The figure below illustrates these findings.

Figure 7-2: Extent to which the Nature of Work has Changed as a result of the 4IR



Source: MQA Impact of 4IR Survey, 2023

As can be seen above, overall 73% of stakeholders surveyed agreed that the nature of work within their organisations has changed as a result of the adoption of 4IR-related technologies. Stakeholders were of the view that the greatest shift in the nature of work relates to the transition from performing tasks manually within the mines, such as the driving of haulage trucks, to operating the software and related computers that control the new technologies implemented to perform the same tasks.

> "Yes, an autonomous vehicle needs a person at the other end to [operate] it still. So, it is not like it can do its own thing yet. There is still a person sitting behind a laptop or whatever screen driving the machine. I think at the end of the day, the man that drives that vehicle physically, you are going to have to teach him to be electronically minded sitting behind the screen. You might not have to cut down too many jobs."
>
> *Respondent 2, Employer Interview, Gold Mining, 2023*

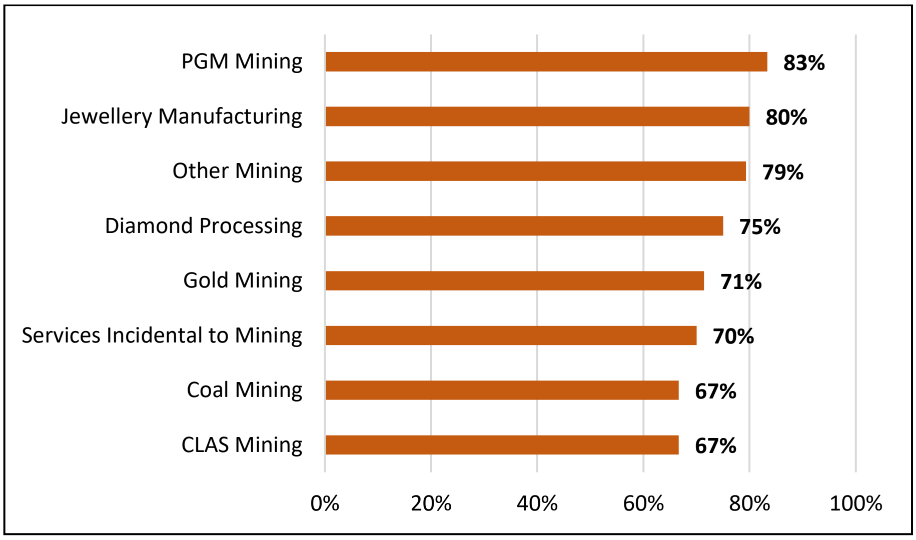
> "We do exploration studies in our organisation before we can tender for construction of a plant. I foresee the mine having technology to do the studies that we do in future."
>
> *Respondent 24, Employer Interview, Services Incidental to Mining, 2023*

In addition, it was found that the adoption of 4IR technologies has enabled organisations to conduct predictive maintenance on their machinery through, for example, the installation of technology that allowed the organisations to identify and diagnose potential problems with systems before they occur, thus ensuring that there are no delays in operations.

> "We have installed cameras to help with surveillance and monitoring plant performance indicators. Previously [we used to do] feedback control after a disturbance [was identified], but now we try to do feedforward control with camera systems. We also installed online analysers. Now we do real time analysis."
>
> *Respondent 31, Employer Interview, Services Incidental to Mining, 2023*

Further analysis was conducted to determine the sub-sector in which the greatest proportion of stakeholders had observed a change in the nature of work. This is illustrated in the figure below.

Figure 7-3: Extent to which the Nature of Work has Changed as a result of the 4IR, per Sub-sector



Source: MQA Impact of 4IR Survey, 2023

As can be seen above, some of the top sub-sectors in which stakeholders observed a change in the nature of work are PGM mining (indicated by 83% of stakeholders), Jewellery Manufacturing (80%) and Other mining (79%).

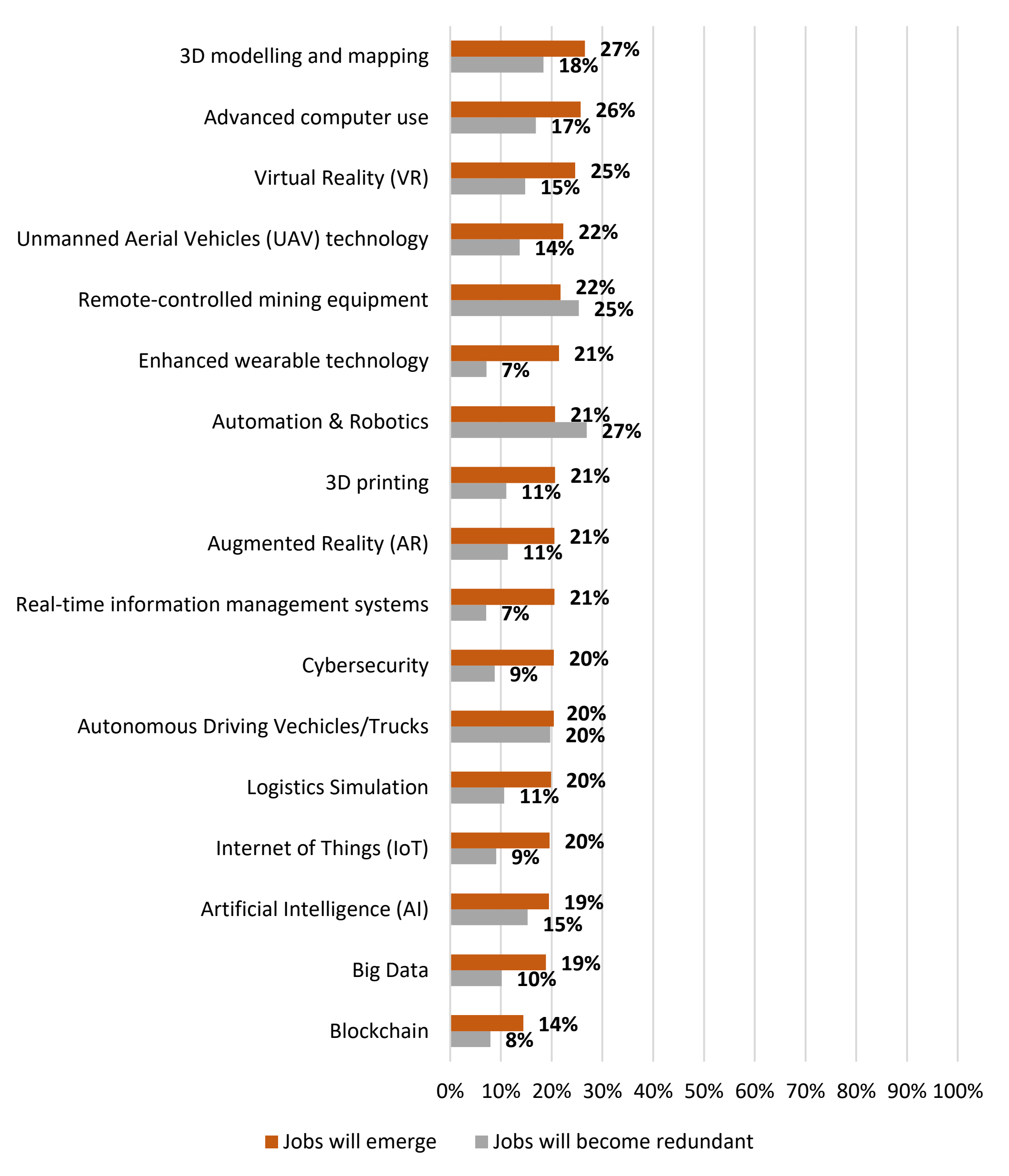
Key Finding

It was found that the majority of stakeholders observed a change in the nature of work as a result of the adoption of 4IR-related technologies with stakeholders highlighting that the key change related to the shift from performing tasks manually to operating the software controlling the technologies implemented to perform the same task.

7.2.2 Occupational Changes as a Result of the 4IR

In addition to impacting the nature of work, the 4IR is anticipated to have implications on the occupational landscape, creating the potential for new occupations to emerge while also causing some occupations to become redundant. Furthermore, the 4IR has the potential to impact the demand for some occupations over the next 5 years. The figure below outlines the extent to which respondents agreed that the various 4IR-related technologies will result in jobs becoming redundant or jobs emerging.

Figure 7-4: Occupational Changes as a Result of the 4IR



Source: MQA Impact of 4IR Survey, 2023

As seen in the graph above, the top technologies for which jobs are anticipated to emerge are 3D modelling and mapping (with 27% of stakeholders indicated this), advanced computer use (26%), and VR (25%). Some of the other occupations that the stakeholders highlighted as potentially emerging, through employer interviews, include IT related occupations, which may include IT managers, web developers, network and systems administrators and software engineers.

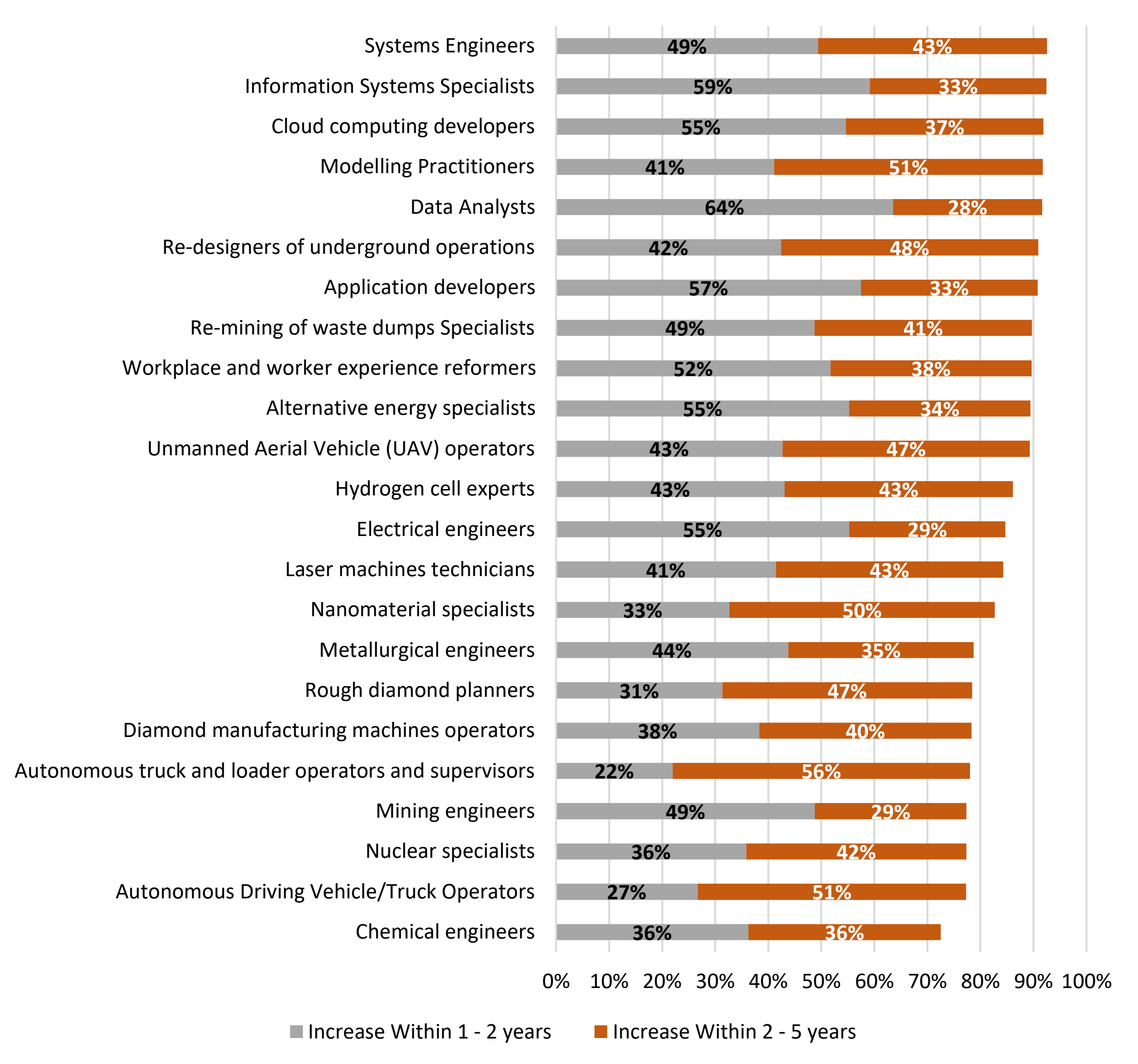
> "The first one [that will emerge] is a broader technical and IT scope, definitely that will grow."
>
> *Respondent 10, Employer Interview, Coal Mining, 2023*

Contrastingly, the top technologies which are anticipated to result in jobs becoming redundant include automation and robotics (27%), remote controlled mining equipment (25%), and autonomous driving vehicles/trucks (20%). Stakeholders were of the view that with the implementation of technologies such as remote-controlled equipment, jobs would become redundant as fewer people would be required to operate the equipment than would have previously been required to do the same task.

> “For remote controlled machines especially, labour will have to be replaced as only one person is required to use the remote, that is a downside to 4IR unfortunately.”
>
> *Respondent 11, Employer Interview, Coal Mining, 2023*

Given the changing nature of work within the MMS, the study further sought to determine whether demand for specific occupations would increase within the MMS within the next 5 years. The figure below illustrates the findings.

Figure 7-5: Occupations for which Demand is Anticipated to Increase[27]



Source: MQA Impact of 4IR Survey, 2023

As can be seen, the top three occupations for which demand is anticipated to increase in the next 1 to 2 years include data analysts (with 64% of employers noting this), information systems specialists (59%) and application developers (57%). These findings are consistent with literature, where data management was identified as being key for organisations to make informed and data-driven decisions, underscoring the demand for individuals in data and/or systems related roles. This necessity arises from heightened challenges faced by mining organisations as a result of the vast amounts of data generated daily, compelling the organisation to devise strategies for handling these substantial volumes of data and information. This was further supported by the

[27] The results presented in this graph focus on two views out of three. The remaining percentage (not illustrated in the graph) illustrates those respondents who indicated that there won't be an increase in demand for a specific occupation. The percentages in the graph therefore will not amount to 100%.

sentiments emerging from qualitative data, with several employers noting increased demand for data analysts and systems specialists.

> "The others we have seen coming up is this data analyst because with automation or 4IR there's a lot of data that comes around. We've seen a trend in the industry of mining houses creating positions, so-called data analysts."
>
> *Respondent 1, Employer Affiliation Body Interview, 2023*

Beyond the occupations noted in the figure above, an increase in demand is also expected for workplace and worker experience reformers (i.e., change management specialists), due to their potential role in guiding organisations and their employees through the significant transition that will be brought about by the 4IR, including the implementation of new systems, technologies and processes.

> "There will be some form of resistance [to the adoption of 4IR-related technologies] that will have to be addressed [by] change management [specialists] because the employees need to be reassured that it would be for the better."
>
> *Respondent 18, Employer Interview, Diamond Mining, 2023*

Within the next 2 to 5 years, it was noted that demand may increase for "machine operator" occupations, including autonomous truck and loader and supervisors (with 56% of stakeholders indicating this) and autonomous driving vehicle operators (51%). Furthermore, demand is anticipated to increase for modelling practitioners (51%). In the medium-term, focus should, thus be placed on developing individuals to fill these occupations.

In addition, stakeholders noted a potential increase in the demand for alternative energy specialists, such as specialists in hydrogen powered trucks. This is as a result of recent developments within the mining sector where traditional diesel powered trucks are being replaced by those powered by hydrogen, an example being Anglo American's (2023) nuGen™ Zero Emissions Haulage Solution, which uses hydrogen to power heavy duty transport within their mine, thus lessening carbon emissions caused by diesel operated trucks.

> "Probably in the future, we may need some people called hydrogen technicians. Like we've got a diesel mechanic, maybe we might in future need a "hydrogen mechanic". I'm putting it in inverted commas because we haven't landed on the names of the occupations..."
>
> *Respondent 1, Employer Affiliation Body Interview, 2023*

Key Finding

The top 3 occupations highlighted as potentially increasing in demand within the MMS in the next 1 to 2 years include data analysts, information systems specialists and application developers, while those anticipated to increase in demand in the next 2 to 5 years include truck and loader operators and supervisors, autonomous vehicle operators and modelling practitioners.

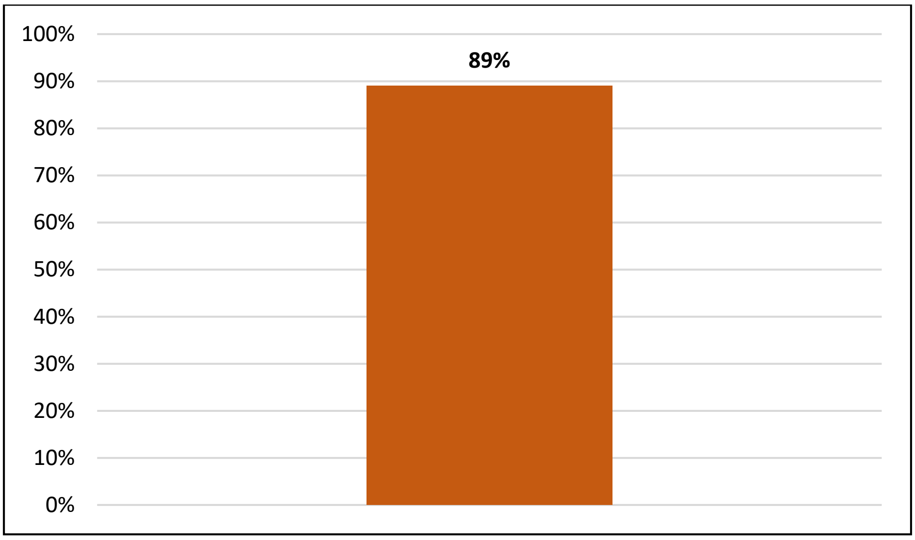
7.3 The 4IR Skills Landscape within the MMS

Similar to the impact that 4IR-related technologies will have on occupations, the technologies are expected to also have an impact on the skills within the sector. This includes understanding the extent to which the nature of skills are anticipated to change, the impact of the 4IR on skills needs in terms of skills for which importance is expected to increase and the occupational levels at which the 4IR is likely to have the greatest impact.

7.3.1 Changes to the Nature of Skills in the MMS

A shift in the nature of work, driven by technological advancements, necessitates a change in the skillsets among workforces. This was confirmed through the employer survey, during which stakeholders were requested to indicate the extent to which they believed 4IR-related technologies had resulted in a change in skills required by mining sector workforces. The results are illustrated below.

Figure 7-6: Extent to which the 4IR has Changed the Nature of Skills



Source: MQA Impact of 4IR Survey, 2023

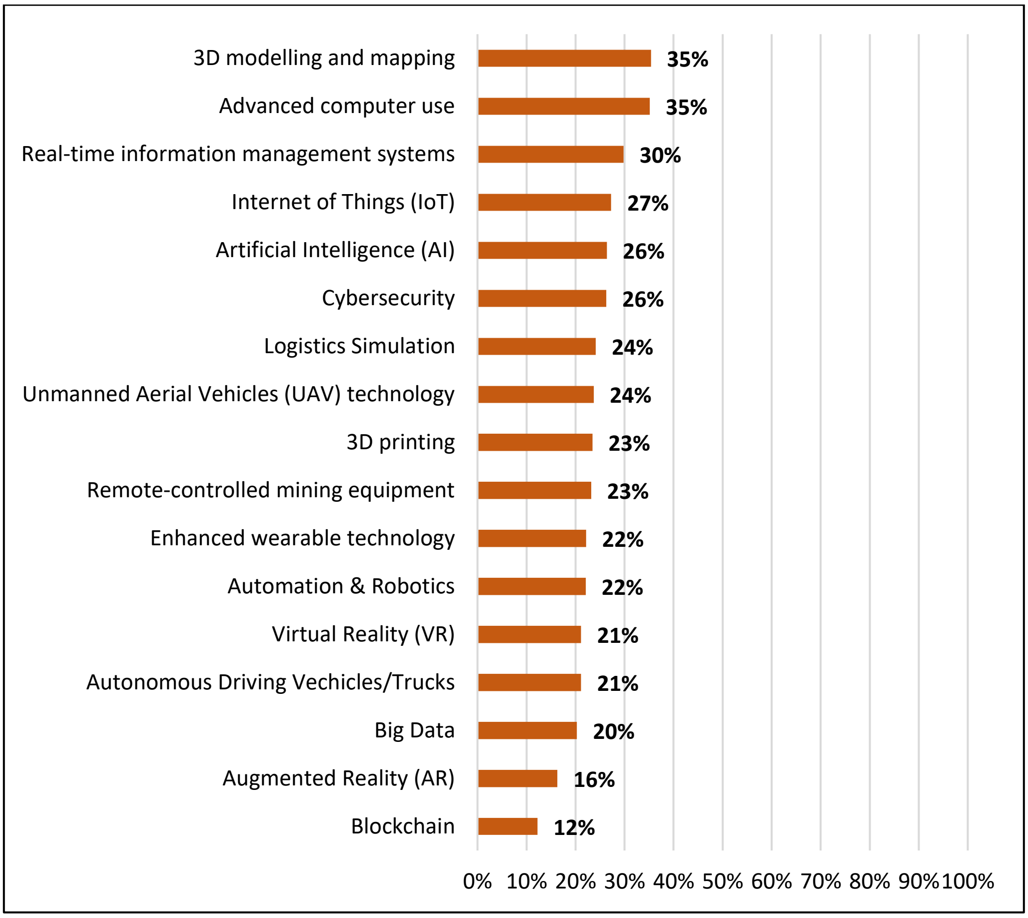
As can be seen above, 89% of stakeholders agreed that the adoption of 4IR-related technologies had resulted in a change in the nature of skills required within their organisations. This change in the nature of skills is most likely due to tasks previously done manually now requiring proficiency in new competencies such as digital tools, data analysis, adaptability to evolving technologies, and problem-solving abilities, which represent some of the major skillsets needed to thrive in a digitally-driven workforce (as discussed in Section 7.3.3).

Inferential Analysis

Chi-Square tests, using a significance level of 0.05, reveal a relationship between the change in the nature of skills required by organisations and the need for employees to be upskilled/reskilled, implying that employees may require reskilling/upskilling as a result of the changes in the nature of skills occurring due to the adoption of 4IR-related technologies.

The various 4IR-related technologies, and their adoption within the MMS, are key in driving the change in the nature of skills and skills requirements. Therefore, in addition to understanding the extent to which the nature of skills is anticipated to change at an overall level, it is also important to understand the extent to which the nature of skills is anticipated to change as a result of individual technologies. The figure below outlines the results.

Figure 7-7: 4IR-related technologies which will Impact Nature of Skills Required[28]



Source: MQA Impact of 4IR Survey, 2023

It can be noted above that the greatest proportion of stakeholders agreed that the nature of skills will change as a result of the implementation of advanced computer use and 3D modelling and mapping (35% each), real time information management systems (30%), the Internet of Things ("IoT") (27%) and AI (26%).

[28] Respondents were allowed to select multiple options according to what was most relevant. Each category is to be assessed separately and totals may not add up to 100%

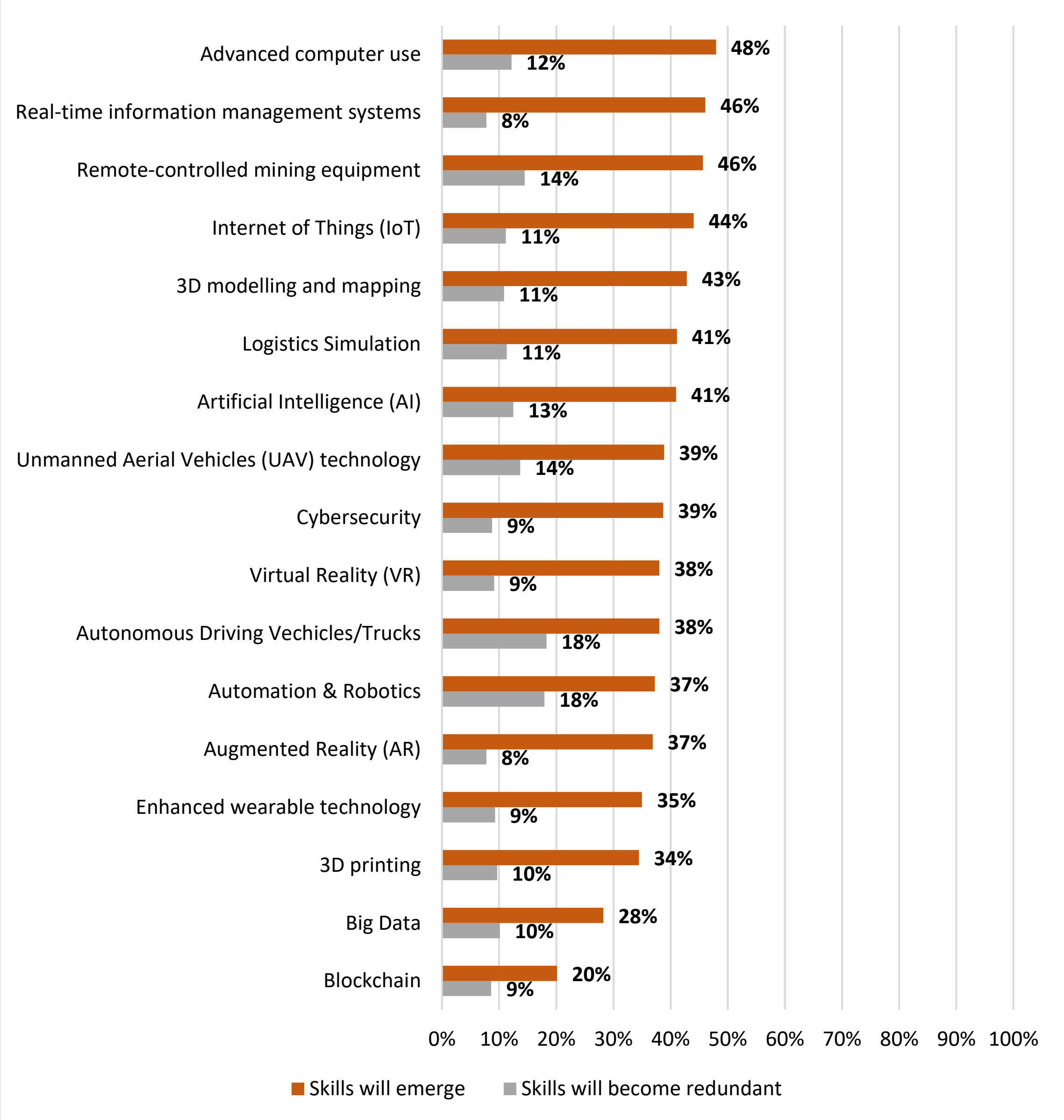
Key Finding

Overall, the majority of stakeholders (89%) were of the view that the adoption of 4IR-related technologies had changed the nature of skills within the MMS. A major contributor to the change is the transition from manual operations to workforces monitoring computers, thus requiring new skillsets. Some of the 4IR-related technologies for which the nature of skills will change include 3D modelling and mapping, real time information management systems, IoT and AI.

7.3.2 Impact of 4IR on Skills

As previously highlighted, the adoption of 4IR-related technologies is anticipated to result in either new skills either emerging, or some skills becoming redundant. The figure below illustrates whether skills are anticipated to emerge or become redundant as a result of various 4IR-related technologies.

Figure 7-8: Impact of 4IR-related Technologies on Skills[29]



Source: MQA Impact of 4IR Survey, 2023

It can be noted from the above that a greater proportion of stakeholders appear to be of the view that skills will emerge as a result of the adoption of 4IR technologies, as opposed to skills becoming redundant. In particular, it was found that the top technologies for which skills will emerge include advanced computer use and real time information management systems, as indicated by 48% and 46% of stakeholders, respectively. An example of a core skill required for advanced computer use and real-time information systems that is emerging is data analysis.

[29] Respondents were allowed to select multiple options according to what was most relevant. Each category is to be assessed separately and totals may not add up to 100%

> "I think at the moment what is becoming a huge need is data, specifically data analysis in the data space, which speaks to automation of equipment that we are currently using, which touches base on 4IR. In terms of skills and know how, that we can teach. In terms of using the data or updating our Risk Assessments and Controls, because introduction of automated machinery requires the introduction of things such as Geo Fencing, so there is a gap at the moment."
>
> *Respondent 15, Employer Interview, Coal Mining, 2023*

Similar findings were noted during a review of the literature, where it was highlighted that digital tools can provide real-time data and analytics on various aspects of mining operations, such as ore quality in the exploration phase, equipment performance during the extraction and processing phases, and energy consumption throughout the mining value chain (McKinsey & Company, 2015). Other top technologies for which new skills were anticipated to emerge, as indicated by 46% and 44% of stakeholders respectively, include remote controlled mining equipment and IoT.

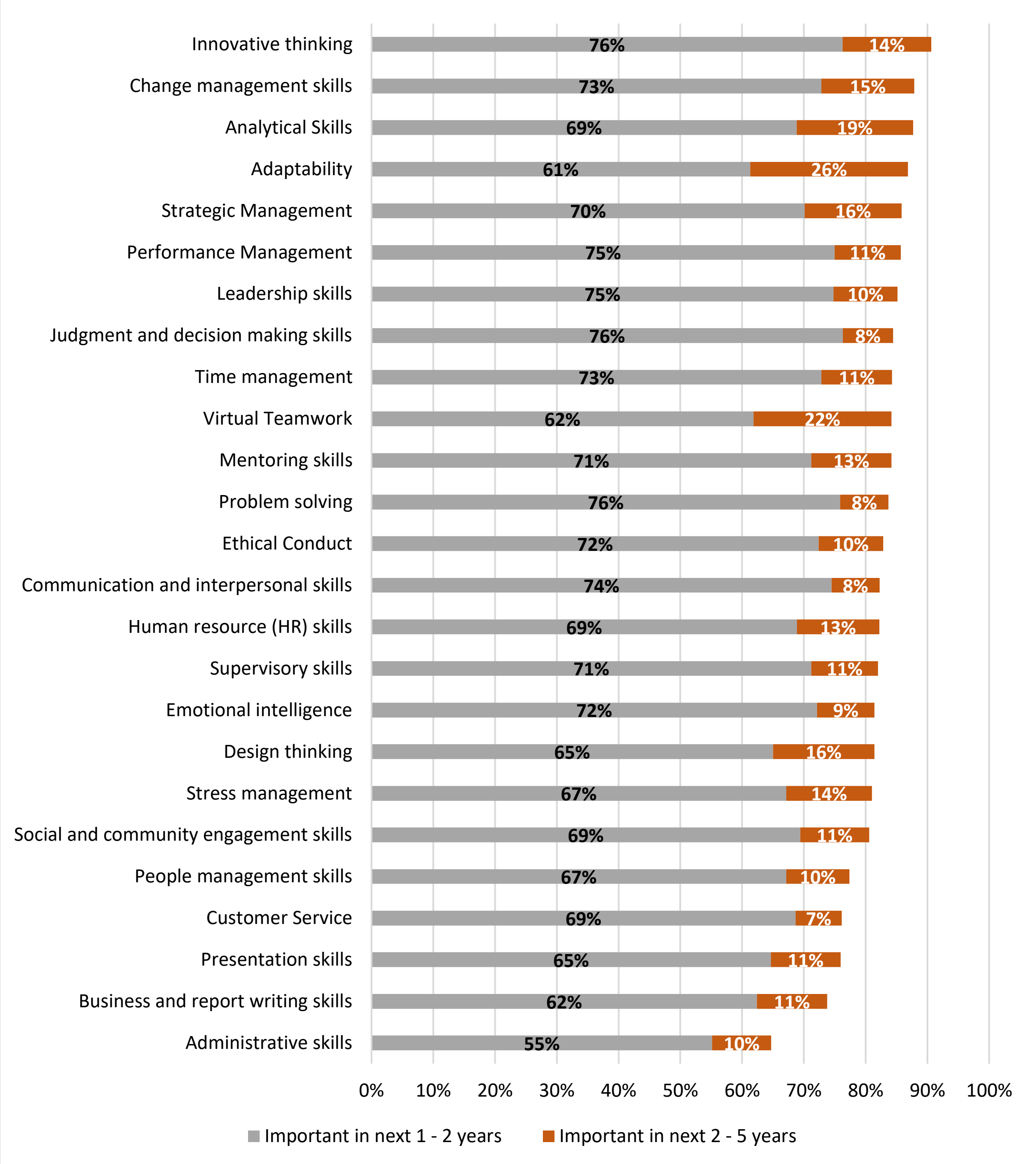
Employer interviews also highlighted the emergence of *system integrators* as a result of the various reports being generated by machinery. This skill allows end users to effectively interpret the data and provide only relevant or key information to relevant parties.

> "One of the things we've seen coming up in skill sets is integrators. We have a few different systems standalones, monitoring various aspects of the business, whether it's technical, HR, finance, or safety. As end users, we get bogged down with a lot of reports, even just within machinery or processes you might have five reports reporting different aspects of a process or a system. What we've seen coming up now is that some of these IT companies, or IM, they've now come with a layer that integrates these various reports and give you an exception report. Like our UCAS, lately, they don't show you what is the temperature of the oil, or it only comes up by exception, when you drive - high temperature. Other than that, it doesn't bother you."
>
> *Respondent 1, Employer Affiliation Body Interview, 2023*

7.3.3 Skills Changes as a Result of the 4IR

In order to ensure that skills training and reskilling and upskilling initiatives within the MMS are provided for the right competencies and skillsets, it is necessary to identify the skills, both soft and technical, for which the importance is anticipated to increase as a result of the adoption of 4IR technologies. The figure below illustrates the soft skills that are likely to become more important with the evolving nature of work.

Figure 7-9: Soft Skills Anticipated to Increase in Importance[30]



Source: MQA Impact of 4IR Survey, 2023

As can be seen, from a soft skills perspective, the skills that are anticipated to become increasingly important in the short to medium term include innovative thinking (with 90% of stakeholders indicating this), change management skills and analytical skills (88% each) and adaptability (87%). During interviews stakeholders noted that

[30] The remaining percentage in the graph represents those stakeholders who indicated that the respective soft skill will not become more important.

adaptability would be a key skill as it will enable employees to quickly learn and build on new skills[31], develop creative solutions, and remain competitive.

> "Adaptability to change is going to be critical because understanding that today's market is very different [and that], 4IR cannot be removed from that [is important]."
>
> *Respondent 20, Employer Interview, Diamond Processing, 2023*

> "Adaptability, a willingness to embrace change, and imagination are all fundamental skills that will be crucial. These are foundational competencies upon which employers can build specific skills or technologies tailored to a particular work environment or mine."
>
> *Respondent 3, Union Representative Interview, 2023*

Within the shorter-term, the skills that are anticipated to become increasingly important include judgement and decision making (76%), which are cognitive processes that involve evaluating information, assessing alternatives, and choosing a course of action (Nitta, 2023); innovative thinking (76%), which involves the generation of creative ideas, the identification of novel solutions, and the development of ground-breaking concepts (Dunlop, 2020); problem solving (76%), which is a process that involves discovering, analysing, and resolving issues or challenges and requires elements of adaptability, effective communication and collaboration skills (Britannica, The Editors of Encyclopaedia, 2023); and leadership (75%), which encompass a range of abilities and qualities that enable individuals to guide, inspire, and influence others to achieve common goals. Importantly, effective leaders demonstrate a combination of interpersonal, strategic, and organisational skills. The development of these soft skills may be achieved through specific teaching methods and continuous mentoring and coaching (Barney, 2023), which is described in detail in the Recommendations section of this report.

Furthermore, employers perceive communication and interpersonal, time management, and change management skills as becoming increasingly important in the immediate to short term future. Change management skills refer to the abilities and strategies that individuals or leaders use to navigate, facilitate, and implement organisational changes effectively, such as those changes that may occur as a result of the 4IR (Lawton, 2022). These findings align with sentiments emerging from qualitative data, with employers citing the increasing importance of leadership and change management skills, particularly as organisations attempt to integrate more sophisticated technologies in their operations.

[31] The remaining percentage in the graph is for stakeholders that said each of the soft skills will not become important.

> "Change management is going to be huge. I think we're going to have to do a lot of work in our mid-management levels because they're going to feel the pressure from top management to get this done [implement 4IR technologies] and get the pressure from your bottom labour which don't want to get this done."
>
> *Respondent 33, Employer Interview, Diamond Processing, 2023*

> "Coaching and mentoring and leadership are critical. It is important to understand implications on employees, you want people to evolve but in a controlled manner and secure manner."
>
> *Respondent 21, Employer Interview, Jewellery Manufacturing, 2023*

A detailed analysis was conducted on the impact of the 4IR on skills in order to determine what soft skills are likely to become more important in the next 1 to 2 years and the next 2 to 5 years, per sub-sector. This would enable focus to be placed on relevant skills when developing skills within the sector. The table below illustrates soft skills that are likely to become more important in the next 1 to 2 years, with the top 3 skills per sub-sector indicated in a light green shade.

Table 7-1: Soft Skills Likely to Become more Important within the next 1 to 2 years, per Sub-sector

Skills	Coal Mining	Gold Mining	Diamond Mining	PGM Mining	CLAS Mining	Other Mining	Services Incidental to Mining	Diamond Processin	Jewellery Manufactu
People management skills	96%	44%	75%	80%	50%	63%	48%	80%	64%
Performance Management	92%	67%	100%	87%	54%	77%	54%	75%	75%
Problem solving	92%	56%	100%	93%	69%	69%	67%	80%	75%
Emotional intelligence	88%	56%	100%	88%	62%	74%	65%	20%	55%
Social and community engagement skills	88%	63%	75%	93%	67%	58%	50%	100%	56%
Stress management	88%	56%	100%	73%	50%	69%	48%	60%	56%
Strategic Management	88%	44%	75%	80%	75%	74%	45%	100%	50%
Supervisory skills	85%	67%	75%	93%	58%	72%	46%	100%	70%

Skills	Coal Mining	Gold Mining	Diamond Mining	PGM Mining	CLAS Mining	Other Mining	Services Incidental to Mining	Diamond Processin	Jewellery Manufactu
Time management	85%	44%	100%	93%	50%	72%	52%	100%	83%
Ethical Conduct	83%	56%	100%	88%	69%	74%	62%	60%	56%
Judgment and decision making skills	83%	88%	100%	88%	75%	79%	57%	60%	70%
Mentoring skills	83%	56%	75%	80%	58%	71%	58%	100%	75%
Presentation skills	83%	56%	50%	93%	42%	60%	55%	50%	56%
Leadership skills	83%	67%	75%	93%	50%	77%	63%	100%	73%
Communication and interpersonal skills	81%	56%	100%	94%	62%	74%	78%	80%	45%
Human resource (HR) skills	81%	75%	100%	87%	38%	74%	50%	50%	56%
Analytical Skills	80%	75%	75%	56%	67%	69%	60%	75%	80%
Virtual Teamwork	80%	44%	25%	69%	62%	61%	48%	40%	82%
Innovative thinking	78%	78%	100%	69%	69%	76%	71%	75%	92%
Design thinking	78%	67%	75%	69%	54%	58%	62%	60%	69%
Administrative skills	76%	50%	100%	63%	27%	43%	48%	50%	64%
Customer Service	76%	63%	50%	81%	58%	73%	57%	75%	67%
Change management skills	74%	56%	75%	88%	54%	78%	71%	60%	70%
Adaptability	60%	56%	50%	80%	54%	63%	48%	60%	78%
Business and report writing skills	60%	63%	75%	81%	54%	73%	39%	40%	64%

Source: MQA Impact of 4IR Survey, 2023

Similarly, the table below illustrates the soft skills that are likely to become more important in the next 2 to 5 years, with the top 3 per sub-sector indicated in a light green shade.

Table 7-2: Soft Skills Likely to Become more Important within the next 2 to 5 years, per Sub-sector

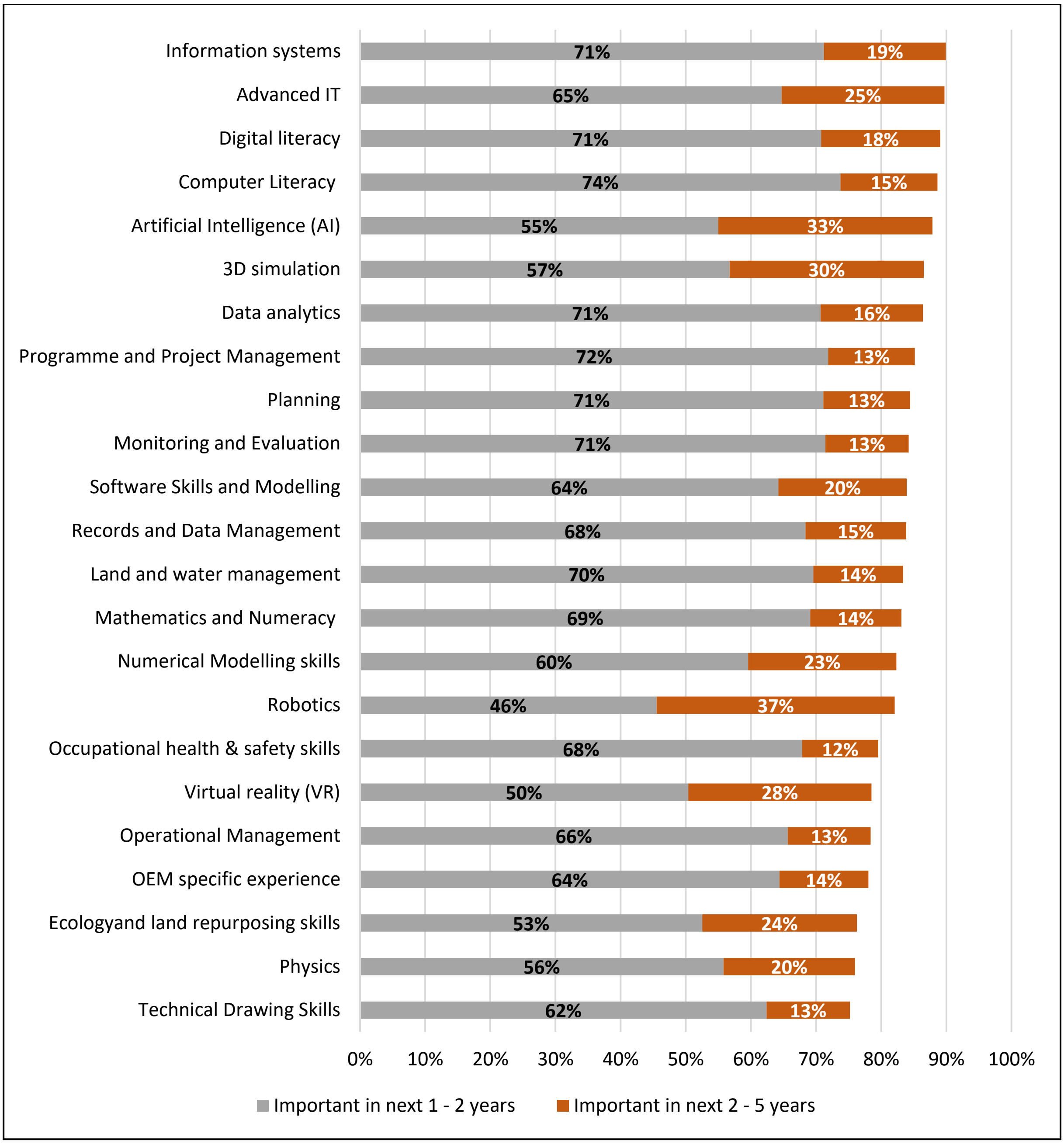
Skills	Coal Mining	Gold Mining	Diamond Mining	PGM Mining	CLAS Mining	Other Mining	Services Incidental to Minin	Diamond Processin	Jewellery Manufactu
Adaptability	32%	11%	50%	20%	23%	23%	30%	20%	22%
Innovative thinking	22%	0%	0%	19%	15%	15%	13%	25%	8%
Design thinking	19%	0%	0%	25%	31%	18%	10%	0%	15%
Change management skills	17%	33%	25%	6%	23%	8%	17%	0%	20%
Analytical Skills	16%	13%	25%	31%	17%	23%	16%	0%	10%
Business and report writing skills	16%	0%	0%	6%	15%	8%	22%	0%	9%
Virtual Teamwork	16%	22%	50%	25%	31%	19%	24%	20%	18%
Human resource (HR) skills	15%	13%	0%	7%	23%	11%	9%	25%	22%
Mentoring skills	13%	11%	25%	7%	17%	14%	17%	0%	8%
Administrative skills	12%	0%	0%	0%	9%	6%	22%	25%	9%
Customer Service	12%	0%	25%	13%	8%	0%	5%	0%	17%
Leadership skills	9%	11%	25%	0%	17%	9%	17%	0%	9%
Strategic Management	8%	22%	25%	13%	17%	17%	14%	0%	30%
Emotional intelligence	8%	0%	0%	0%	15%	9%	13%	20%	18%
Performance Management	8%	11%	0%	7%	8%	14%	17%	0%	8%
Social and community engagement skills	8%	13%	25%	0%	17%	11%	18%	0%	11%

Skills	Coal Mining	Gold Mining	Diamond Mining	PGM Mining	CLAS Mining	Other Mining	Services Incidental to Mining	Diamond Processin	Jewellery Manufactu
Communication and interpersonal skills	8%	11%	0%	0%	15%	6%	9%	0%	18%
Supervisory skills	8%	0%	25%	0%	8%	11%	21%	0%	20%
Time management	8%	22%	0%	0%	8%	14%	22%	0%	8%
Ethical Conduct	4%	22%	0%	0%	15%	12%	10%	20%	22%
Judgment and decision making skills	4%	0%	0%	6%	8%	6%	17%	20%	10%
Stress management	4%	22%	0%	20%	8%	14%	26%	0%	11%
People management skills	0%	11%	25%	7%	8%	14%	17%	0%	9%
Presentation skills	0%	11%	25%	7%	17%	17%	14%	0%	11%
Problem solving	0%	11%	0%	0%	15%	14%	8%	0%	8%

Source: MQA Impact of 4IR Survey, 2023

Similar to the above, the figure below illustrates the technical skills that are likely to become more important given the evolving nature of work.

Figure 7-10: Technical Skills Anticipated to Increase in Importance[32]



Source: MQA Impact of 4IR Survey, 2023

As can be seen, employers have indicated that technical skills related to information systems and advanced IT (with 90% of stakeholders indicating this), digital literacy and computer literacy (89% each) will likely become more important within the next 5 years. Technical skills related to project management (72%) and planning (71%) were also cited as skills that may become important in the immediate future.

[32] The remaining percentage in the graph represents those stakeholders who indicated that the respective technical skill will not become more important.

Within the next 2 to 5 years, the technical skills that stakeholders noted are likely to become more important include robotics (37%), AI (33%), 3D simulation (30%) and VR (28%). The adoption of technologies that require these skills was found to be increasing, with technologies such as automated drilling equipment (that use robotics and AI) being applied across mining exploration and extraction activities. Automated drilling equipment in mining refers to machinery that utilises advanced automation and technology to perform drilling operations in mining activities. This type of equipment is designed to improve efficiency, safety, and precision in drilling processes. Stakeholders such as training providers were in agreement that the use of robotics will emerge within the sector.

> "There will be an opportunity for upskilling for the new issues that will be there, such as employees using robotics..."
>
> *Respondent 18, Training Provider Interview, Other Mining, 2023*

It was further highlighted that IT skills will be needed to facilitate the seamless integration and collaboration between AI and robotics.

> "IT related skills that will merge with the AI programmes and robotic programmes."
>
> *Respondent 6, Training Provider Interview, All Subsectors, 2023*

Furthermore, 3D printers are being deployed in jewellery manufacturing to improve the overall design, customisation, and production processes, allowing for greater volumes of jewellery to be produced. Lastly, VR simulators are being adopted in training facilities to simulate the working environment and allow employees to gain practical training in a safe and controlled environment, as discussed in Section 6.

Similar to the soft skills, further analysis was conducted to determine what technical skills are likely to become more important in the next 1 to 2 years and the next 2 to 5 years, per sub-sector. The table below illustrates the technical skills that are likely to become more important in the next 1 to 2 years, with the top 3 skills expected to become more important per sub-sector indicated in a light green shade.

Table 7-3: Technical Skills Likely to Become more Important within the next 1 to 2 years, per Sub-sector

Skills	Coal Mining	Gold Mining	Diamond Mining	PGM Mining	CLAS Mining	Other Mining	Services Incidental to Mining	Diamond Processin	Jewellery Manufactu
Mathematics and Numeracy	83%	56%	100%	67%	50%	78 %	48%	60%	90%
Software Skills and Modelling	80%	67%	75%	63%	67%	63 %	52%	25%	70%

Skills	Coal Mining	Gold Mining	Diamond Mining	PGM Mining	CLAS Mining	Other Mining	Services Incidental to Mining	Diamond Processin	Jewellery Manufactu
Programme and Project Management	79%	50%	75%	69%	67%	71%	70%	60%	90%
Monitoring and Evaluation	76%	56%	100%	81%	69%	76%	57%	50%	70%
Planning	75%	44%	75%	73%	58%	75%	65%	75%	89%
Ecology and land repurposing skills	74%	56%	25%	44%	33%	54%	36%	75%	56%
Numerical Modelling skills	73%	44%	75%	50%	58%	61%	39%	80%	80%
Information systems	72%	67%	100%	75%	58%	75%	64%	60%	73%
Land and water management	71%	44%	75%	75%	62%	78%	65%	75%	60%
Technical Drawing Skills	71%	44%	100%	67%	58%	76%	45%	0%	50%
Computer Literacy	70%	56%	100%	81%	50%	86%	65%	50%	83%
Artificial Intelligence (AI)	69%	44%	75%	63%	46%	43%	55%	60%	55%
Advanced IT	68%	38%	50%	56%	77%	70%	55%	75%	83%
Data analytics	68%	78%	75%	63%	62%	86%	54%	80%	70%
Digital literacy	68%	56%	75%	69%	69%	80%	59%	50%	90%
Occupational health & safety skills	68%	63%	75%	80%	38%	81%	57%	25%	80%
OEM specific experience	67%	67%	75%	80%	42%	74%	43%	80%	56%
Records and Data Management	64%	44%	100%	81%	50%	83%	59%	25%	67%
Operational Management	63%	44%	75%	79%	42%	74%	65%	75%	60%
Physics	57%	63%	25%	67%	50%	60%	40%	75%	56%
3D simulation	56%	67%	50%	56%	54%	51%	52%	60%	75%

Skills	Coal Mining	Gold Mining	Diamond Mining	PGM Mining	CLAS Mining	Other Mining	Services Incidental to Mining	Diamond Processin	Jewellery Manufactu
Virtual reality (VR)	54%	56%	25%	75%	38%	53%	43%	20%	50%
Robotics	36%	56%	25%	33%	33%	56%	55%	25%	50%

Source: MQA Impact of 4IR Survey, 2023

Similar to the above, the table below illustrates the technical skills more likely to become important in the next 2 to 5 years, per sub-sector. The cells highlighted in green signify the top three skills expected to become more important as a result of the 4IR, per sub-sector.

Table 7-4: Technical Skills Likely to Become more Important within the next 2 to 5 years, per Sub-sector

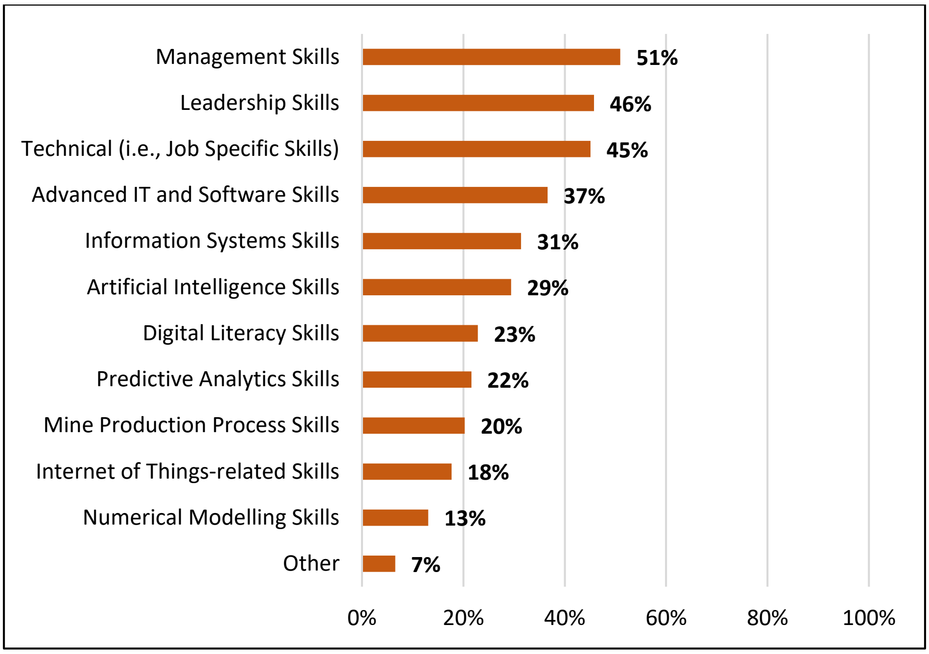
Skills	Coal Mining	Gold Mining	Diamond Mining	PGM Mining	CLAS Mining	Other Mining	Services Incidental to Mining	Diamond Processin	Jewellery Manufactu
Robotics	52%	11%	50%	67%	58%	21%	23%	75%	20%
Virtual reality (VR)	38%	11%	50%	19%	46%	21%	26%	60%	13%
3D simulation	36%	22%	25%	31%	46%	34%	22%	20%	17%
Physics	35%	13%	25%	27%	17%	17%	20%	0%	0%
Artificial Intelligence (AI)	31%	33%	0%	31%	54%	43%	27%	20%	18%
Land and water management	29%	11%	25%	19%	15%	6%	13%	0%	0%
Advanced IT	28%	38%	50%	38%	8%	24%	18%	25%	17%
Data analytics	28%	11%	25%	19%	15%	6%	17%	0%	20%
Digital literacy	28%	22%	25%	25%	23%	11%	18%	25%	0%
Computer Literacy	26%	11%	0%	13%	25%	9%	17%	0%	8%

Skills	Coal Mining	Gold Mining	Diamond Mining	PGM Mining	CLAS Mining	Other Mining	Services Incidental to Mining	Diamond Processin	Jewellery Manufactu
Operational Management	25%	22%	0%	7%	8%	11%	4%	0%	20%
OEM specific experience	25%	11%	0%	13%	17%	12%	19%	0%	0%
Information systems	24%	11%	0%	19%	17%	17%	18%	40%	18%
Occupational health & safety skills	24%	25%	25%	13%	8%	6%	9%	0%	0%
Records and Data Management	24%	11%	0%	13%	25%	11%	14%	50%	11%
Numerical Modelling skills	23%	33%	25%	44%	25%	17%	30%	0%	0%
Technical Drawing Skills	21%	11%	0%	27%	8%	0%	9%	75%	10%
Monitoring and Evaluation	19%	22%	0%	13%	8%	9%	9%	25%	20%
Ecology and land repurposing skills	19%	11%	25%	44%	25%	24%	27%	0%	11%
Planning	17%	11%	25%	20%	8%	14%	9%	0%	11%
Software Skills and Modelling	16%	11%	0%	25%	17%	20%	22%	75%	10%
Programme and Project Management	13%	13%	25%	19%	8%	18%	9%	20%	0%
Mathematics and Numeracy	9%	22%	0%	33%	8%	6%	30%	0%	0%

Source: MQA Impact of 4IR Survey, 2023

When evaluating the skills that will gain significance in the short to medium term within the MMS, it is crucial to also ascertain if there are any existing gaps in these skills need to be addressed. These gaps, often known as "top-up skills," emerge when employees lack the essential competencies and specific skills mandated by industry standards to proficiently execute their job responsibilities (Department of Higher Education and Training, 2022). It is within this context that current skills gaps have been explored as a part of this Study. The figure below provides an overview of the current skills gaps within MMS organisations.

Figure 7-11: Current Skills Gaps Within Organisations



Source: MQA Impact of 4IR Survey, 2023

As seen in the figure above, the top skills gaps amongst organisations within the MMS include management skills (as indicated by 51% of stakeholders), leadership skills (46%), technical i.e., job specific skills (45%), advanced IT and software skills (37%) and information systems skills (31%). These findings present a concerning outlook, particularly considering that management skills, including performance (75%) change (73%) and strategic (70%) management skills for example, are projected to escalate in significance within the MMS over the next 1 to 2 years. Similarly, 76% of stakeholders are of the view that leadership skills will increase in significance within the short term. It is, thus, imperative that the MQA address these gaps to ensure that they do not widen further.

Through the interview process, employers highlighted the significance of the gaps they face, particularly with regard to leadership in managerial and supervisory related roles, indicating that decision making was one of the areas negatively impacted.

> "[We have gaps in] leadership skills, supervision in particular, and safety culture. This is because of the number of incidents that we are experiencing an accident, although we have plans in place to mitigate and to address the issues. The supervision is one of the key skills that people are lacking - leadership at the management, supervisory level and at operational level, is still a big challenge. The sense of ownership and decision making is a challenge."
>
> *Respondent 33, Employer Interview, Other Mining, 2023*

Other key skills gaps include technical, i.e., job specific skills, which was noted by 45% of stakeholders. Specific skills highlighted include diamond cutters and polishers.

> "I would say a couple of gaps I've identified are diamond cutters and polishers. Gaps are also dependent on geographical location, for example if you are looking for a diamond cutter in an area where you are not aware of skills providers then you won't easily get that information. Diamonds are also a very expensive commodity so it is crucial that they are handled by a skilled person that values the sustainability of the business and their employment."
>
> *Respondent 20, Employer Interview, Diamond Processing, 2023*

Key Findings

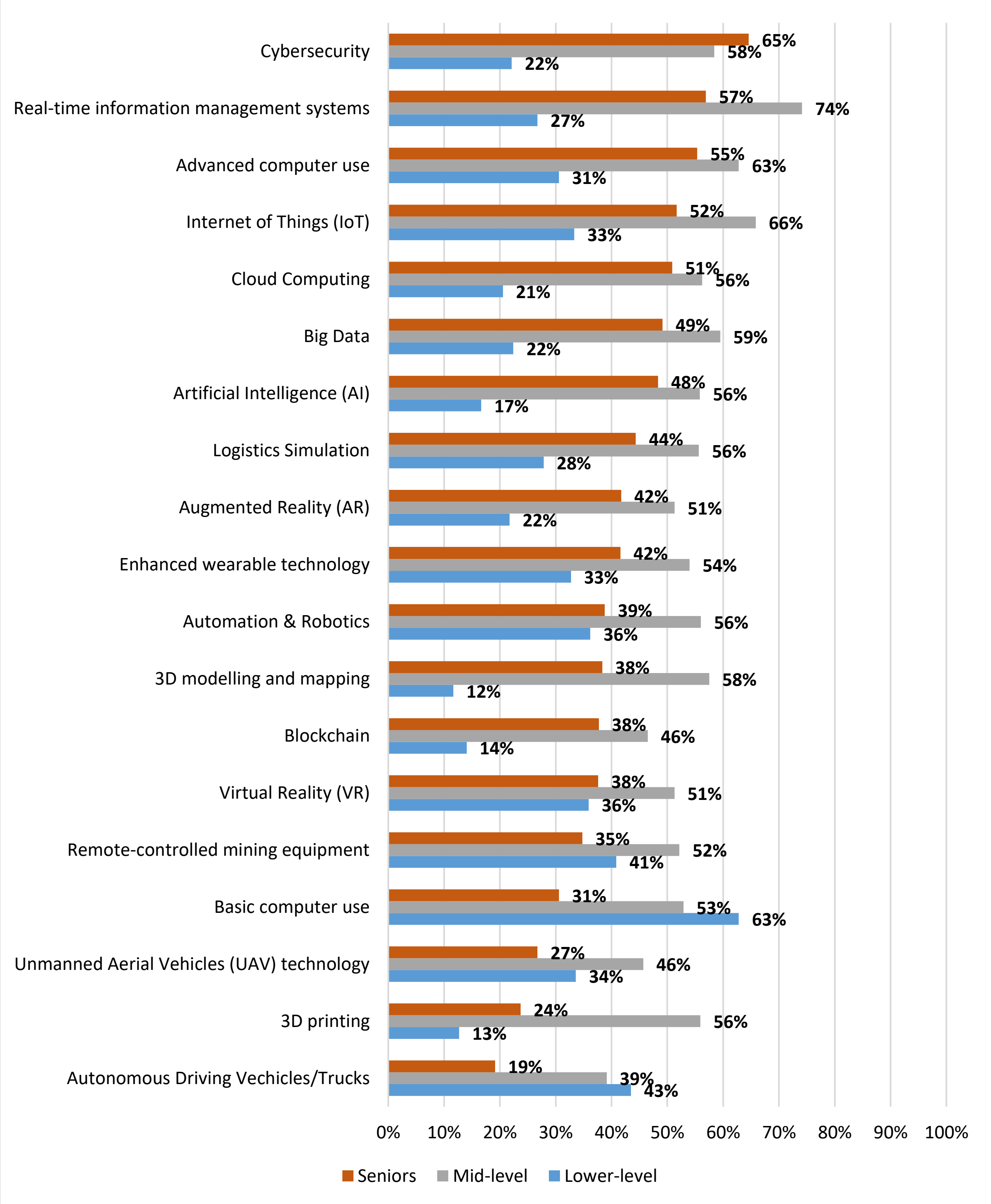
- The top soft skills for which importance is anticipated to increase in the short term include innovative thinking, change management and analytical skills and adaptability, whereas those anticipated to increase in significance in the medium term include judgement and decision making, innovative thinking, problem solving and leadership skills.
- The top 3 technical skills anticipated to increase in significance in the short term include information systems and advanced IT, digital literacy and computer literacy, while robotics, AI and 3D simulation are anticipated to increase in significance in the medium term.
- Management and leadership skills were identified as some of the key skills that are anticipated to increase in significance in the short term, it was found, however, that these skills are amongst the top skills gaps currently in the MMS. It is, therefore, critical that focus is placed on addressing these gaps to avoid them widening further.

7.3.4 Occupational Levels at which 4IR Skills are Required

Further analysis of the findings was conducted to assess the occupational levels at which 4IR-related skills and knowledge will be required within the MMS in the short to medium term. This analysis is crucial in assessing how technological advancements affect the various occupational levels in order to facilitate the development of targeted strategies for upskilling and reskilling of employees.

The figure below illustrates the occupational levels at which 4IR-related skills and knowledge will be required within the next 1 to 2 years.

Figure 7-12: Occupational Levels at which 4IR-related Skills and Knowledge will be Required within the Next 1 to 2 years[33]



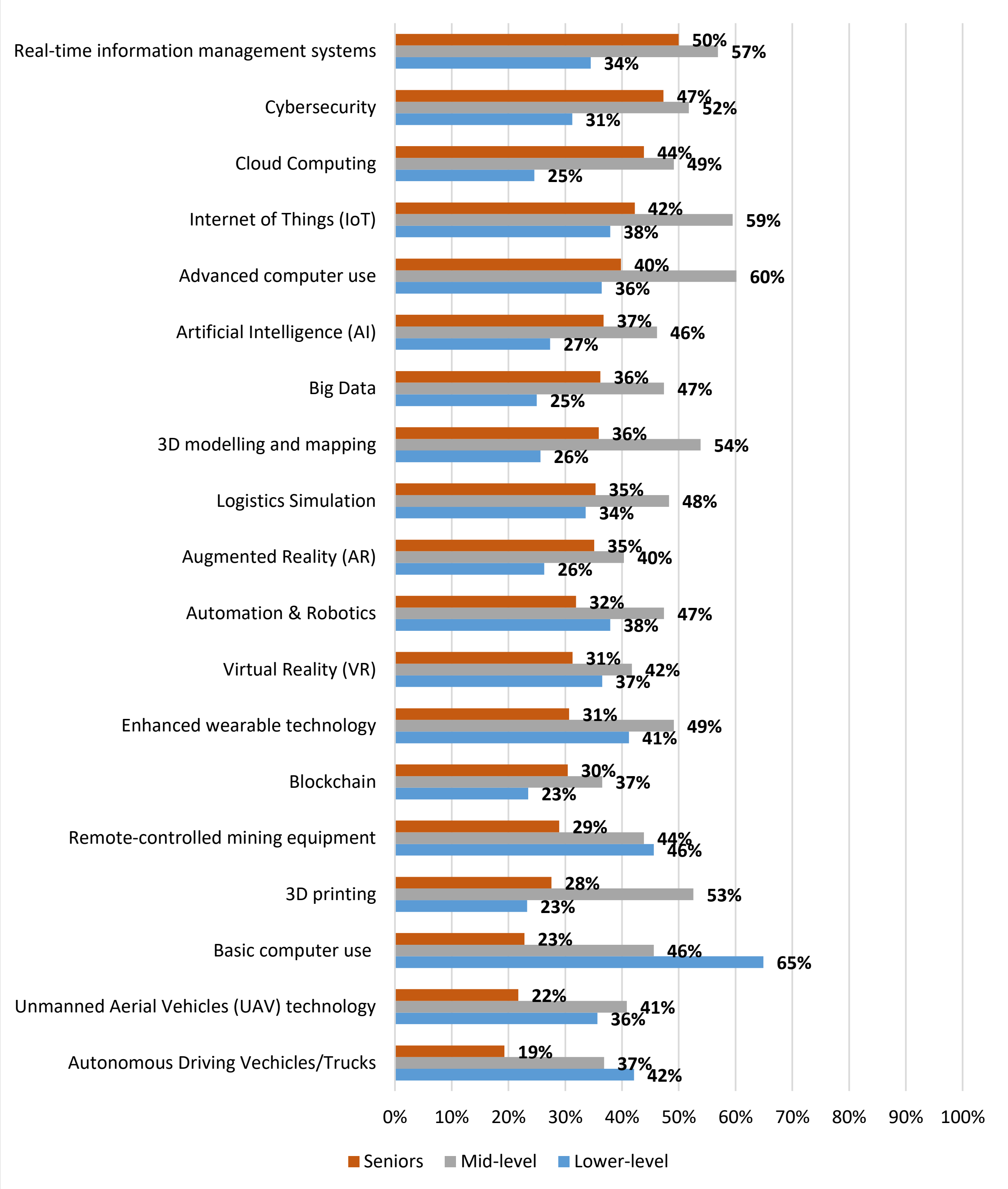
Source: MQA Impact of 4IR Survey, 2023

[33] Stakeholders were allowed to select multiple options. Each category is to be assessed separately and the maximum achievable percentage for each category is 100%. The total sum of these categories may equate to either less or more than 100% due to the questions asked in the survey.

It can be seen from the above graph that 4IR related knowledge and skills will mostly be required by employees in mid-level occupations within the next 1 to 2 years. Individual analysis indicates that senior employees will require skills and knowledge mainly in cybersecurity (as indicated by 67% of stakeholders), real time information management systems (57%) and advanced computer use (55%), while mid-level employees will require the knowledge and skills in real time information management systems (74%), IoT (66%) and advanced computer use (63%). Lower-level employees, on the other hand, will require skills and knowledge in basic computer use (63%). This may be attributed to the relatively lower average level of education amongst the lower levels of employees as highlighted in Section 4.3, indicating that they will need to be equipped with the basic skills as pertains to the 4IR. Other areas in which 4IR related knowledge and skills will be required include autonomous driving trucks/vehicles (43%) and remote controlled mining equipment (41%).

Similar analysis was conducted to determine occupational levels at which 4IR-related skills and knowledge will be required within the next 2 to 5 years in order to inform which skills should be prioritised for which occupational groups in the medium term. The figure below highlights the results.

Figure 7-13: Occupational Levels at which Additional 4IR-related Skills and Knowledge will be Required within the Next 2 to 5 years[34]



Source: MQA Impact of 4IR Survey, 2023

[34] Stakeholders were allowed to select multiple options. Each category is to be assessed separately and the maximum achievable percentage for each category is 100%. The total sum of these categories may equate to either less or more than 100% due to the questions asked in the survey.

The figure above illustrates that, within the next 2 to 5 years, 4IR related knowledge and skills will still mostly be required by employees in mid-level occupations. Further analysis indicates that the top technologies for which employees at all occupation levels will require knowledge and skills in the medium term are similar to those required in the short term and include technologies such as cybersecurity, cloud computing and advance computer use.

Key Findings

- It was found that mid-level employees would require the most 4IR related knowledge and skills within the short to medium-term.
- In the short-term, these include areas such cybersecurity, real time information management systems and advanced computer for middle to senior occupations and basic computer use, autonomous driving trucks/vehicles and remote controlled mining equipment for lower level employees. In the medium term, information management systems, cybersecurity and cloud computing were identified as key areas for middle to senior management, while basic computer use, remote controlled mining equipment and autonomous driving vehicles/trucks remain the key competencies for lower level occupation.

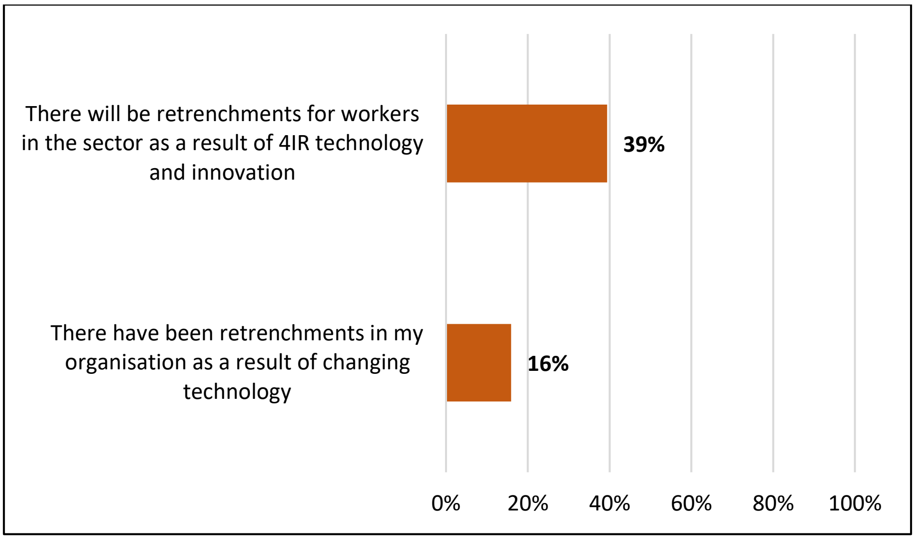
7.4 Key Changes in the MMS Workforce as a Result of the 4IR

From the discussion in the above sections, it is evident that the 4IR has significant impact on occupations and requisite skills alike within the MMS. As a result, the workforce within the sector is either already undergoing, or likely to undergo, varying forms of transformation such as potential retrenchments, an increased need for reskilling and upskilling, as well as increases in the demand for some employees. These impacts are outlined in the sections that follow.

7.4.1 Potential Retrenchments as a Result of the 4IR

Technological advancements can, at times, render certain positions in an organisation unnecessary as a result of changes in operations. This, in turn, often leads to retrenchments (Jordaan, 2019). As highlighted in Section 7.2.2, some jobs are expected to become redundant as a result of the adoption of 4IR technologies. In light of this, it is important to understand the extent to which retrenchments have occurred or the extent to which retrenchments are expected to occur as a result of the 4IR.

Figure 7-14: Retrenchments within the MMS as a result of the 4IR[35]



Source: MQA Impact of 4IR Survey, 2023

As noted above, 39% of stakeholders were of the view that the adoption of 4IR technologies may potentially result in retrenchments for workers in the sector. These stakeholders were of the view that lower level occupations were most vulnerable to the retrenchments, due to activities being automated and streamlined.

"Your general workers will be less. I'm talking about your unschooled, lower-level employees because of the automated system - then there's no need for clean-ups and spills because it's more of a streamlined automatic system, which the employer takes away. In general, your lower to, let's call it junior positions in your company will be directly impacted." *Respondent 19, Employer Interview, Diamond Processing, 2023*

Some of the occupations identified as potentially facing the threat of retrenchment include stoping labourers, as well as machine operators.

"Stoping labourers underground, those are some of the people that will feel the impact. The wedge operators and pump operators as well." *Respondent 6, Employer Interview, PGM Mining, 2023*

"Area for possible retrenchments include machine operators and engineering staff with the support functions who will need to be trained on how to fix and service the machines. They are used to the operation of the current machines but they will require new skills as the technology evolves - they are qualified artisans." *Respondent 11, Employer Interview, Coal Mining, 2023*

Contrastingly, there is a general perception that the impact of the 4IR on the mid to senior levels of management will either be more positive, or there will not be any. Stakeholders were of the view that these particular occupation groups are better

[35] The graph indicates the percentage of stakeholders who agreed or strongly agreed with each statement. The responses were calculated separately for each statement. Therefore, the graph does not add to 100%.

prepared for a changing environment, as they have a clearer grasp on the concept of the 4IR and what opportunities it may present for organisations and employees alike.

> "Not so much on a higher level, because I think people on a higher level have a better understanding of the whole concept and they are aware of how they need to prepare themselves for the future."
>
> *Respondent 6, Employer Interview, PGM Mining, 2023*

A smaller percentage of stakeholders (16%) indicated that there had already been retrenchments within their organisations. These stakeholders indicated that it was difficult to avoid these when new technologies were adopted, but that retrenchments did not impact the entire workforce, with some occupations still required to operate and/or monitor the machines.

> "The downside to adoption, if we are bringing in latest technology, [then this] automatically means downsizing of labour forces, but not completely because there are still tasks that may require human labour."
>
> *Respondent 20, Employer Interview, Diamond Processing, 2023*

However, stakeholders further noted that as opposed to retrenching employees, the majority of these employees are rather reskilled and re-assigned to different roles within the organisations.

> "Most of those people were upskilled, they did not retrench…"
>
> *Respondent 1, Labour/Union Representative Interview, 2023*

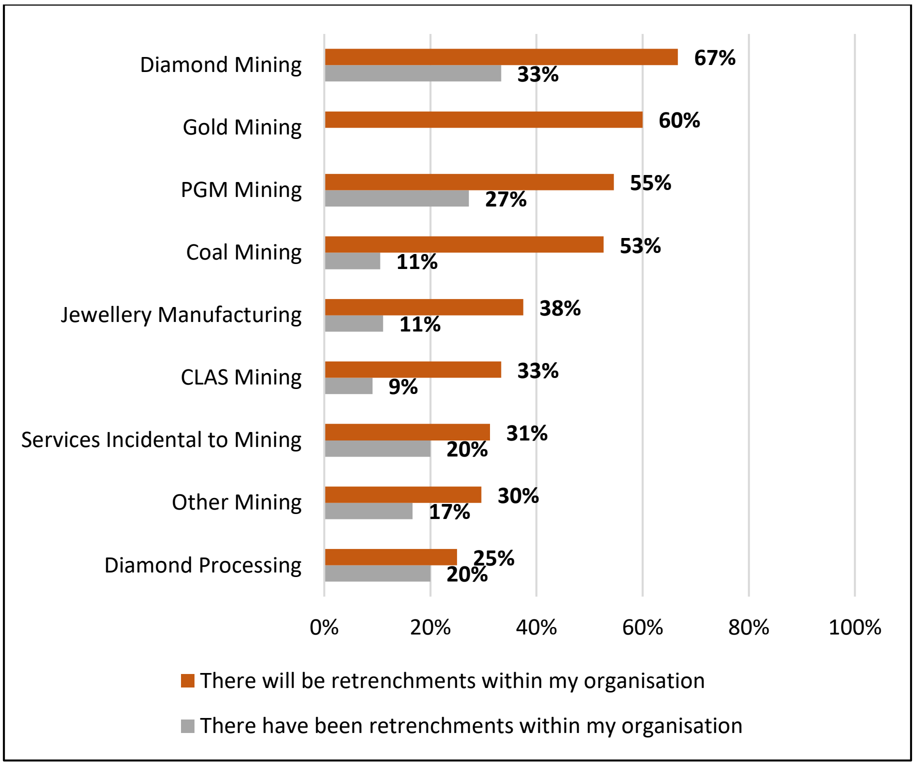
> "We will retrain those that can be retrained using the new [technologies]."
>
> *Respondent 11, Employer Interview, Coal Mining, 2023*

Inferential Analysis

Chi-Square tests, using a significance level of 0.05, reveal no significant relationship between the size of the organisation and the planned retrenchments nor between the sub-sector and the planned retrenchments, implying that should retrenchments occur, the extent of these retrenchments are unlikely to be influenced by the size of the organisation or the sub-sector in which the organisation operates.

Further analysis was conducted to determine the extent of retrenchments across the different sub-sectors in order to get a sense of which sub-sectors are likely to experience the most significant reductions in employees. The results are illustrated below.

Figure 7-15: Retrenchments within the MMS as a result of 4IR, per Sub-sector[36]



Source: MQA Impact of 4IR Survey, 2023

It can be seen above that the greatest proportion of retrenchments are anticipated from the Diamond mining sub-sector (with 67% of stakeholders indicating this), the Gold mining sub-sector (60%), PGM mining (55%) and the Coal mining sub-sector (53%). The Jewellery Manufacturing sub-sector was also highlighted by 38% of stakeholders. Occupations identified as potentially facing retrenchments within the Jewellery Manufacturing sub-sector include craftsmen, goldsmiths and bench workers.

> "Craftsman, Goldsmiths, and bench workers will lose their jobs. I think sadly, as things become automated you will lose those lower skilled jobs. It's either the people with the lower skills will have to upskill to be able to select the right programme, or they will lose their jobs. They have to migrate to higher skills levels."
>
> *Respondent 21, Employer Interview, Jewellery Manufacturing 2023*

Similarly, the greatest proportion of retrenchments that have already taken place have been within the Diamond mining sub-sector (as indicated by 33% of stakeholders). This is followed by PGM mining, with 27% of stakeholders indicating this.

[36] Respondents were allowed to select multiple options according to what was most relevant. Each category is to be assessed separately and totals may not add up to 100%

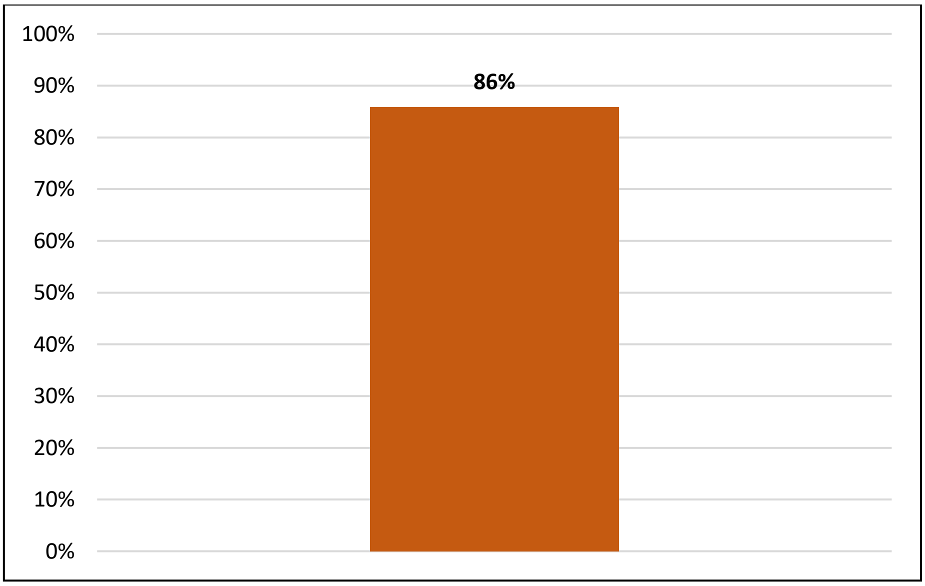
Key Findings

- There was a general perception from stakeholders that 4IR-related technologies have not resulted in significant retrenchments across the MMS. Instead, employees impacted by possible retrenchments were rather reskilled so as to allow them to transition into new roles.
- However, stakeholders were of the view that should retrenchments occur, lower level occupations were the most vulnerable. This was attributed to the lower level of skillsets possessed by lower level employees. Occupations such craftsmen, goldsmiths, and bench workers were noted as likely to be impacted should occupations become redundant.

7.4.2 Increased Demand for Upskilling/Reskilling of Existing Employees

Due to the changing nature of work and skills brought on by the adoption of 4IR-related technologies, workers performing the tasks in which 4IR-related technologies are being adopted must undergo reskilling or upskilling in order to be able to transition into different roles, or potentially face unemployment. This is further compounded by the need to create new roles in mining due to digital transformation, which may call for a blend of traditional mining skills or in some cases, may not require traditional mining skills at all (PwC, 2023). This necessity to upskill and reskill employees is supported by research findings that indicate that within the next four years, 48% of mining employees will need reskilling or upskilling, with the average employee's skillset projected to change by 40% (Black & Sandström, 2021). This underscores the critical need for ongoing skills development in the mining sector (Coates, 2019). The figure below illustrates the extent to which stakeholders agreed that employees within mining sector organisations require reskilling and/or upskilling.

Figure 7-16: Extent to which Employees Require Reskilling/Upskilling



Source: MQA Impact of 4IR Survey, 2023

It can be seen above that 86% of stakeholders were of the view that employees within the organisations they represent require reskilling and/or upskilling. Reskilling and upskilling of employees may be carried out in order to provide employees with the soft and technical skills that are anticipated to emerge as a result of the 4IR, as well as to close the current skills gaps that exist within organisations, as discussed in the previous sections. For example, employees may require upskilling in order to obtain management and leadership skills and/or advanced IT skills. The stakeholders indicated that the reskilling and upskilling were necessities, and noted further that once their employees have trained in the relevant skills, then they would seek to ensure that they keep these employees in-house and don't have a high employee turnover.

> "We will be forced to actually do a lot more upskilling. And then from there, we will have to ensure that we keep our people. Generally, I do see technology reducing the need for more unskilled people."
>
> *Respondent 1, Employer Interview, Gold Mining, 2023*

Other stakeholders noted the reskilling and upskilling as key to ensuring that organisations continue to be operational and thrive within a 4IR context, indicating that should they not be able to adapt to the changing world then they would cease to exist.

> "Yes, they don't have a choice, if they don't do It, they will die. It's adapt or die."
>
> *Respondent 1, Labour/Union Representative Interview, 2023*

In particular, stakeholders were of the view that reskilling and/or upskilling were important to ensure that those employees in occupations that are becoming redundant may potentially make the transition to other careers, and thus avoiding potential job losses.

> "I think that employees with redundant skills or in redundant occupations can be trained for other positions so that they can be well-equipped when they open another shaft. If they have the underground experience, then they know most of the work."
>
> *Respondent 8, Employer Interview, PGM Mining, 2023*

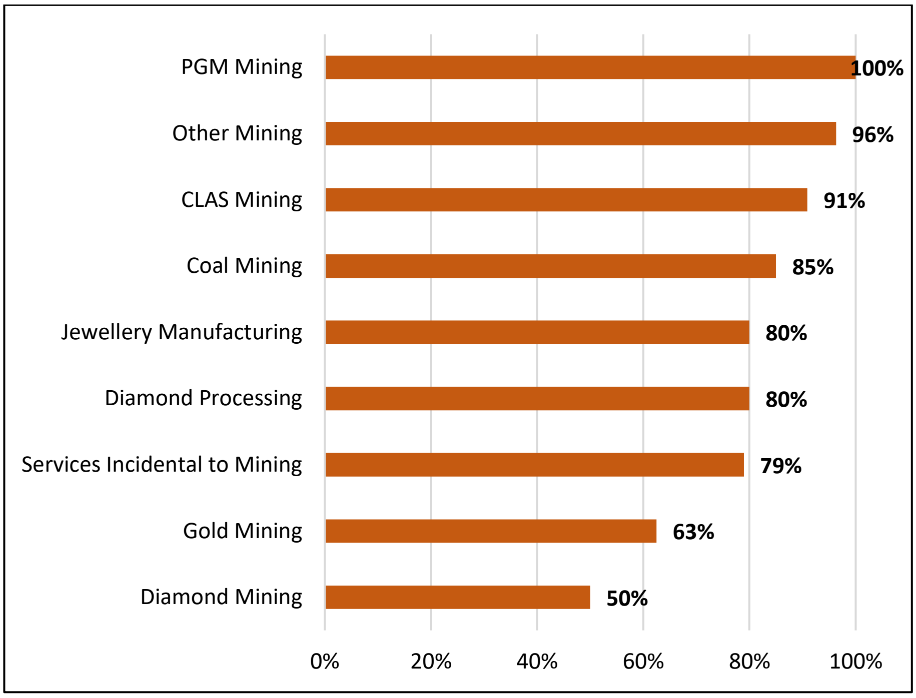
> "We will retrain those that can be retrained using the system…They are used to the operation of the current machines but they will require new skills as the technology evolves - they are qualified artisans."
>
> *Respondent 11, Employer Interview, Coal Mining, 2023*

In this regard, it was noted that some organisations have already commenced with providing 4IR-related training to their employees, with representatives from Labour Unions applauding these efforts from employers. Further discussion on the training initiatives currently being offered to employees by organisations is found in Section 7.

> "What I observe in practice is that many of the employers have multiple programs in place to reskill their personnel. There is, therefore, a genuine effort from current mining companies to reskill their workers and the surrounding communities."
>
> *Respondent 2, Labour/Union Representative Interview, 2023*

Detailed analysis of the findings above was conducted to determine the sub-sectors in which the greatest proportion of stakeholders believe that employees require reskilling/upskilling. This is illustrated in the figure below.

Figure 7-17: Extent to which Employees Require Reskilling/Upskilling, per Sub-sector



Source: MQA Impact of 4IR Survey, 2023

It can be seen above that the PGM, Other mining and CLAS mining sub-sectors have the greatest proportion of stakeholders who indicated that the employees within the organisations they represent require reskilling/upskilling (100%, 96% and 91% respectively). The above results align to findings on the extent to which the nature of work has changed across the mining sector, where the PGM and Other mining sub-sectors represented two of the top 3 sub-sectors in which a change in the nature of work was observed, thus necessitating the acquisition of new skills.

Inferential Analysis

Chi-Square tests, using a significance level of 0.05, reveal no significant relationship between the sub-sector of the organisation and the need for employees to be reskilled/upskilled nor between the mineral extraction technique adopted and the need for reskilling/upskilling, implying that the need for reskilling/upskilling of employees is fairly consistent across both sub-sector and mineral extraction technique and is therefore, unlikely to be influenced by these factors.

Key Finding

It was found that the majority of organisations believe that employees across the MMS require reskilling and upskilling in order to equip them with the necessary 4IR-related skills. This reskilling and upskilling would further enable the employees to be able to transition into new roles should their current jobs become redundant.

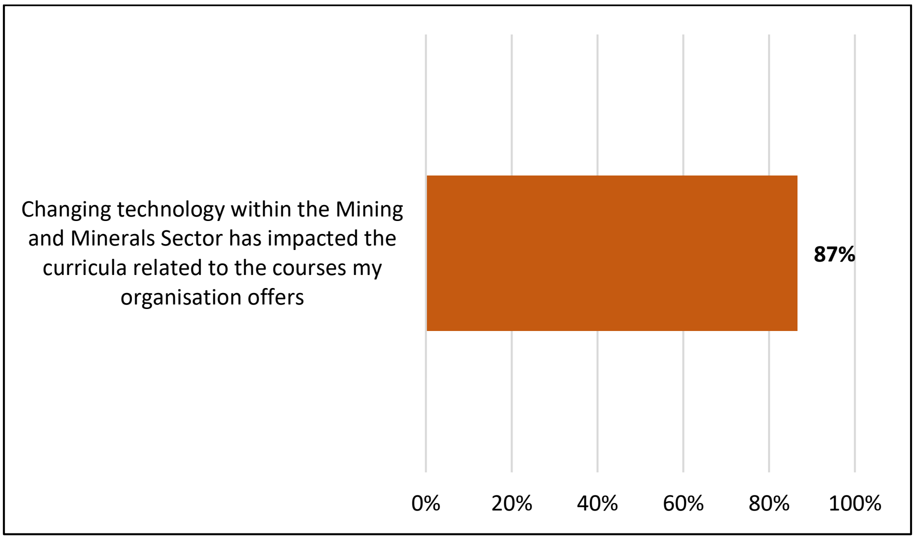
8 Training for Future Skills

A key part of understanding where to focus skills development interventions to meet the demand for occupations and skills emerging as a result of the 4IR, is understanding whether changes are currently occurring to the curricula offered by training providers in response to the changing nature of work and skills and the extent to which employees in the sector are receiving training on the 4IR-related technologies. The training for future skills and the training required should be considered within the context of the changing skills and occupations requirements outlined in the section above, as well as the intentions of organisations to adopt 4IR related technologies, as outlined in Section 5. Beyond providing an illustration of the current 4IR related training offered, this section further provides an overview of the perceived optimum training methods for training on 4IR related skills, as well as the support required by training providers to be able to provide the training.

8.1 Changes to Curricula for Training Providers

To help ensure that training providers' curricula remains relevant and equips learners with the latest skills needed in rapidly evolving industries, it is important to understand the extent to which training providers' curricula has been impacted and is changing as a result of changing technologies. The figure below illustrates the extent to which stakeholders agreed that the 4IR has impacted their curricula.

Figure 8-1: Impact of 4IR on Training Provider Curricula



Source: MQA Impact of 4IR Survey, 2023

It can be noted from the above graph that the majority of the training providers (87%) agreed that the changing technologies have impacted on the curricula related to the courses offered by their institutions. Some training providers indicated that they were constantly required to update training material as a result of the ever-changing and new machinery being adopted.

> "Yes, because remember all your new technology machinery like drill rigs, come with certain procedures of new technology. So, part of that was a lot of change on training material and we have made use of our OEM, and subject matter expert. Those training material had to adapt and to change. We have made use of the OEMs training material for certain machinery."
>
> *Respondent 4, Training Provider Interview, Diamond Mining, 2023*

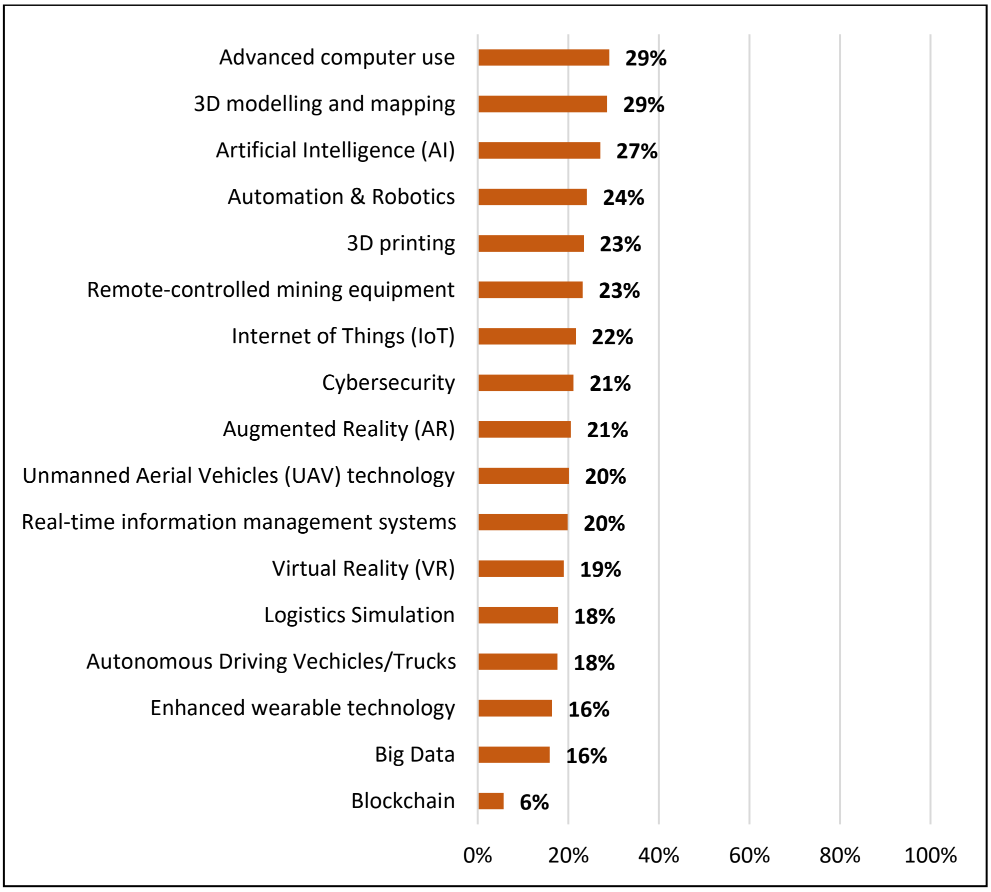
> "Of course, it has most definitely changed because the machines have changed. These are the changes we have had in the industry. Machines are much more technically driven. If you put the machines together, you are looking at 50 million worth of machinery – so the person operating the machinery needs to be trained appropriately."
>
> *Respondent 19, Training Provider Interview, All Sub-sectors, 2023*

Other training providers, however, indicated that they had not been able to adjust their curricula to respond to changing technology as the process for revisions was lengthy and required the involvement of and input from several other stakeholders such as subject matter experts and SAQA.

> "Currently, they haven't had to change much. When you look for example at the learnerships, we are talking about qualifications that last a certain period that get revised by SAQA (i.e. the "Teach Out" period). When they are revised, there are subject matter expertise that are invited to go and review the learning material that has been developed and the qualifications before they can determine whether there is a need for a change and to say this is how training will look going forward. It will take time for the changes that need to happen, firstly because the qualification teach out period may not have been reached, whereby certain things have to be revised and to retrain employees."
>
> *Respondent 6, Training Provider Interview, All Sub-sectors, 2023*

To further understand the extent to which and how training providers curricula were changing as a result of the 4IR, organisations were requested to indicate whether the implementation of 4IR related technologies will require new qualifications. The figure below outlines these findings.

Figure 8-2: 4IR related Technologies for which new Qualifications will be Required[37]



Source: MQA Impact of 4IR Survey, 2023

As noted above, 29% of stakeholders indicated that new qualifications will be required as a result of advanced computer use and the use of 3D modelling and mapping that may occur as a result of the 4IR. Furthermore, 27% and 24% of stakeholders noted that new qualifications will be required as a result of the implementation of AI and automation and robotics, respectively. These findings correlate with findings in Section 6.3.3, which highlighted robotics, AI and 3D simulation as the key technical competencies most likely to be important in the medium term (2 to 5 years). It is, thus, imperative that relevant qualifications are developed in order to ensure that workforces are adequately skilled in the identified competencies.

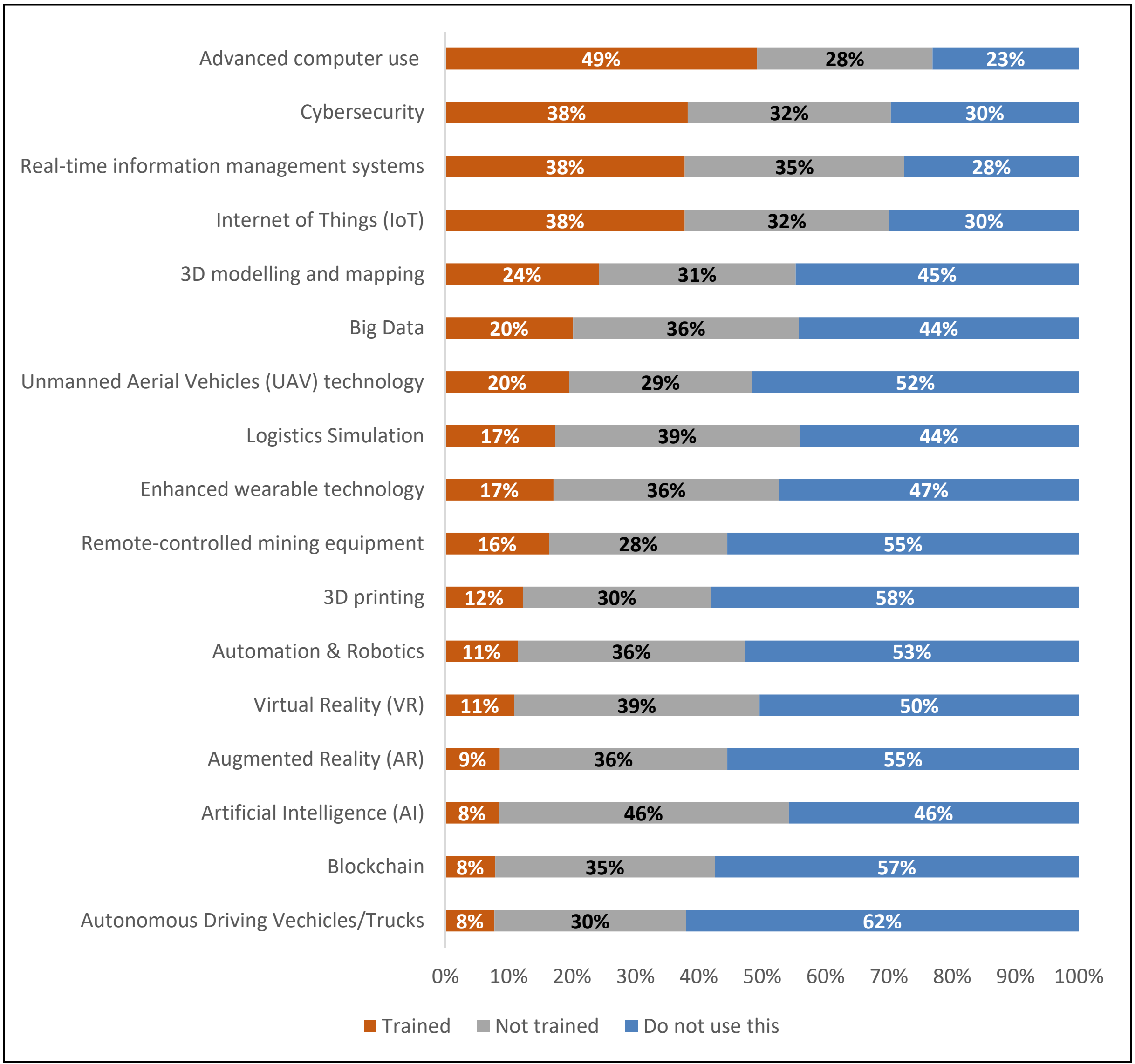
8.2 The State of 4IR-Related Training within the MMS

To understand the skills and training needed to advance the 4IR in the sector beyond identifying the current and required skills, it is crucial to assess the extent of training available for 4IR-related technologies. This may help pinpoint any potential gaps that may exist. The figure below provides an overview of the extent to which employees

[37] Respondents were allowed to select multiple options according to what was most relevant. Each category is to be assessed separately and totals may not add up to 100%

operating within organisations that are currently using 4IR related technologies, are trained on said technologies.

Figure 8-3: State of Training on 4IR-Related Technologies



Source: MQA Impact of 4IR Survey, 2023

As can be seen in the figure above, the 4IR technology which appears to have been adopted by the majority of organisations in the sector is ‘advanced computer use’. Positively, 49% of organisations also indicated that their employees are trained in this technology, with organisations noting during interviews that they had placed focus on providing computer training to their employees to allow them to develop their skills.

> "We have started with the computer training with the community, but now we have brought it closer to our employees. We have built a computer centre within the mine where employees can go during their spare time and learn some skills; but it is difficult because they do not have much time when they are there on duty. In partnership with a service provider, we are looking into opening a computer school in the area where most of our employees are based, where they will be able to go and do basic computer skills for free."
>
> *Respondent 15, Employer Interview, Coal Mining, 2023*

Findings from this study (see Section 7.2.2) identified advanced computer use as one of the top technologies for which jobs are anticipated to emerge within the MMS, as well as one of the top technologies for which the nature of skills will change. From the literature is was also noted that as more technological advancements are introduced, there is a higher demand for a workforce that is digitally fit and have the necessary skills to leverage the advancements (PWC, 2019). As such, it is imperative that emphasis is placed on ensuring that training in this competency is provided to employees within the MMS.

Findings further indicate that there appear to be more organisations with employees that that have not received 4IR-related training than those that have. It is worth noting, however, that this may be attributed to the organisations not using these technologies currently, therefore, limiting the need for said training. Beyond this, interviews with stakeholders highlighted some other reasons for employees having not received 4IR specific training, including financial constraints and focus being placed elsewhere.

> "Not at the moment. It is very much a financial issue. We are very physically focused and manual labour intensive. But what we are doing is we are growing the local community because we are quite influenced by local recruitment. We are growing the local people up into the technologies. So, we are taking a lot of local people in as general workers, then they go on to the drill rigs and the LHDs and the dump trucks. Any training that we will do will be very task and occupation-specific, that is what we are focusing on the moment. So, we are not spending too much time on 4IR focused training yet."
>
> *Respondent 1, Employer Interview, Gold Mining, 2023*

The table outlines the percentage of employees who have not received training on the various 4IR technologies in each sub-sector, from those organisations that currently make use of the 4IR technology. This analysis allows for the differences in the levels of untrained employees across the sub-sectors to be observed and focused interventions to be implemented. The areas highlighted in light green in the table below indicate the top three 4IR related technologies for which employees have not received training.

Figure 8-4: Current Level of Employees without Training on 4IR Technologies

4IR Technology	Coal Mining	Gold Mining	Diamond Mining	PGM Mining	CLAS Mining	Other Mining	Services Incidental to Mining	Diamond Processin	Jewellery Manufactu
3D modelling and mapping	50%	40%	100%	50%	80%	53%	50%	100%	38%
3D printing	50%	100%	100%	50%	100%	60%	91%	100%	36%
Advanced computer use	20%	60%	50%	20%	45%	15%	41%	67%	57%
Artificial Intelligence (AI)	75%	100%	67%	75%	67%	79%	86%	100%	100%
Augmented Reality (AR)	63%	100%	50%	63%	80%	80%	85%	-	100%
Automation & Robotics	63%	100%	50%	63%	67%	58%	100%	100%	80%
Big Data	50%	75%	50%	50%	80%	69%	56%	50%	100%
Blockchain	67%	100%	50%	67%	100%	69%	77%	100%	100%
Cybersecurity	27%	83%	100%	27%	22%	25%	75%	100%	67%
Enhanced wearable technology	56%	80%	100%	56%	40%	56%	85%	100%	100%
Internet of Things (IoT)	25%	60%	33%	25%	63%	29%	75%	100%	80%
Logistics Simulation	73%	60%	100%	73%	67%	56%	77%	100%	100%
Real-time information management systems	33%	75%	100%	33%	45%	36%	67%	75%	50%
Remote-controlled mining equipment	63%	50%	50%	63%	25%	54%	70%	100%	100%
Unmanned Aerial Vehicles (UAV) technology	14%	80%	100%	14%	50%	38%	100%	100%	100%
Autonomous Driving Vehicles/Trucks	71%	100%	50%	71%	100%	64%	100%	100%	100%
Virtual Reality (VR)	60%	100%	100%	60%	100%	57%	85%	100%	100%

Source: MQA Impact of 4IR Survey, 2023

It may be observed from the table above that the Diamond Mining and Diamond Processing sub-sector employees are not at all trained in 3D modelling and mapping and VR. Employees within the Gold and CLAS mining, as well as Jewellery Manufacturing sub-sector also appear to lack training in VR.

While it is important to note the levels of training on 4IR-related technologies in different sub-sectors, it is also important to understand this perspective per organisation size as this may provide valuable insight into the specific training needs and capacities of businesses of varying sizes. The table below brings to light some differences between the training levels and the size of the organisation.

The areas highlighted in light green in the table below indicate the top three 4IR related technologies for which employees have not received training, per company size.

Figure 8-5: Current Level of Employees without Training on 4IR Technologies by Company Size

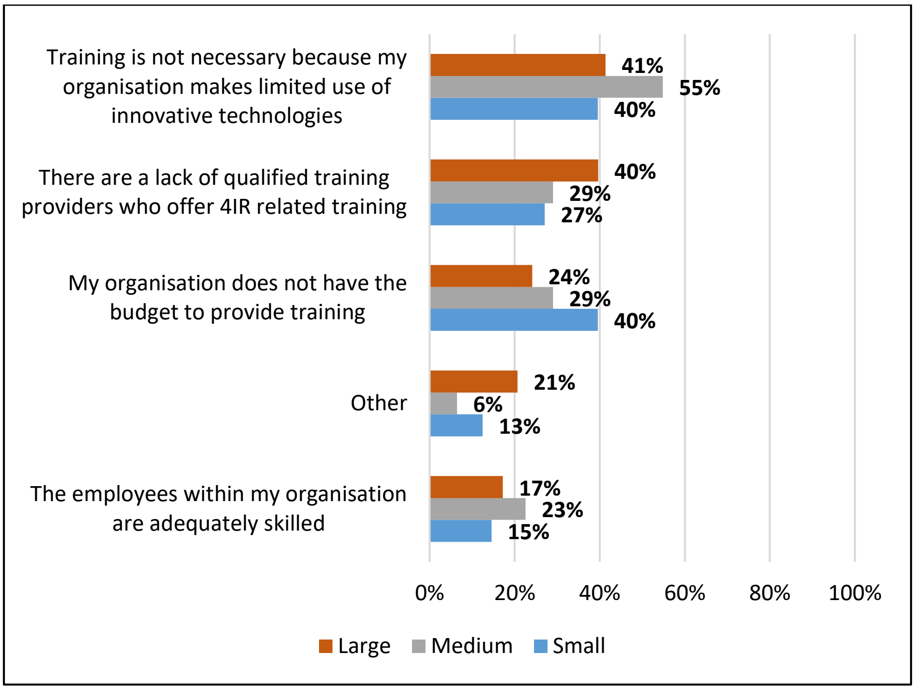
4IR Technology	Small	Medium	Large
Advanced computer use	47%	62%	67%
Real-time information management systems	72%	100%	64%
Internet of Things (IoT)	27%	41%	50%
3D modelling and mapping	82%	88%	86%
3D printing	73%	83%	94%
Cybersecurity	77%	79%	74%
Automation & Robotics	47%	71%	86%
Big Data	72%	92%	88%
Logistics Simulation	26%	53%	76%
Remote-controlled mining equipment	54%	79%	89%
Unmanned Aerial Vehicles (UAV)	23%	79%	63%
Autonomous Driving Vehicles/Trucks	56%	85%	85%
Artificial Intelligence (AI)	38%	55%	62%
Blockchain	47%	75%	81%
Enhanced wearable technology	39%	82%	83%
Virtual Reality (VR)	80%	78%	80%
Augmented Reality (AR)	72%	77%	89%

Source: MQA Impact of 4IR Survey, 2023

As per the table above, it can be noted that employees of small and medium sized organisations lack training in 3D modelling and mapping, as indicated by 82% and 88% of stakeholders, respectively. As illustrated in Section 6.2.2, one of the top technologies for which jobs are anticipated to emerge are 3D modelling and mapping, therefore, it is important to ensure that focus is placed on providing training amongst those organisations where it is lacking. In addition, employees in the small sized organisations also lack training in the VR, which is also one of the top 3 technologies for which jobs are anticipated to emerge.

Further to the above, in order to adequately support skills development related to the 4IR within the MMS, it is key to understand the reasons why organisations have not provided training to employees on certain 4IR related technologies. The following figure provides an indication of these reasons, including a detailed analysis per organisation size.

Figure 8-6: Factors Contributing to a Lack of Training for MMS Employees by Organisation Size[38]



Source: MQA Impact of 4IR Survey, 2023

As per the figure above, most organisations (41% of large organisations, 55% of medium organisations and 40% of small organisations), noted that they did not need to provide training on 4IR related technologies due to their organisations making limited use of said technologies.

Further to the above it may be noted that a key challenge that appears to be hampering the ability of small organisations to provide training is budget constraints, with 40% of small organisations noting this. Another reason for not providing training mentioned by the employers across all organisation sizes, particularly large organisations (40%), is that there is a lack of qualified training providers that offer 4IR related training. During

[38] Stakeholders were allowed to select multiple options. Each category is to be assessed separately and the maximum achievable percentage for each category is 100%. The total sum of these categories may equate to either less or more than 100% due to the questions asked in the survey.

interviews with training providers, it was noted that, at the moment, training providers are not adequately capacitated to provide training on emerging skills.

> "Our organisation is not capacitated, I still have a lot to catch up on and figure out what the mines are implementing, and skills required for such technologies. I would say we would need training, theoretical and exposure. A chance to go to different mines and gain knowledge on all this new equipment being introduced in the sector."
>
> *Respondent 10, Training Provider Interview, All Sub-sectors, 2023*

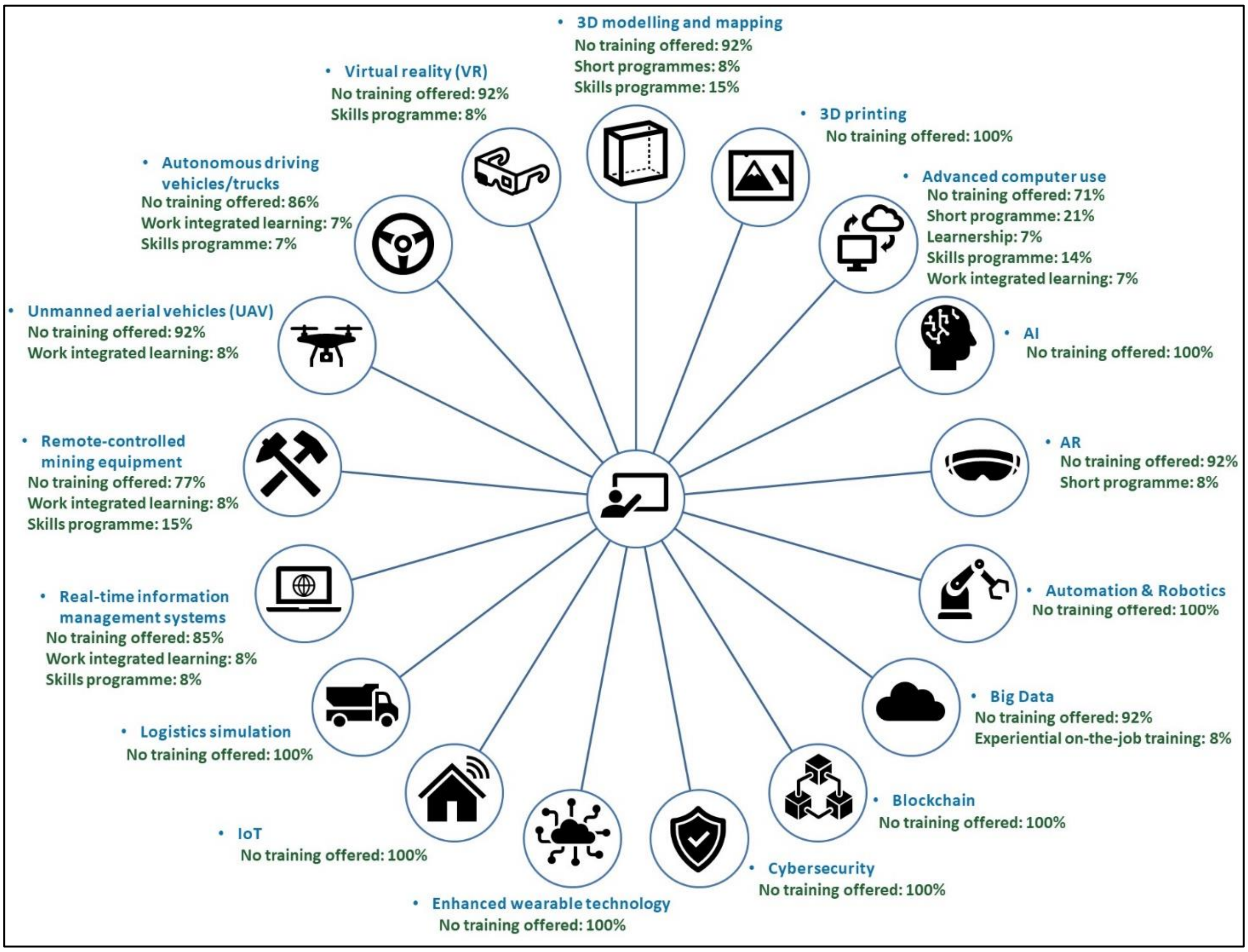
Key Findings

- It was noted that advanced computer use and the development of advanced computer skills were key parts of the 4IR. Notably, 49% of employees have received training in advanced computer use.
- A key reason that appeared to limit the ability of small organisations to provide training on 4IR related technologies was budgetary constraints, whilst for large organisations a lack of qualified training providers was cited as one of the main reasons.

8.3 4IR-Related Training Currently Offered

From the training providers currently offering 4IR-related training or the training providers that have seen 4IR-related training, it is important to determine the extent to which training is offered in each of the different 4IR-related technologies, as well as the different forms of training that are utilised to provide the training. The figure below illustrates the findings.

Figure 8-7: Training Provided by Organisations relating to 4IR Skills



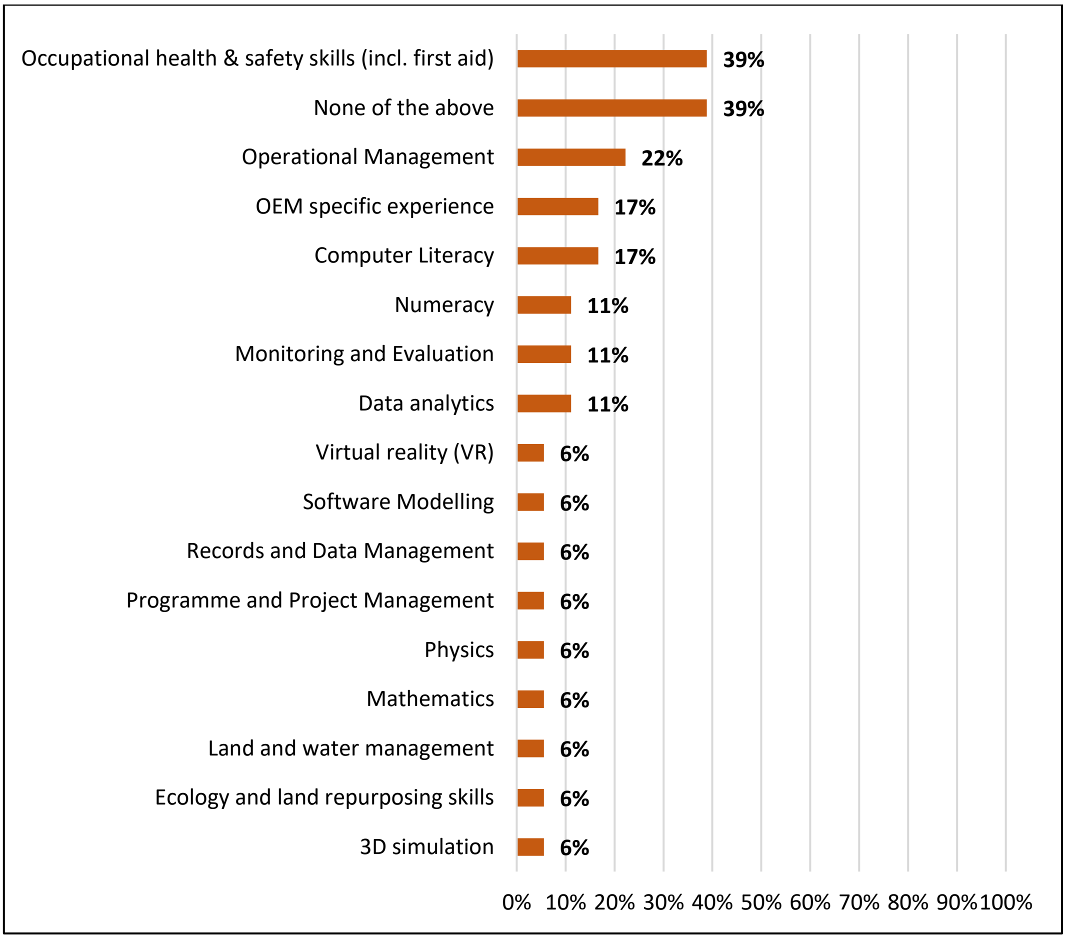
Source: MQA Impact of 4IR Survey, 2023

As can be seen, 100% of training providers do not offer training related to 3D printing, AI, automation and robotics, blockchain, cybersecurity, enhanced wearable technology, IoT, or logistics simulation, with the percentage of training being provided on the other technologies also being minimal. Considering the planned adoption of 4IR technologies such as IoT (indicated by 52% of stakeholders) enhanced wearable technology (51%) and logistics simulation (51%) in the short to medium term (as outlined in Section 5.2), it is key that focus is placed on capacitating training providers to provide training on these technologies. It was flagged, however, during interviews with stakeholders that the ability of training providers to provide training related to 4IR technologies was being limited by a variety of factors, such as the cost of equipment.

> "As we move and progress in the fourth industrial revolution, a lot of things need to be done digitally but the equipment is very expensive. It is difficult for us to do it without the equipment. We have limited funds that don't allow the purchase of new and advanced equipment and doesn't allow for us to teach the students with these technologies. Grants are mainly for the operational costs which are not even enough to cover those things."
>
> *Respondent 3, Training Provider Interview, Jewellery Manufacturing, 2023*

The figure below provides further context to the training currently being provided by training providers.

Figure 8-8: Training Offered by Training Providers



Source: MQA Impact of 4IR Survey, 2023

The graph above indicates that the most trained skill offered amongst training providers are skills that appear not to be related to the 4IR such as Occupational health & safety skills (including first aid) with 39% of training providers offering this skill, as well as Operational Management at 22%. The skills relating to the 4IR that are offered amongst training providers are Computer Literacy (17%) followed by Data analytics (11%) and Virtual Reality (6%). The graph serves as an indication that training on 4IR skills are being offered by limited training providers.

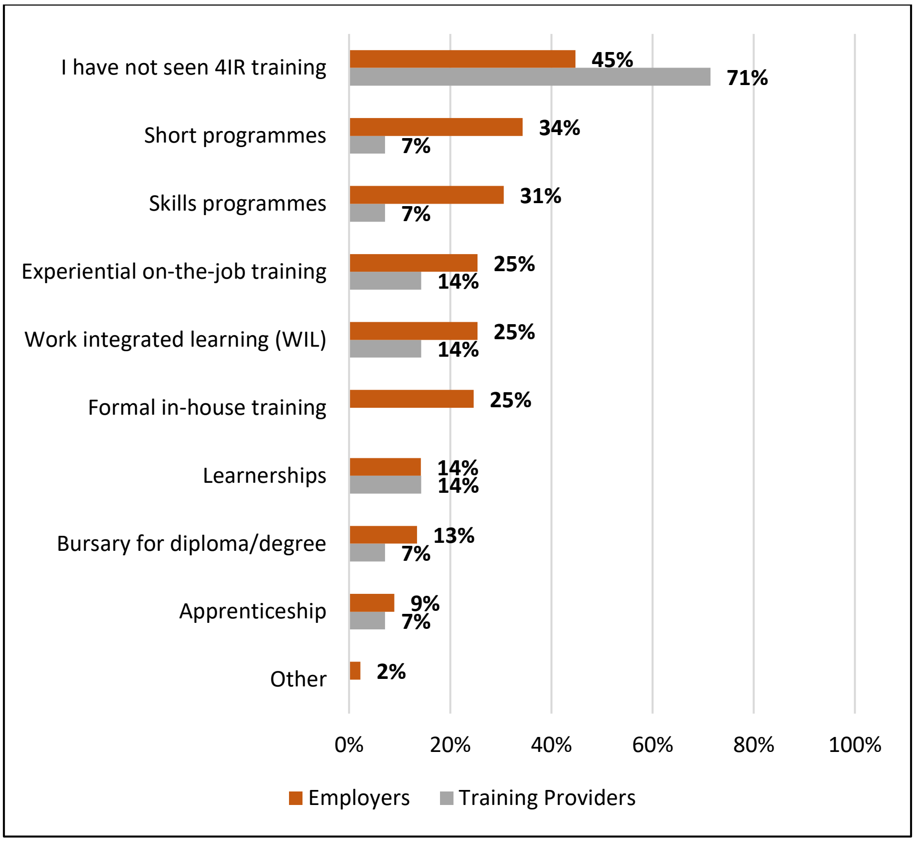
Key Finding

Limited training on 4IR related technologies appears to be offered by training providers currently, with training providers citing challenges such as the cost of equipment hampering their ability to provide training.

8.4 Optimum 4IR Training Methods

In order for training providers to be able to effectively provide training on 4IR skills to stakeholders, it is necessary to ensure that optimum training methods that may be adopted. Therefore, to gain a better understanding of this, employers and training providers were requested to indicate, where they had seen training for 4IR skills, which training method was the most effective. These results are illustrated in the figure below.

Figure 8-9: Optimal Training Methods for 4IR Skills



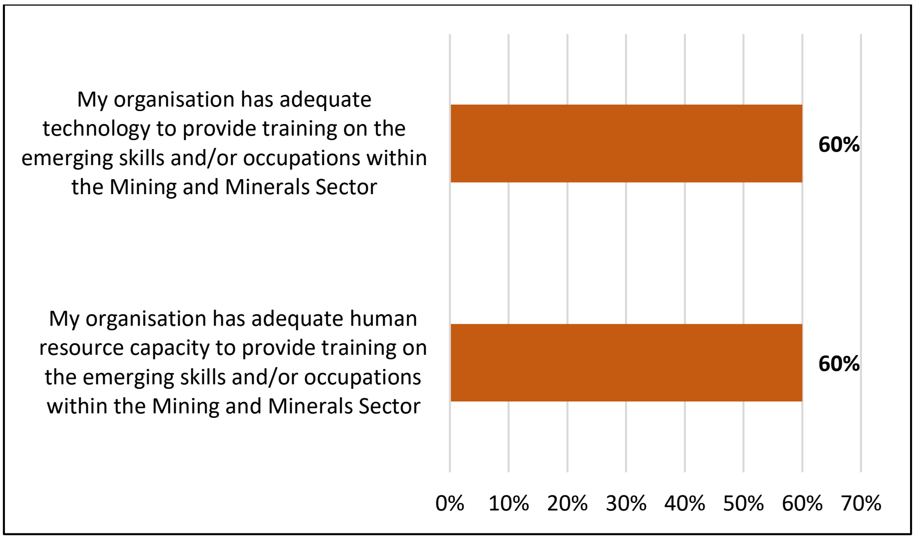
Source: MQA Impact of 4IR Survey, 2023

While many of the stakeholders had not seen instances of 4IR related training, of the stakeholders that had, 34% of employers believed that short programmes worked best, while 31% indicated the same for skills programs. A smaller proportion of employers were of the view that training in the form of on-the-job learning (25%) and learnerships (14%) worked best. While only a small percentage of training providers had seen 4IR related training of those that had, a higher number agreed that experiential on-the-job training, work integrated learning and learnerships were the best methods of training for 4IR skills.

8.5 Capacity to Provide 4IR Training and Support Required

To understand the steps that need to be taken to ensure training for future skills is provided it is necessary to assess the capacity of training providers to provide the 4IR related training, including having access to the adequate technologies and human resources. The figure below provides an overview of the technological as well as human resource capacity of training providers to provide training on 4IR related skills.

Figure 8-10: Resource Evaluation for Emerging Skills Training in the MMS[39]



Source: MQA Impact of 4IR Survey, 2023

It can be seen in the graph above that 60% of training providers agree that their organisations have both adequate technology as well as human resource capacity to provide training on emerging skills and/or occupations within the MMS. These stakeholders indicated that their training staff are able to easily grasp 4IR related concepts and subsequently transfer these to learners.

> "I think we have capable training staff that are able to grasp the new technologies that have been introduced. They are able to adapt and also able to transfer the skills they have."
>
> *Respondent 5, Training Provider Interview, Gold Mining, 2023*

The training providers highlighted some of the approaches they had adopted in order to ensure that they have the necessary capacity to provide training in 4IR related competencies. This included exposing training staff to external training programmes that ultimately equipped them with the basic knowledge and skills in terms of the 4IR.

> "…others were sent out for additional training just to get the basics so that they have enough to transfer the skills. They just have the basics, which is what they are transferring to the learners."
>
> *Respondent 3, Training Provider Interview, Jewellery Manufacturing, 2023*

Other training providers indicated that they always ensure that they align themselves with relevant organisations such as the MQA and training OEMs in order to ensure that they are kept abreast of any new competencies emerging.

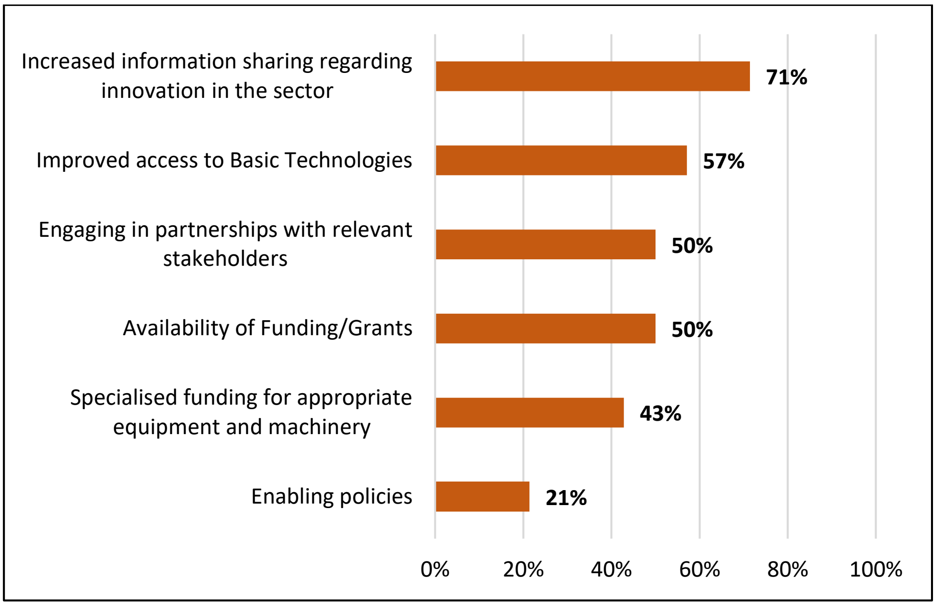
[39] Stakeholders were allowed to select multiple options. Each statement is to be assessed separately and the maximum achievable percentage for each statement is 100%

> "We try by all means to involve ourselves with the MQA if there is any provincial forums so that we are able to keep abreast with what is latest. We also have a good relationship with our institutions of higher learning, whereby we attend forums where there is sharing of information within the mining sector, so that we are not kept away from what is happening in the sector."
>
> *Respondent 5, Training Provider Interview, Gold Mining, 2023*

> "We work very close with a couple of the technology OEMs and mining machine OEMs to make sure that wherever they introduce new technologies we are part of the upskilling of the trainers. There's no need to send trainer out to provide them with additional training."
>
> *Respondent 13, Training Provider Interview, All Sub-sectors, 2023*

Further to the above and in order to identify the resources, infrastructure, and expertise that training providers who weren't sufficiently capacitated required to effectively implement 4IR related training programs, the support required by training providers was assessed. The results are illustrated in the table below.

Figure 8-11: Support Required to Provide Training on Emerging Skills



Source: MQA Impact of 4IR Survey, 2023

As illustrated above, the majority (71%) of the training providers indicated that they require support in the form of increased information sharing regarding innovation in the sector. The stakeholders indicated that continuous engagement with relevant authorities, including in the form of workshops, were key to ensuring that information is adequately shared with regard to emerging innovations.

> "More workshops are required. I think that is how you can get more information from different providers. Then we can have a way forward."
>
> *Respondent 14, Training Provider Interview, Coal Mining, 2023*

> "I think it is to continuously engage stakeholders. For instance, within the mining sector, we have our partners or stakeholders who are the representatives. [We need] to make sure that we keep them abreast of our targets and what training opportunities are available."
>
> *Respondent 5, Training Provider Interview, Gold Mining, 2023*

The availability of funding and grants was highlighted as another key form of support required, as indicated by 50% of stakeholders. The stakeholders noted that the current grants provided by the Sector Education and Training Authority ("SETA") were not adequate in meeting the training needs of learners and were of the view that they can be increased.

> "Look at the grant that we as providers are getting to provide learnerships, we are only getting R35 000 to train a learner. The SETA really needs to look into giving providers enough money so that they don't cut corners so that they give learners what needs to be done."
>
> *Respondent 11, Training Provider Interview, Jewellery Manufacturing, 2023*

Engaging in partnerships with relevant stakeholders was flagged as a key form of support by 50% of training providers with stakeholders noting that through partnerships, they were able to source relevant equipment that they needed.

> "One of the mines that have been supporting one of our projects, they supported in the way of assisting us to buy some of the equipment that we need. I'm hoping to go further with them, supporting us with the enterprise development side."
>
> *Respondent 16, Training Provider Interview, Jewellery Manufacturing, 2023*

> **Key Finding**
>
> The key forms of support required by training providers in order to effectively provide training on 4IR related skills were identified as information sharing sessions, funding as well as partnerships with relevant stakeholders.

9 Key Findings

The following provides a summary of the key findings emerging from the research conducted on the impact of the 4IR, as explored in the sections above. The key findings have been categorised into 6 key themes, as outlined below.

1. Emerging skills and the changing nature of work as a result of the 4IR

Overall, the majority of stakeholders (89%) were of the view that the adoption of 4IR-related technologies had changed the nature of skills within the MMS. Furthermore, the majority of stakeholders observed a change in the nature of work, particularly amongst the PGM mining and Jewellery manufacturing sub-sectors. It was noted that a major contributor to this change is the transition from manual operations to workforces monitoring computers or operating the software controlling the technologies implemented, thus requiring new skillsets and changing the nature of work.

The top soft skills identified for which importance is anticipated to increase for all sub-sectors in the short term include innovative thinking, change management and analytical skills and adaptability, whereas those anticipated to increase in significance in the medium term include judgement and decision making, innovative thinking, problem solving and leadership skills. On the other hand, the top 3 technical skills anticipated to increase in significance in the short term include information systems and advanced IT, digital literacy and computer literacy, while robotics, AI and 3D simulation are anticipated to increase in significance in the medium term. The Diamond processing sub-sector, in particular, expects the need for robotics and technical drawing skills to increase significantly within the next 2 to 5 years.

In terms of occupations, the top 3 occupations highlighted as potentially increasing in demand within the MMS in the next 1 to 2 years include data analysts, information systems specialists and application developers, while those anticipated to increase in demand in the next 2 to 5 years include truck and loader operators and supervisors, autonomous vehicle operators and modelling practitioners.

Stakeholders further indicated that the 4IR related skills required by mid-level employees in the short term include areas such cybersecurity, real time information management systems and advanced computer for middle to senior occupations and basic computer use, autonomous driving trucks/vehicles and remote controlled mining equipment for lower level employees. In the medium term, information management systems, cybersecurity and cloud computing were identified as key areas for middle to senior management, while basic computer use, remote controlled mining equipment and autonomous driving vehicles/trucks remain the key competencies for lower level occupation.

2. Adoption of 4IR-related technologies

The top three technologies that were noted as already having been adopted by organisations include advanced computer use, cybersecurity, and 3D modelling and mapping, with a higher number of organisations in the PGM mining sub-sectors appearing to have adopted the use of 4IR technologies when compared to the other sub-sector while the Diamond mining sector has currently not adopted any forms of technology. It was further noted that the adoption of 4IR technologies still appears to be relatively low, overall and amongst smaller organisations.

The top three technologies organisations plan to adopt within the next 1 to 2 years include real-time information systems, advanced computer use, and IoT. Within the next 2 to 5 years, the top three technologies that will be adopted include advanced computer use (amongst those organisations that have not already adopted this technology), AI as well as 3D modelling and mapping and automation and robotics. Additionally, the Diamond mining sub-sector organisations, which has currently not adopted any of the listed 4IR-technologies, has plans to adopt 4IR-related technologies within the next 1 to 2 years, the most notable being logistics simulation, autonomous driving vehicles, AR, and enhanced wearable technology. Despite this, majority of respondents representing the Diamond mining sector largely do not intend to adopt 4IR-related technologies.

Within the next 1 to 2 years, it was noted that small organisations appear to be planning to adopt more 4IR-related technologies compared to that of medium and large organisations, whilst more medium sized organisations are likely to adopt 4IR-related technologies, compared to that of small and large organisations within the next 2 to 5 years.

3. Development of scarce skills that are key to the 4IR

The majority of respondents agreed that the adoption of the 4IR is being limited by a lack of relevant skills within the sector, particularly within the Diamond Processing and CLAS mining sub-sectors. Within the Jewellery manufacturing sub-sector, it was noted that there appears to be lack of training and workplace opportunities for people to gain the necessary skills, often having to study abroad to receive training and qualifications. Some of the skills that were highlighted as limiting the adoption of 4IR-related technologies included a lack of basic skills, such as reading and writing.

Management and leadership skills were identified as some of the key skills that are anticipated to increase in significance in the short term. It was found, however, that that these skills are amongst the top skills gaps currently in the MMS. It is, therefore, critical that focus is placed on addressing these gaps to avoid them widening further.

4. Support required by MMS organisations and training providers

The main forms of support required by all organisations to adopt 4IR-related technologies include additional funding and grants, availability of reskilling upskilling and skilling/ training opportunities and an increased knowledge of innovations. Some of the key reasons that were flagged by organisations as limiting their ability to provide training on 4IR-related technologies included budgetary constraints amongst small organisations and a lack of qualified training providers amongst large organisations.

It was further noted that limited training on 4IR related technologies appears to be offered by training providers currently, with training providers citing challenges such as the cost of equipment hampering their ability to provide training. These training providers indicated that in order to effectively provide training on 4IR related skills they would require support such as information sharing sessions, funding as well as the facilitation of partnerships with relevant stakeholders.

5. The impact of the 4IR on the MMS organisations and employees

Stakeholders were of the view that the 4IR and the adoption of 4IR-related technologies presents several potential benefits to organisations within the MMS, including business growth, improved competitive advantage, cost savings, improved efficiency and improved safety standards. It was found, however, that there were concerns that the adoption of 4IR-related technologies and the automation of activities may potentially result in job losses for the mining sector, particularly within the Diamond, Gold, PGM and Coal mining sub-sectors. Stakeholders indicated that if retrenchments are to occur the lower-level occupations were mostly likely to be the most vulnerable. This was attributed to the lower level of skillsets possessed by lower-level employees. Occupations such craftsmen, goldsmiths, and bench workers were noted as likely to be impacted should occupations become redundant.

On the other hand, however, stakeholders noted that to-date 4IR-related technologies have not resulted in significant retrenchments across the MMS. Instead, employees impacted by possible retrenchments were rather reskilled so as to allow them to transition into new roles. It was found that the majority of organisations believe that employees across the MMS require reskilling and upskilling in order to equip them with the necessary 4IR-related skills, including 100% of respondents representing the PGM mining sub-sector. This reskilling and upskilling would enable the employees to be able to transition into new roles should their current jobs become redundant.

6. Partnerships and engagement to drive change

Engaging in partnerships with relevant stakeholders is another area that was identified by stakeholders, particularly with Original Equipment Manufacturers (“OEMs”), who are key to the development and transfer of skills to mining organisations and workers. OEMs are responsible for developing and supplying cutting-edge equipment and technologies to the sector. Involving them in the skills development process establishes a direct link between the skills required by the workforce and the technological requirements of the equipment, facilitating seamless integration and optimal utilisation of resources. OEMs are currently being used by mining organisations to transfer the skills needed to operate machinery to their workers.

10 Recommendations

The MQA has a crucial role to play in the preparing the sector's workforce for the 4IR through the development of relevant curricula and facilitating the provision of skilling, upskilling and reskilling opportunities. Because a skilled workforce is a key requirement in order for organisations within the MMS to implement 4IR-related technologies, steps need to be taken to support the development thereof. The specific recommendations below stem from the findings contained within this report and provide the MQA with strategic, practical and innovative ways to respond to the skills development needs, related to the 4IR, in the MMS. It should be noted that the feasibility and cost implications with respect to the application of the below recommendations should be assessed and taken into consideration by the MQA.

10.1 Recommendation 1: Increase the Availability of and Access to Training Opportunities Focused on Core 4IR Skills

The MQA should ensure that there are adequate training opportunities provided that focus on the core emerging skills needed to work within a 4IR environment such as digital literacy, information systems and advanced IT, by collaborating with employers and training providers. Additionally, in order for employees within organisations to access the relevant training needed to implement and operate the 4IR-related technologies that organisations plan to adopt, such as real-time information systems, IoT and logistics simulation, and to prevent any skills gap that may arise, it is recommended that the MQA ensures the provision of relevant training courses related to these technologies.

Activity:	The MQA should identify and develop specific qualifications and unit standards in the form of short programmes and skills programmes related to emerging skills and occupations. Examples of these specific qualifications that have already been developed include the Occupational Certificate: Data Science Practitioner, developed by MICT SETA and accredited by SAQA **(MICT SETA, 2021)**.
Frequency:	Once-off, to be reviewed annually

Further to the above, the MQA should market the developed and accredited training programmes to ensure uptake thereof.

Activity:	The MQA should provide its constituents (i.e., employer organisations registered with the MQA) with a list of 4IR-related, MQA-developed learning programmes to ensure they are informed of ongoing changes within the sector. This list should be made available on the MQA website.
Frequency:	Ongoing

10.2 Recommendation 2: Incorporate Digital Skills/ Literacy into Training Programmes

To facilitate the transition from manual operations to workforces monitoring computers or operating the software controlling the technologies implemented and to meet the evolving demands of the job market, digital skills should be incorporated into training programmes.

Activity:	Introduce basic and advanced level computer courses as a mandatory requirement for the completion of a mining-related qualifications, **including AET and FLC programmes** undertaken by **mine workers.** The MQA should provide resources and support to make basic and advanced level computer courses accessible and achievable for individuals pursuing mining-related qualifications. This may include the provision of grants to training providers specifically to purchase the necessary educational equipment including textbooks, online resources, and software tools, to facilitate the teaching of basic and advanced computer skills.
Frequency:	Once-off

10.3 Recommendation 3: Increase the Development of Soft Skills within the MMS

To address soft skills gaps, as well as to meet the demand as it pertains to the soft skills for which demand will increase within 1 to 2 years, the MQA should consider reviewing and redesigning the existing technical curriculum to include opportunities for students to practice and develop soft skills. This is cognisant of the fact that there is no specific training for the development of soft skills, which necessitates the development of these skills through an integrated approach as part of technical training.

Activity:	Review and redesign the existing technical curriculum (i.e., all mining related learning programmes with a practical and/or theoretical component currently accredited by the MQA) to include opportunities for students to practice and develop soft skills. This can be done through group projects, presentations, and teamwork exercises which may emphasise the development of communication, leadership and team work, innovative thinking and problem solving skills.
Frequency:	Review and redesigning of the curriculum to occur within the next 1 to 2 years, to be updated in line with MMS trends on a biennial basis (i.e., once every 2 years).

10.4 Recommendation 4: Conduct Regular Monitoring of Training Programmes and Skills Initiatives

Given that the occupational and skills needs of the sector are continuously evolving, the MQA should regularly monitor the success and effectiveness of training programmes in meeting the projected skills and occupational demands. To achieve this, the MQA should clearly define the goal of regularly monitoring the success and effectiveness of training programmes in meeting the projected skills and occupational demands within the sector by establishing measurable indicators to assess the success and effectiveness of training programmes

Activity:	Regularly conduct monitoring of the training programmes skills initiatives in line with the clearly defined goals to ensure they remain effective and keep up with industry standards. Measurable indicators must be established prior to implementation of the training programme, so that monitoring can be done against these indicators.
Frequency:	Performance achieved against established measurable indicators to be updated biennially (once every two years). Based on performance against measurable indicators, training programmes to be revised accordingly.

10.5 Recommendation 5: Develop Skills within the MMS to Close Identified Skills Gaps, Placing Focus on Basic Numeracy and Literacy Skills

In order to promote awareness and encourage uptake of programmes that will assist in closing the current identified skills gaps, the MQA should market the current programmes being offered such as the short programme, “Skills Programme: Advanced Generic Management”, to organisations within the MMS.

Activity:	Distribute circulars via email to all MQA registered organisations outlining the training opportunities available for scarce skills and/or skills in high demand, such as management skills, that have been identified through this study and the WSPs submitted by organisations.
Frequency:	Bi-annually

Further to the above, in an attempt to prevent any existing skills gaps widening, the MQA should continue to promote the development of literacy and numeracy skills amongst the current and future MMS workforce, particularly those more at risk of being impacted by 4IR technologies and the implementation thereof, through the provisioning of funding for Foundational Learning Competence Programmes and Adult Education and Training Programmes and the prioritisation of the enrolment of certain individuals on these courses. This may be done through the two key activities noted below.

Activity:	Continue prioritising the provisioning of funding for Foundational Learning Competence Programmes and Adult Education and Training Programmes focused on developing basic literacy and numeracy skills.
Frequency:	Activity to be conducted annually, in line with MQA's discretionary grant planning processes.

Activity:	**Revise funding guidelines for AET and FLC programmes to prioritise the enrolment of individuals belonging to specific occupational groups (such as elementary workers and plant and machine operators and assemblers) into said programmes.**
Frequency:	Annually, in line with MQA's discretionary grant planning processes.

10.6 Recommendation 6: Conduct Information Sharing Sessions

To ensure that Training Providers are adequately prepared to provide training on 4IR-related technologies, it is critical that they stay up to date with emerging 4IR-related trends and the implications on skills training.

Activity:	Develop and conduct information sharing campaigns by hosting workshops, seminars, and webinars; and distributing newsletters to training providers. The information shared with training providers should contain information on 4IR-related changes occurring within the sector, such as emerging skills and occupations, and the implications these will have on training, both in terms of content as well as delivery. While workshops and seminars/webinars may be conducted on a quarterly basis, to ensure that training providers are continuously updated with the latest information, the MQA should create a communication landing page on its website specifically for training providers. All information impacting on training providers, including information on scheduled information sharing sessions, the latest developments in the sector regarding 4IR, changes to policies/regulations, and other relevant information should be posted on this landing page. The communication landing page should be similar to the 'communique' landing page that is currently accessible through the MQA website.
Frequency:	Information sharing sessions, such as workshops, seminars, and webinars, to be conducted on a bi-annual basis. On the other hand, the communications landing page to be updated on a bi-weekly (i.e., every 2 weeks) basis by the MQA's marketing and communications department.

10.7 Recommendation 7: Facilitate Information Sharing on Employment Opportunities and New Career Paths

There is a need to educate stakeholders on the employment possibilities that new technologies make available. This may be achieved by the MQA and other key stakeholders such as the MCSA undertaking roadshows bi-annually, to training centres within the sector to educate learners, current employees and employers regarding new career paths and opportunities available within the mining sector as a result of the 4IR. The roadshows should be conducted separately for learners, as well as current employees and employers, with the focus being on informing the stakeholders on emerging technologies being adopted within the sector, as well as the related skills and occupations required and the opportunities to receive training in this regard.

Activity:	Conduct bi-annual roadshows at training centres within the sector to educate learners and current employees and employers regarding emerging technologies being adopted within the sector, the related skills and occupations emerging as a result, and the available training opportunities within the mining sector as a result of the 4IR.
Frequency:	Bi-annually

10.8 Recommendation 8: Establish Collaborative Forums Between Organisations and OEMs

In order to ensure a seamless integration and optimal utilisation of resources supplied by OEMs into organisational operations, the MQA may consider partnering with or facilitating partnerships with OEMs and MMS organisations to involve OEMs in the skills development process and establish a direct link between the skills required by the workforce and the technological requirements of the equipment. This proactive approach can enhance communication, understanding, and coordination between OEMs and MMS organisations in the skills development process.

Activity:	Establish collaborative forums or working groups that bring together OEMs, MMS organisations and training providers to serve as spaces for ongoing dialogue, where the specific skills needed for operating OEM-supplied equipment are discussed and aligned with training programmes. Additionally, the MQA can create joint initiatives between MMS organisations, training providers and OEMs in order to facilitate the provision of training workshops or educational materials, to bridge the gap between workforce skills and technological demands.
Frequency:	Collaborative forums to occur bi-annually

10.9 Recommendation 10: Adopt and Implement the Framework for Future Skills Needs Identification

In order to keep up to date with changes occurring in the sector and proactively respond to shifting skills needs, the MQA should look to implement the Framework for Future Skills Needs that has been developed, once this framework has been adopted.

Activity:	**Adopt and implement the Framework for Future Skills Needs**
Frequency:	Biennially

11 Conclusion

The purpose of this research was to investigate the extent of adoption of 4IR-related technologies and innovations and the related impact on occupational profiling within the MMS. The findings revealed a minimalistic embrace of 4IR from organisation within the sector, while, of the organisations that have embraced the phenomenon, medium-sized ones have embraced it the most. Key technologies already adopted include advanced computer use, cybersecurity, 3D modelling, real-time information management systems, and IoT. Notably, ongoing plans for further adoption were observed, with real-time information systems, advanced computer use, and IoT being immediate priorities, while the medium-term focus includes advanced computer use, AI, 3D modelling, and automation and robotics. In addition, it was found that small organisations expressed a more immediate intent to adopt 4IR-related technologies, while medium-sized ones have the greatest intent within the mid-term. While some organisations have either already adopted, or plan to adopt 4IR-related technologies, it was noted that others currently experience challenges in adopting 4IR-related technologies. In particular, skills related challenges were identified as key in limiting the adoption. Another challenge limiting the adoption amongst organisations included financial constraints. In this regard, the main forms of support required by organisations to adopt 4IR-related technologies include additional funding and grants, availability of reskilling upskilling and skilling/ training opportunities and an increased knowledge of innovations. Other challenges identified include cost implications, as well as a resistance to change from older generations.

Further to the above, Employers within the MMS expressed a positive outlook on the potential benefits associated with the adoption of 4IR-related technologies, foreseeing business growth, enhanced competitiveness, cost savings, efficiency improvements, and increased safety standards. However, concerns about potential job losses due to automation were raised, especially with the shift from manual tasks to monitoring/operating machinery. While this concern was evident, it is also worth noting that potential job losses may be offset by increases in demand for new occupations. Accordingly, the study identified various occupations anticipated to increase in demand, such as data analysts, information systems specialists, and application developers in the short term. In the medium term, roles including truck and loader operators, supervisors, autonomous vehicle operators, and modelling practitioners are anticipated to increase in demand. Similarly, some skills are also anticipated to increase in significance, with soft skills like innovative thinking and adaptability expected to increase in significance in the short term, while judgement and decision making, problem solving, and leadership skills may increase in the medium term. Among technical skills, information systems, advanced IT, digital literacy and computer literacy are highlighted as likely to increase in significance in the short term, while robotics, AI, and 3D simulation are highlighted as likely to increase in significance in the medium term.

With regard to the impact on employment, the study found that stakeholders generally believe that the adoption of 4IR-related technologies has not resulted in significant job losses thus far. Rather, employees facing potential retrenchments are being reskilled for smoother transitions into new roles. However, there is a consensus that lower-level occupations could be more vulnerable to possible retrenchments due to lower skill levels. Occupations like craftsmen and goldsmiths in particular, are anticipated to be most affected.

The majority (87%) of Training Providers within the MMS also acknowledged that the adoption of 4IR technologies has altered the curricular they offer, with constant updates to curricula required to keep up with the changing skills needs with the sector. This shift necessitates the development of new qualifications, particularly in response to technologies such as advanced computer use and 3D modelling and mapping, with short programmes, skills programmes and on-the-job experience highlighted as the optimal methods of delivering the training. However, while the majority of Training Providers indicated that they have the necessary human and technological resources to provide 4IR-related training, they also indicated a need for additional support in order to effectively provide training, including information sharing sessions, funding as well as partnerships with relevant stakeholders.

It is evident that the 4IR is having a significant impact on the MMS. As a result, the sector must proactively prepare for these changes by equipping the workforce with the necessary skills and knowledge. This preparation is vital to ensure the continued competitiveness, sustainability, and adaptability of the MMS in the evolving landscape of technological advancements. As we navigate this era of rapid innovation, strategic planning and investment in human capital will be essential to harness the full potential of 4IR and secure a prosperous future for the mining industry.

12 Appendix A: Inferential Analysis Outputs

The following table provides the outputs for the inferential analysis conducted for this study and included throughout the Report. Where applicable, chi-square tests were conducted in order to assess the relationship between two categorical variables, to understand whether changes in one are significantly associated with changes in another.

As indicated in the table below, for the purposes of this study, the significance level was set at 0.05 The table below further highlights the chi-square value and critical value for each set of variables that was assessed, indicating whether a correlation or relationship exists between the two variables, or not.

Table 12-1: Inferential Analysis Outputs

Variables	Significance Level	Chi-Square Value	Critical Value	Relationship (Yes/No)
Current Adoption of 4IR Technologies and Size of Organisation	0.05	0.72	5.991	No
Current Adoption of 4IR Technologies and Sub-Sector	0.05	7.35	15.507	No
Current Adoption of 4IR Technologies and Mineral Extraction Technique	0.05	0.45	3.841	No
Planned Adoption of 4IR Technologies and Sub-Sector: Real-time Information Management Systems	0.05	12.07	15.507	No
Planned Adoption of 4IR Technologies and Sub-Sector: Advanced Computer Use	0.05	7.52	15.507	No
Planned Adoption of 4IR Technologies and Sub-Sector: IoT	0.05	4.49	15.507	

Variables	Significance Level	Chi-Square Value	Critical Value	Relationship (Yes/No)
Extent Adoption of 4IR Technologies is being Limited by Lack of Skills and Size	0.05	0.29	5.991	No
Extent Adoption of 4IR Technologies is being Limited by Lack of Skills and Sub-Sector	0.05	6.67	15.507	No
Change in the Nature of Skills and Demand for Upskilling/Reskilling	0.05	13.61	3.841	Yes
Planned Retrenchments and Size of Organisation	0.05	0.13	5.991	No
Planned Retrenchments and Sub-sector	0.05	6.29	15.507	No
Demand for Upskilling/Reskilling and Sub-Sector	0.05	12.71	15.507	No
Demand for Upskilling/Reskilling and Mineral Extraction Technique	0.05	0.80	3.841	No

References