



MANDELA MINING PRECINCT
MINDS FOR MINES

Article:

**THE ERGONOMIC STATUS OF MODERN MINING
EQUIPMENT USED BY WOMEN IN MINING
TOWARDS SUPPORTING HEALTH AND SAFETY
SATCAP & LoCM/MMS 2023**

About the Mandela Mining Precinct

The Mandela Mining Precinct is a Public-Private Partnership between the Department of Science and Innovation and the Minerals Council South Africa. The Precinct is jointly hosted by the Council for Scientific and Industrial Research and the Minerals Council. The Mandela Mining Precinct is an initiative aimed at revitalising mining research, development and Innovation in South Africa to ensure the sustainability of the industry. This is achieved through the South African Mining Extraction, Research, Development and Innovation (SAMERDI) strategy.

The strategy comprises six research programmes:

1. **Longevity of Current Mining;**
2. **Mechanised Mining Systems;**
3. Advanced Orebody Knowledge;
4. Real-Time Information Management Systems;
5. **Successful Application of Technologies Centred Around People;** and
6. Test Mine.

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INTRODUCTION

1.1. CONTEXT AND NEED FOR THE STUDY

The South African mining sector is considered a labour-intensive industry, characterised by manual drilling methods with blasting and cleaning on a stop-start basis (Minerals Council, n.d.). These extractive methods used in deep-level mining have remained unchanged since the 1900s particularly in gold and platinum group metals (PGM) mines (Minerals Council, n.d.). These methods are unsustainable and physically demanding, and present health and safety challenges, decreased production and are costly. Furthermore, they hamper job creation and retention of women in the mining environment due to the physicality and high stamina demand of mining operations (Pelders and de Riddler, 2020).

To address the health and safety challenges, job creation and retention, increased production and longevity of mines, the industry is making a move towards mining modernisation. Modernisation helps improve health and safety, with an objective to achieve zero harm to people and the environment, extend the longevity of mines and job creation and retention (Minerals Council, n.d.). Mining modernisation creates inclusivity of historically discriminated and underrepresented groups in the industry, by creating physically safe and attractive careers for women. One critical focus on modernisation is the development of new mining equipment and systems, that follows a people-centric best practice approach to equipment design and development (Minerals Council, n.d.).

The ergonomic features of some traditional mining equipment such as manual drill rigs or load haul dump do not fully support the physiological make-up of women; operating such machinery can prove to be dangerous and uncomfortable and consequently have a negative effect on the overall health of these women (Botha et al., 2012). Modernisation of mining operations, such as employing automated equipment removes miners from the rock face with potential risks to operating low-profile and multi-functional machinery remotely or from a safe and healthy distance (Minerals Council, n.d.). This has a potential of increasing the participation of women in core mining operations.

As mining modernises, modern mining equipment is being used. This project report discusses the ergonomics of modern mining equipment used in underground mining in consideration to the health and safety of women. Modern mining equipment use may enable increased women participation and contribute to the health and safety of women. The methodology to be employed will include a desktop literature review.

1.2. BACKGROUND

Mining is one of the major contributors to the South African economy. Although plagued by many challenges, including safety-related issues, it remains on the forefront of job creation and community development (Botha and Cronje, 2015). Historically, mining was a male-dominated industry, particularly in underground mining due to the physicality and high stamina demand of the mining operations. Women in underground mining encounter multiple challenges although not limited to women operators, related to safety and healthy. Nevertheless, the number of women entering the underground mining environment is gradually increasing (Pelders and de Riddler, 2020)

Various protocols, initiatives, and legislature has been introduced to promote gender equality, increasing the participation of women in the mining industry (Botha, 2017). With the introduction of the Mineral and Petroleum Resources Development (MPRDA) Act 28 of 2002 and accompanying Broad-Based Socio-Economic Empowerment Charter for the Mining and Minerals industry, 2018 (Mining Charter, 2018), women are to make up 10% of the mining workforce (Botha, 2017). Both the MPRD Act 28 of 2002 and the Mining Charter, 2018 were established to address and reform drawbacks within the mining industry, particularly on the inclusion of historically disadvantaged populations, including women. As such, more employment opportunities for women were created in both surface and underground mining contexts. Women being incorporated into the mining workforce implies that women perform similar tasks to their male counterparts.

Female miners' safety continues to be the main challenge in mining operations (Inside Mining, 2020). Underground mining activities are extremely physically demanding, and for most women, due to their inherent physiological restrictions, participating in such activities such as manual drilling processes causes occupational health and safety challenges (Botha & Cronje, 2015). Gender diversity is impacted by modernisation (digitalization, automation, and Artificial Intelligence (AI)), and this redesigns the mining work environment and increases participation of women in core mining operations. Modernised mining equipment removes technical and physical barriers for women, and makes it possible to operate equipment remotely, away from mine sites, which may be appealing to women who have not previously considered the industry (Inside Mining, 2020). Modernised mining equipment include digital visualization of underground operations from remote control rooms above surface. This improves occupational health and safety, further improving access to job for women (Tekinbas and Ramdoo, 2021).

1.3. PROBLEM STATEMENT

Working in the mining industry is associated with physically demanding conditions, and certain mine activities pose greater challenges for women compared to men due to differences in work capacity and physical

strength. Moreover, traditional mining equipment has been identified as a hindrance to women's participation in core mining operations (Cronje, 2015). The current mining equipment used by women lacks appropriate ergonomic design considerations. This lack of ergonomic features can lead to discomfort, physical strain, and potential health issues for female miners. The absence of suitable ergonomic features in mining equipment for women poses safety risks and can contribute to occupational hazards. It is crucial to address these concerns to ensure the well-being and physical safety of women working in the mining industry. Underground mining equipment often demands significant physical strength to operate effectively. However, these strength requirements may not align with the physiological characteristics and capabilities of women. This mismatch can result in increased fatigue, reduced productivity, and potential musculoskeletal injuries.

1.4.RATIONALE OF STUDY

The mining industry is known for its physically demanding nature, and it is crucial to ensure the health and safety of all workers, including women. However, the specific challenges faced by women in this industry, particularly related to the ergonomic status of mining equipment, have not received adequate attention.

The rationale for this study is to investigate the ergonomic status of modern mining equipment used by women in mining operations and its implications for health and safety. By focusing on the ergonomic features of mining equipment designed for women, the study aims to address the existing gaps in knowledge and contribute to the overall well-being of female miners.

Furthermore, the study recognizes the importance of considering the physiological characteristics and capabilities of women when designing mining equipment. Underground mining equipment often demands significant physical strength to operate effectively, which may not align with the unique physiological characteristics of women. This mismatch can further exacerbate the challenges faced by female miners and increase the risk of work-related injuries. Therefore, exploring the ergonomic features that can better accommodate the specific needs of women becomes imperative to ensure their comfort, safety, and overall job satisfaction.

1.5.AIMS AND OBJECTIVES

The aim of this study is to discuss the ergonomics of modern mining equipment used in underground mining in consideration to the health and safety of women in mining operators.

This study looked into:

- Report how the mechanization of Load haul dump equipment accommodates the health and safety of women in the underground mining environment
- Evaluation of challenges and benefits with the current modern mining equipment
- Investigate how modern mining equipment enables women in underground mining positions
- Investigate if there is increased participation in underground mining due to the use of modern mining equipment
-

1.6. ETHICAL CONSIDERATIONS

This study is subject to ethical considerations as it involves human participants. Ethical clearance was not obtained due to time constraints. Participants must voluntarily provide verbal consent to participate in the research study. The identity of the participants will remain anonymous for the purpose of the study.



Methodology

2.1. INTRODUCTION

As mining modernises, modern mining equipment is being used. This project report discusses the ergonomics of modern mining equipment used in underground mining in consideration to the health and safety of women. Modern mining equipment use may enable increased women participation and may contribute to the health and safety of women.

Data was gathered by conducting a literature search utilising various database, supplemented by interviewing industry stakeholders. All interviews were conducted in english, virtually and in person. Interviews were recorded with the respondents' permission, and notes were taken.

This section outlines the research methodology adopted for the study.

2.2. QUALITATIVE METHOD

This research study will utilise qualitative research methods as data gathering will be conducted through literature search using multidisciplinary databases; CSIR catalogue, google scholar, and mining weekly.

2.3. DATA COLLECTION AND RESEARCH INSTRUMENTS

Desktop literature review

To probe deeper into the topic, a literature search was undertaken using various databases, including Google Scholar, CSIR catalogue, and Mining weekly, to identify influential papers in these research domains. The research was limited to the keywords 'Health and Safety of women in mining,' 'Ergonomics of modern mining equipment on women,' and 'Mining equipment modernisation and women in mining. A desk-top review was conducted.

2.4. LIMITATIONS TO THE METHODOLOGY

The Limitations of this methodology are described as follows. Firstly, the research study focused on remote-controlled load haul dump in underground gold mines, however access to equipment and information was restricted to publicly available information. Secondly, there was no physical access to a mechanised mine utilising remote controlled load haul dump, thus no female operators' interviews were conducted.



Literature

3.1. INTRODCUTION

Over the last decade, mining productivity in South Africa has reduced by 7.6%, with mining cost inflation increasing to 2-3% than general inflation per annum. Mining output has declined by 10% and mineral sales contracted by 11%. Additionally, the sector struggles with global challenges, such as climate change and environmental, social and governance (ESG) issues that are important in global competitiveness assessments (PwC & MCSA, 2021). These demands are providing the mining industry an opportunity to increasingly make use of innovative and modernised mining systems and equipment to run efficient operations, improve health and safety, mitigate risk, reduce the cost of maintenance and extraction and skills development (PwC & MCSA, 2021).

Mining modernisation utilises a people-centric, 4IR-enabled modernisation strategy that provides solutions to issues faced by the mining industry to best compete globally. Mining companies are gradually investing in adoption of digital technologies with an aim of connecting machines to visualize their data and connect people and assets to provide insights (PwC & MCSA, 2021). Among increased production per capita and reduced operational costs, Improved health and safety is highlighted as one of the main benefits mining companies are investing in digital technologies. Health and Safety benefits are not limited to collision avoidance and environmental monitoring, but improved employee engagements (PwC & MCSA, 2021).

3.2. BENEFITS AND CHALLENGES OF MINING MODERNISATION FOR WOMEN

Health and safety are a major concern for mining companies, and the sustainability of the industry. Mining companies are to provide for protection of health and safety of all employees in the mines and minimise the risks relating to health and safety (Mine health and Safety Act, 1996). Furthermore, as far as reasonably practicable, ensure that mines are commissioned, maintained, operated, and decommissioned that employees can perform their work without endangering the health and safety of themselves or others. However, use of conventional mining equipment creates physiological problems with accommodating women due to their mechanical effects.

Legislature has been introduced to promote gender equality in the workplace, including in the mining industry. These laws aim to eliminate discrimination against historically disadvantaged persons, including women and ensure that they have equal access to opportunities, training, and promotion. One example is the Mining Charter, which requires mining companies to develop plans to promote gender diversity and create equal opportunities for all employees in the workplace. The Charter also requires companies to report on their progress toward meeting these targets (Government-Gazzet, 2018).

The Minerals and Petroleum Resources development Act 28 Of 2002 and the Mining Charter, 2018 were among other objectives, established to generate more and better jobs for women in mining and address structural barriers faced by women (International labour organisation, 2021). In addition, addressing restrictive jobs that women can participate in and practices that aggravate gender-based discrimination.

To address some of these challenges, the mining industry is digitally transforming and mining companies are investing in the adoption of modern technologies. Investment in digital technologies translates to a safer working environment for employees (PwC & MCSA, 2021). One critical aspect is automation of equipment which can improve safety in underground conventional operations, using advanced systems that collect and analyses data combined with automation to identify unsafe working conditions for immediate intervention (PwC & MCSA, 2021). Modernised mining equipment include digital visualization of underground operations from remote control rooms above surface and automated collision avoidance both supported by automation. This improves occupational health and safety for all and will further improve access to job for women (Tekinbas and Ramdoo, 2021).

Increased participation of women can be anticipated as supported by the benefits of modernisation and use of 4IR tools such as automation as previously mentioned. Since women struggle with the physicality of conventional mining operations and inherent conventional equipment, for example, severe vibrations emitted by the load haul dump, adoption of digital technologies provides women the opportunity of being involved in core mechanised mining operations (PwC & MCSA, 2021). Women can operate digitized equipment remotely, removing them from the rock face and place them at a safe distance. Furthermore, the demand of strength and resilience are eliminated, supporting their health and safety in the workplace (International labour organisation, 2021).

Advantages of mining modernisation are not only limited to the health and safety of operators improved by equipment digitization, but also helps address traditional gender stereotypes within the industry (International labour organisation, 2021). Masculinity was associated with miners and the mining environment, along with the demand for strength and survival in difficult situations, thus, birthed a notion that women due to their physiological nature were ill-suited for the underground operations and limited to above surface duties in administrative roles or health clinics within the mines (International labour organisation, 2021). Modernisation eliminates these gendered notions as women can now be involved in all mining activities.

The 4IR tools that are implemented in mining modernisation to improve health and safety of operators will aid mining companies in identifying and eliminating hazards, control and minimise the risks relating to health and safety of the miner, circumventing the negative impacts of conventional equipment on the physiology of women (Mine health and Safety Act, 1996). In addition, improve reporting cycles to regulate the employee's

duties to identify hazard, control and minimise risk to health and safety (Mine health and Safety Act, 1996; PwC & MCSA, 2021).

A direct consequence of digital transformation is the change in the nature of the workforce and growth of new skilled positions equating to increased level of productivity per person. There is a significant departure from the historic mining skills profile and mining companies are investing in reskilling and upskilling the current workforce to equip staff with digital skills, this supports the Social and Labour Plan (SLP) requisites for implementing career progression plans in the mining industry for women (HDI) (Social and Labour Plan Guidelines, 2010). It is envisioned, this legislatively supports the increased participation of women in the mining sector as per the MPRDA Act 28 of 2002 and the accompanying Mining charter (MPRDA, 2002; Mining Charter, 2018)

It is predicted that adoption of digital technologies will help maintain the social licencing to operate of mining companies, focusing on social labour planning by helping companies with their commitment to local communities. As a pre-requisite for granting of mineral rights, mining companies are mandated by the MPRDA (Act 28 of 2002) to submit a SLP plan, inclusive of an employment equity plan and a career progression plan. As historically disadvantaged individuals, women are to participate in core occupational categories in the mining industry to ensure diversity (Social and Labour Plan Guidelines, 2010). And develop individual plans for employees, however not neglecting following normal procedures. Consequently, adoption of digital technologies (automation), will increase the probability of increased participation of women in core mining operations and maintain compliance of mining companies with the objectives of the MPRDA act.

Challenges

Literature suggests that mine digitization and remote controlling have the potential to significantly improve safety, efficiency, and productivity in the mining industry. However, there are also significant challenges associated with implementing these technologies including the high cost of implementation and the need for specialized training (PwC & MCSA, 2021). Mining companies are using Virtual Reality (VR) tools for health and safety, such as drilling training to lessen standing time and manage risk in underground operations. However, there are high costs associated with digital training and onboarding (PwC & MCSA, 2021). Implementation of digital technology will impact the number of jobs as reskilling the entire workforce to be digitally competent would be impractical. There is an expected change in the skills of employees, with transition to more skilled employees thus an increase in labour costs due to higher salaries (PwC & MCSA, 2021).

Automation translates to remote human supervision of equipment or the entire operation but results in a lower number of operators reducing the number of jobs in the industry, reducing opportunities for women to participate in mining operations (Bhattacharyya et al., 2023). To comply with the social and labour plan

regarding potential social and economic impact, processes need to be outlined including training and portable skills development (Social and Labour Plan Guidelines, 2010).

Although not all mines can be mechanised, adoption of digital technologies can help identify hazardous environments in non-mechanised mines and improve the health and safety of operators, through speedy reporting cycles through mobile tools in underground operations (PwC & MCSA, 2021).

3.. MINING EQUIPMENT MODERNISATION AND WOMEN PARTICIPATION

According to a study conducted by Botha & Cronje (2015) there is significant growth in the number of women employed in the South African mining industry, rising from approximately 11,400 in 2002 to 54,154 women in 2018. Approximately 12% of the mining workers are women (Minerals Council, 2022). These women operators, though in low numbers are employed in all sectors of the mine. Additionally, there is a notable increase of women participating in underground mining operations. This increase has brought to light several challenges women face in the industry, including ergonomic issues with mining equipment (Botha & Cronjé, 2015).

Mining modernisation will create significant opportunities for women in the industry. As mining becomes more mechanised, physical strength and stamina will be less essential to operate the equipment (Minerals Council, 2018). Modernisation can increase participation of women in mining by updating policies and practices to promote gender equality in the workplace. In addition, skill diversification - modern mining methods and technologies require a broader range of skills beyond physical strength, such as data analysis, automation, and environmental management. This shift allows women to contribute their diverse skill sets and expertise, creating a more inclusive and innovative work environment.

Adoption of digital technologies will improve health and safety contributing to employee engagement, and positively impacting workplace dynamics and foster a more inclusive culture. It can lead to improved communication, increased collaboration, and better overall working conditions and increasing the visibility of women in the mining industry. The inclusion of women in the mining industry can lead to economic empowerment for them and their families. By accessing well-paid jobs in mining, women can contribute to their households' income, improving their financial independence and social status.

Although it is predicted that digital transformation of the mining industry will have a positive impact on increased women participation, there are challenges including workplace culture and harassment and gender stereotypes (Botha, 2017). Deep-rooted gender stereotypes and biases may hinder women's progress in the mining industry. These stereotypes often associate mining with physical strength and are often reinforced by cultural norms. Modernisation helps overcome these stereotypes as women can now be involved in all

mining operations and perform as their male – counterparts. In light of modernisation, mining companies can invest in awareness campaigns aimed at reducing gender bias and promoting inclusivity in the workplace, to create a supportive environment for women which will impact participation and retention of women in mining roles (Nunkoob, 2019).

3.4. RETROSPECTIVE VIEW OF TRADITIONAL LOAD HAUL DUMP

The retrospective view of traditional Load Haul Dump (LHD) operations in underground mining reveals a multitude of challenges that significantly impact the health and safety of LHD operators. The harsh production environment, characterized by hostile interspaces filled with dust, noise, and humidity, poses serious risks to the well-being of the operators. Additionally, the presence of narrow tunnels with poor illumination further exacerbates the operational difficulties. Moreover, the traditional LHDs consume a high amount of energy while operating with low efficiency, further compounding the challenges faced by operators. These challenges collectively contribute to high safety risks and increase the likelihood of accidents, as operators often experience fatigue while driving the machines. Ensuring the proficiency and stability of LHD operations becomes a critical factor in enhancing work efficiency (Xiao, et al., 2022).

In light of these challenges, guaranteeing the safety and effectiveness of LHD operations remains a significant concern. The demanding working conditions underground necessitate proactive measures to address the health and safety risks faced by LHD operators. Improving the design and functionality of LHDs can contribute to mitigating these challenges. Implementing ergonomic features such as enhanced operator comfort, better visibility, and improved noise and vibration control can reduce operator fatigue and enhance their performance. Furthermore, incorporating advanced technologies and automation into LHD operations can improve overall efficiency and reduce the reliance on human operators, thereby minimizing safety risks. To achieve optimal work efficiency and ensure the well-being of LHD operators, a comprehensive approach that encompasses ergonomic design, technological advancements, and effective training programs for operators should be adopted (Löw, 2019)

3.5. INNOVATION OF AN AUTONOMOUS LOAD HAUL DUMP

An Autonomous Load Haul Dump (LHD) is a type of mining equipment that is operated without human intervention. In the South African mining industry, autonomous LHDs have been used to improve safety, increase productivity, and reduce costs. One example of an autonomous LHD used in the South African mining industry is the Sandvik LH621i. This machine is equipped with advanced technology, including a digital control system, sensors, and cameras, that allow it to operate autonomously in underground mining environments. The Sandvik LH621i can be remotely controlled by operators who are located on the surface or in a control room, which allows them to monitor the machine's performance and adjust as needed.

The use of autonomous LHDs in the South African mining industry has several advantages. First, these machines are safer to operate than traditional LHDs because they can operate in hazardous environments without exposing workers to risks such as rock falls or gas leaks. Second, autonomous LHDs are more productive than traditional LHDs because they can operate continuously, without the need for breaks or shift changes. Finally, autonomous LHDs are more cost-effective than traditional LHDs because they require less maintenance and downtime, which reduces the overall cost of operation.

The use of autonomous LHDs in the South African mining industry represents a significant technological advancement that has improved safety, productivity, and efficiency in the mining sector. Digitalization and automation are taking South African mines to the next level. Gold Fields South Deep mine has started applying these technologies to improve employee's health, safety, and productivity of the mine. The LHD is operated from the surface using tele-remote technologies. Machine-Human interaction poses a risk to the health and safety of mining employees, to help alleviate this problem laser barriers are used to prevent the interaction between miners and machines. The machines are designed to stop when the barriers are broken, additionally miners can be detected by the onboard guidance system which will also automatically stop the machine (Macnamara, 2022).

Initial analysis has shown that even though automated LHDs run slowly compared to the physically operated ones, they have other advantages derived from the limited human intervention when they are in operation. Some of the advantages include lower maintenance cost, improved machine availability and utilization. Reduced incidences due to limited personnel working underground is a big plus towards the strategic objective of zero harm. Due to the onboard guidance system, collision free shifts are always achieved. The LHDs have efficient self-driving capabilities which frees the operators time to switch between multiple machines to execute the digging function (Macnamara, 2022).

Mine digitization and remote controlling are two technologies that are becoming increasingly popular in the mining industry. The technology includes a variety of unmanned equipment, including a rock-drilling jumbo, underground mining trucks, and a loading machine.

Loading and hauling plays an integral role in mining operations both underground and surface mines. The loading and hauling machine of choice for a particular mine must be able to maneuver the sharp curves and harsh underground conditions (Lewis, 2018). Over 75% of the underground mines in the world use LHDs for loading and hauling blasted ore from the face or draw points to the tip (Tatiya, 2013).



Analysis of Findings

4.1. WOMEN PARTICIPATION IN THE MINING INDUSTRY

Women comprise approximately 12% of the mining sector in South Africa, placing it behind other countries worldwide. It falls behind mining nations like Australia and Canada, where female participation in mining stands at 17% and 16% respectively, although still relatively low. One of the main reasons for the higher participation of women in mining in these countries is the process of modernization that has taken place in their mining industries. Australia and Canada have made significant efforts to modernize their mining operations by implementing advanced technologies, automation, and safer working conditions (Minerals Council South Africa, 2020).

These advancements have helped to reduce the physical demands and risks associated with mining, making it more appealing and accessible to women. Additionally, the modernization of the mining sector has also resulted in the creation of diverse job roles beyond traditional manual labour, opening opportunities for women with a wider range of skills and expertise. In contrast, South Africa's mining industry has been slower to adopt modernization measures, which has contributed to the lower participation of women. To increase female representation in the mining sector, South Africa needs to prioritize modernization efforts, invest in technology and safety measures, and create a more inclusive and supportive environment that attracts and retains women in the industry.

It is important to note that the mining industry in South Africa lags behind other industries in terms of employing women, as indicated by the statistics below (Statista Research Department, 2023). This emphasizes the need for the mining industry to improve its gender representation and opportunities for women. The mining industry is known for its demanding working conditions and potential hazards, which can create barriers and deterrents for women seeking employment in this sector. The physically challenging nature of the work, coupled with safety concerns, has historically contributed to the underrepresentation of women in mining (Hlangabeza, 2018).

To promote gender equality and harness the full potential of the workforce, the mining industry must prioritize initiatives such as modernization. By embracing technological advancements and automation, the industry can reduce the physical strain and hazards associated with mining operations. This not only creates a safer work environment but also opens up opportunities for women to participate in roles traditionally dominated by men. Modernization can also contribute to the development of more flexible work arrangements, allowing women to balance their professional and personal responsibilities more effectively.

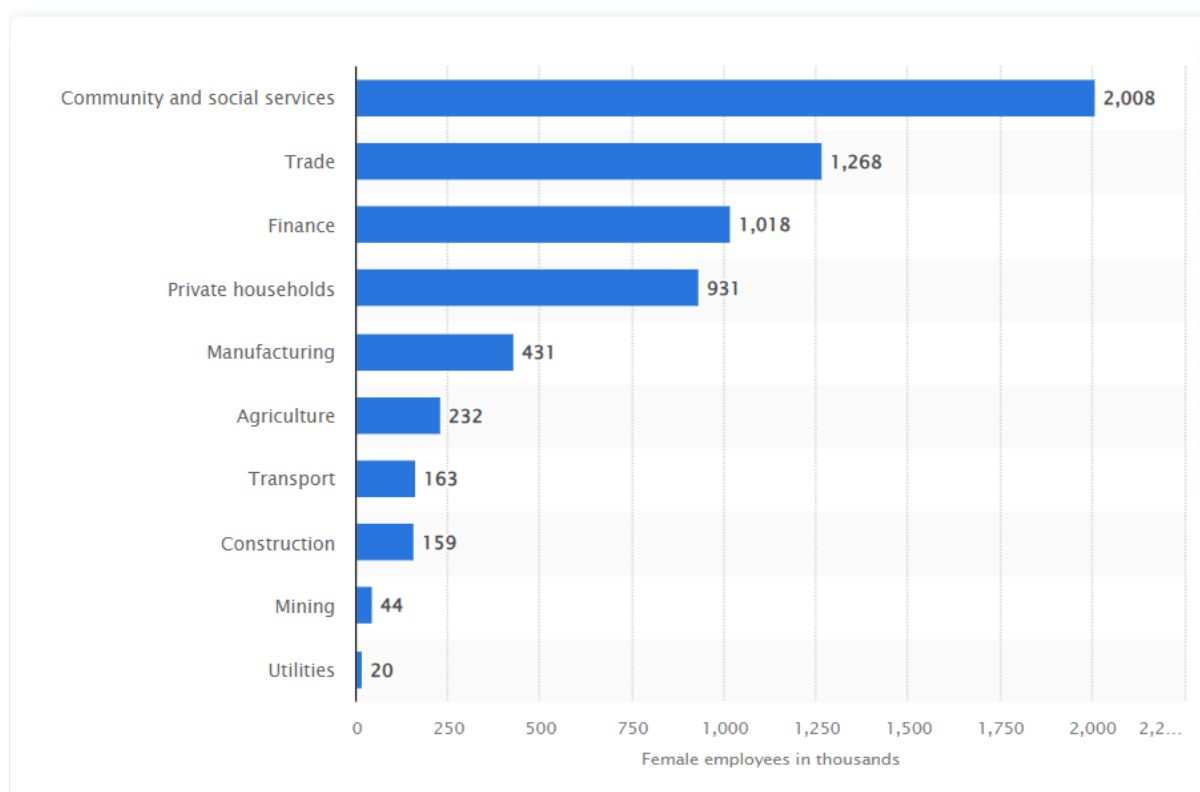


Figure 1: (Statista Research Department, 2023)

The modernization of mines is addressing challenges related to competitiveness, health and safety, and profitability in the mining sector in RSA. The majority of mining businesses in RSA are already implementing their modernization plans, and within the next ten years, most mines will either be modernized or in the process of modernization. These advancements will impact various stakeholders in different ways (Hlangabeza, 2018). The modernization of the mining industry can indeed create opportunities for increased participation of women. However, it also comes with certain benefits and challenges.

The benefits of modernization for women's participation in mining are significant. Firstly, modernization promotes equal employment opportunities by updating policies and practices to ensure gender equality in the workplace. This opens up traditionally male-dominated fields like mining to women, increasing job opportunities. Secondly, the shift towards modern mining methods and technologies requires diverse skills beyond physical strength, allowing women to contribute their expertise and creating a more inclusive work environment. Thirdly, women's inclusion in the mining industry can lead to economic empowerment, as they can access well-paid jobs and contribute to their households' income, improving financial independence and social status. Lastly, the presence of women in mining can improve workplace dynamics, fostering better communication, collaboration, and overall working conditions.

However, there are also challenges that need to be addressed for women's participation in the modernized mining industry. Gender stereotypes associating mining with physical strength can hinder women's progress.

Overcoming these deep-rooted biases and changing societal perceptions is a significant challenge. Additionally, limited access to training and education can impede women's ability to acquire the specialized skills required for modern mining technologies. The male-dominated culture in the mining industry may create a hostile environment, with issues like gender-based discrimination and sexual harassment being prevalent. Furthermore, the remote locations and long shifts in mining operations pose challenges for women with caregiving responsibilities, especially in the absence of family-friendly policies and support.

In conclusion, the benefits of modernization in the South African mining sector outweigh the challenges for women's participation. Encouraging diversity and inclusivity, providing training and educational opportunities, promoting supportive workplace policies, and combating gender biases and stereotypes are crucial steps in increasing women's participation in the modernized mining industry. By addressing these challenges collectively, mining companies, governments, and communities can create a more equitable and inclusive mining sector that benefits all stakeholders.

There is a specific dynamic in RSA that pertains to meeting the legal requirements for gender equality in the mining sector. It is argued that modernization reduces the need for labour-intensive tasks, allowing the industry to continue employing women and individuals with disabilities (Hlangabeza, 2018). Additionally, all workers previously engaged in physically demanding labour in the mining industry can be retrained to operate modernized equipment, enabling them to retain their jobs. Therefore, modernization will not significantly affect the high unemployment rate in South Africa.

There are studies, such as the Mandela Mining Precinct study in the Mechanized Mining Systems program, which discuss the optimization of mechanized mining. This study primarily focuses on automating underground mining equipment and relocating operators from hazardous zones to supported areas, away from moving equipment. An additional improvement to this study is to position the operator on the surface, allowing remote control of the equipment. These types of studies also facilitate the ease of operation for women in the mining industry, ensuring their safety in the mining environment (Mandela Mining Precinct, 2022).

According to Mandela Mining Precinct (2022), Maclean Engineering, a Canadian company, supplies remote-controlled LHDs, roof bolters, and drill rigs to mines in Australia and Canada. Although this equipment is in short supply in South African mines, the company is eager to enter the market. This demonstrates that there are means to ensure modernization in South African mines, ultimately resulting in an increased number of women operating equipment in the mines.

4.2. VIEWS ON MECHANISATION AND WOMEN IN MINING

Participants were questioned about their opinions on mechanization and modernization based on their understanding of mechanization in the mining environment. everybody participants agreed that mechanization had advantages, which were readily acknowledged by everyone and they also agree with literature that modernisation enables women to perform their task easily in the mine. The focus of the participants' responses varied based on their level of subject understanding, but there were recurring themes. The idea that mechanization or modernization improves occupational health and safety; increase production and productivity; and decrease the necessity for manual labour.

In recent years, efforts have been made to address gender disparities and promote diversity and inclusion within the mining sector. The number of women working in the mining sector has increased significantly in the past 15 years or so – from around 11,400 in 2002 to around 53,000 women in 2015, increasing to 54,154 in 2018 (Mineral Council South Africa, 2018). the graph below shows the number of women increasing in the mining industry. The graph shows that there has been progress in achieving gender equality within the mining industry, with a notable increase in female representation. This increase in the number of women working in mining indicates a positive shift towards greater diversity and inclusion. It indicates that efforts to address gender disparities are yielding results.

Mining employment, by sex (2000–19), thousands

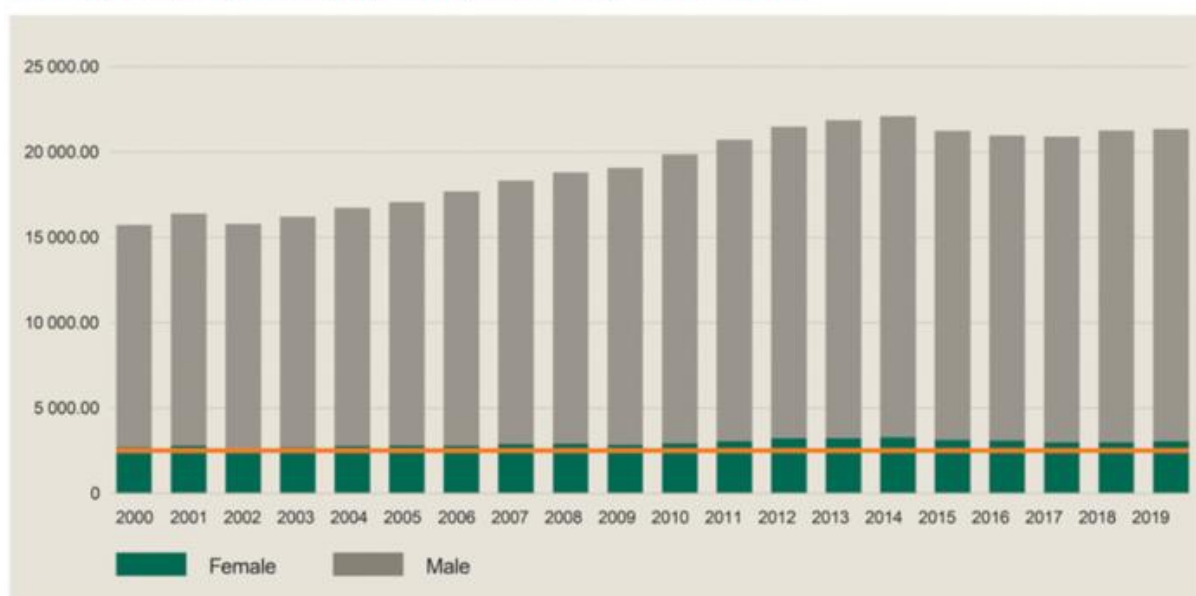


Figure 2: Women representation across different positions in the mining industry (African Mining, 2022)

Women representation in the mining industry varies significantly across different positions. While progress has been made in recent years, women remain underrepresented in leadership roles and technical positions

within the sector. In senior management and executive positions, women continue to face barriers that limit their advancement, such as unconscious bias and traditional gender roles. However, there has been a notable increase in women's participation in non-traditional roles, such as engineering and geology, where efforts to promote diversity and inclusion have been more effective. Nonetheless, further strides are necessary to achieve true gender parity and create a more inclusive mining industry that recognizes and harnesses the valuable contributions of women at all levels (Mining Review Africa, 2019)

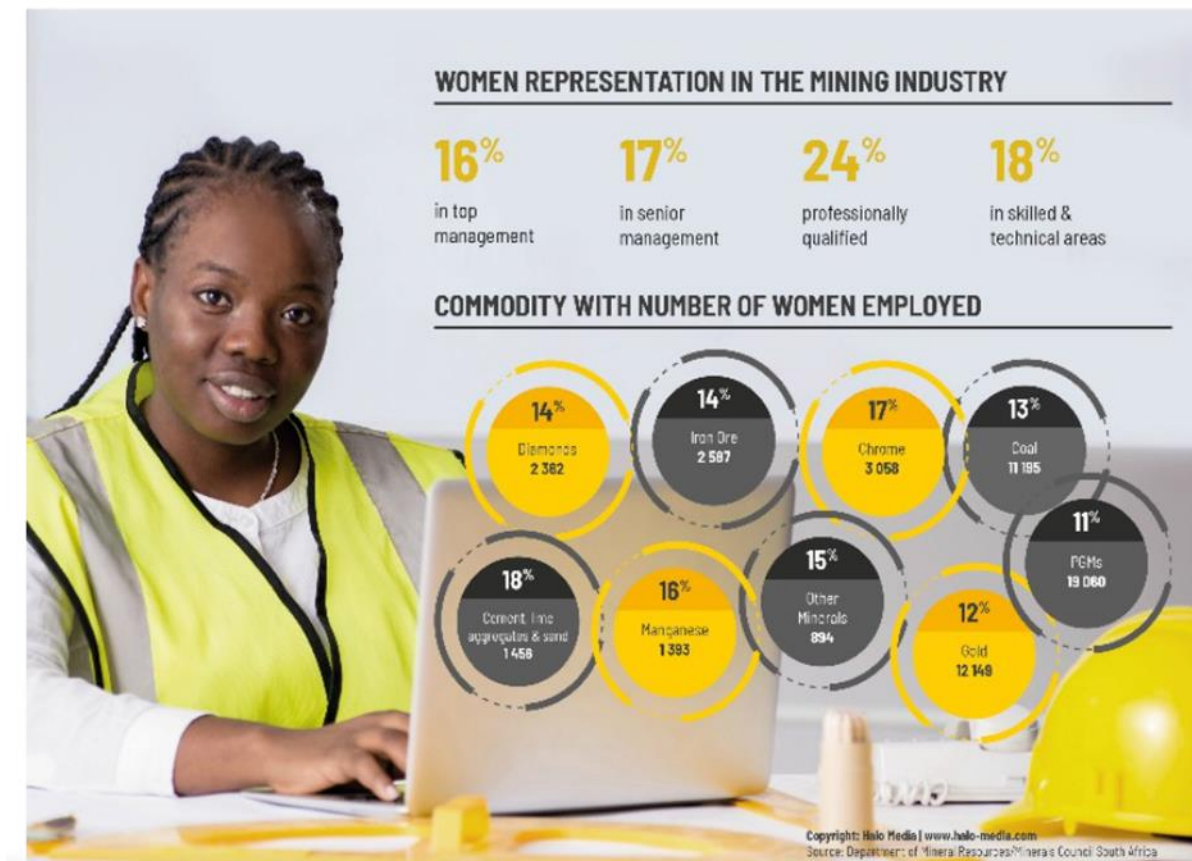
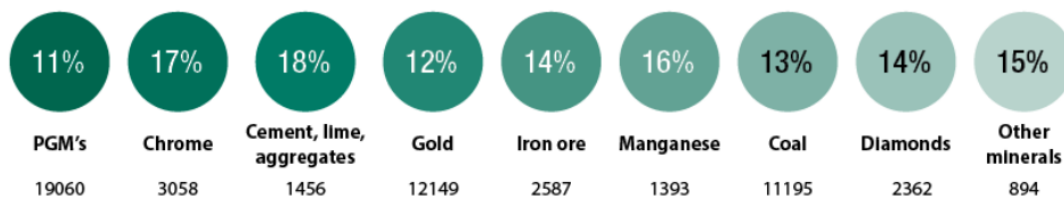


Figure 3: (Mineral Council South Africa, 2018)

Women representation in the mining industry varies significantly across different commodities. In the platinum group metals (PGM) sector, women's participation has been relatively lower compared to other commodities, with around 11% of the workforce comprising women. However, when it comes to gold mining, women participation is slightly increasing, accounting for only about 12% of the workforce. Similarly, in the coal mining industry, women make up a 13% of the workforce. These disparities highlight the urgent need for increased gender diversity and equal opportunities within the mining sector. And modernisation is the key to such an improvement in the mine. The figure below shows these percentages.

Commodity with number of women employed



(African Mining, 2019)

4.3. TECHNOLOGY ADVANCEMENT IN MINING INDUSTRY

The mining industry has witnessed significant technological advancements in recent years, leading to improved efficiency, productivity, and safety. One such advancement is the utilization of autonomous Load-Haul-Dump (LHD) equipment in the South African mining sector. The adoption of autonomous LHDs has not only revolutionized the mining industry but also empowered women, promoting gender diversity and active participation in traditionally male-dominated fields.

The implementation of autonomous LHDs in the South African mining industry represents a significant technological leap. These advanced machines have proven instrumental in breaking down barriers and fostering gender diversity within the sector. With improved features and user-friendly interfaces, LHDs have made operating mining equipment more accessible and appealing to women. Consequently, the inclusion of women in the mining workforce has resulted in increased productivity and overall success in the i[

The modernization of LHD equipment has played a crucial role in empowering women in the mining industry. The incorporation of advanced safety features and technologies in these machines has significantly contributed to enhanced safety standards. For instance, the adoption of vibration dampening technologies not only promotes operator comfort and well-being but also reduces the risk of occupational hazards. This, in turn, has increased job satisfaction among women and encouraged their active participation in mining operations.

The advancements in LHD equipment have gone beyond enhancing safety and have created an environment that is conducive to women's active participation in mining. The ergonomic designs and user-friendly interfaces of modern LHDs have simplified the operation of mining equipment, making it more accessible to a wider range of workers. This has not only broken-down traditional barriers but also encouraged women to explore career opportunities in the mining industry. By facilitating their entry and integration into the workforce, the advancements in LHD technology have resulted in increased women's participation and contributed to a more diverse and inclusive mining sector.



Conclusion and
recommendations

5. CONCLUSION

Ensuring the ergonomic status of modern mining equipment for women is crucial for their health and safety in the mining industry. Modernization plays a key role in improving ergonomic conditions and reducing workplace injuries. By embracing advanced technologies and innovative solutions, the industry can enhance safety and efficiency. Moreover, promoting diversity and inclusivity is essential for increasing women's participation in the modernized mining sector. Embracing diverse perspectives and talent leads to innovation and a more competitive industry. Providing training and educational opportunities empowers women to excel in mining, contributing to the industry's growth. Implementing supportive workplace policies, such as flexible arrangements, improves women's well-being and job satisfaction while attracting and retaining talented individuals. Overall, prioritizing ergonomic needs, diversity, inclusivity, modernization, and supportive policies is key to creating an inclusive and successful mining industry.

6. RECOMMENDATIONS

- **Conduct comprehensive ergonomic assessments:** Perform thorough assessments of the ergonomic factors related to the use of mining equipment by women. This should include an evaluation of equipment design, accessibility, adjustability, and suitability for female operators.
- **Involve women in equipment design and development:** Ensure that women are actively involved in the design and development processes of mining equipment. Their input can provide valuable insights into specific ergonomic needs, considering differences in body proportions, strength, and comfort requirements.
- **Implement adjustable and customizable features:** Incorporate adjustable components in mining equipment, such as seats, controls, and handles, to accommodate different body sizes and preferences. Customizable features can allow operators to optimize their workstations and reduce the risk of musculoskeletal injuries.
- **Foster a supportive work environment:** Promote a work culture that prioritizes health and safety, emphasizing the importance of ergonomics in mining. Encourage open communication channels for operators to report ergonomic concerns and provide feedback on equipment performance.
- **Continual research and innovation:** Foster ongoing research and development efforts focused on improving the ergonomic design of mining equipment. Collaborate with industry stakeholders, researchers, and equipment manufacturers to explore innovative solutions that address the specific ergonomic needs of women in mining.

- Mines are mandated to report on the SLP annually detailing compliance with provisions of the Act and the mining charter. The SLP report can be used to monitor mining modernisation and the increased participation of women.



2017 Z1027.5



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