MANDELA MINING PRECINCT
MINDS FOR MINES

Guideline:

Globally Benchmarked Strategy for the Engagement of Workers in Original Equipment Manufacturer (OEM) Equipment Development Processes

science & innovation
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REPUBLIC OF SOUTH AFRICA

CSIR

MINERALS COUNCIL SOUTH AFRICA

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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 revilatising 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.

This guideline was developed under the Successful Application of Technologies Centred Around People (SATCAP) research programme. The programme is aimed at understanding how both specific and general challenges relating to people in the mining modernization process can be understood from all stakeholder perspectives.

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List of Abbreviations

AOK	:	Advanced Orebody Knowledge
CEO	:	Chief Executive Officer
DMR	:	Department of Mineral Resources
EDEEP	:	Design Evaluation for Earth Moving Equipment Procurement
EMESRT	:	Earth Moving Equipment Safety Round Table
LOCM	:	Longevity of Current Mines
MDB	:	Mechanised Drill and Blast
MEMSA	:	Mining Equipment Manufacturers of South Africa
MHSC	:	Mine Health and Safety Council
MMP	:	Mandela Mining Precinct
MOSH	:	Mines Occupational Safety and Health
MQA	:	Mining Qualifications Authority
NERB	:	Non-Explosive Rock Breaking
OEM	:	Original Equipment Manufacturer
OMAT	:	Operability and Maintainability Analysis
RTIMS	:	Real-Time Information Management Systems
SAMERDI	:	South African Mining Extraction Research, Development and Innovation
SAMI	:	South African Mining industry
SATCAP	:	Successful Application of Technologies Centred Around People

ABSTRACT

INTRODUCTION

The aim of this project was to develop a globally benchmarked strategy for the engagement of workers in Original Equipment Manufacturer (OEM) equipment development processes. The project was informed by a review of literature, and data collected during stakeholder engagements.

REVIEW OF LITERATURE

The South African minerals sector needs to modernise and adopt new technologies to remain sustainable. Successful modernisation will require the optimal design of equipment, human- system integration, training and support, worker acceptance, and trust in technology. Workers should ideally be involved throughout all stages of technology development. The involvement of workers can result in improved product quality, user acceptance, engagement, and ownership of the technology. Human-centred design approaches to worker participation in equipment design and development include user-centred design, participatory design, and participatory ergonomics. Some of the factors which need to be addressed include the development of a systematic approach that involves management support, creation of a team or workgroup with the required members, related training or knowledge sharing, communication, resource availability, and evaluation. Participatory programmes should be adapted to suit specific workplaces and local contexts or cultures.

METHODS

Several engagements were held with stakeholders, including OEMs and industry experts, relating to the engagement of workers in equipment design and development processes. This was a qualitative study, and open-ended semi-structured questions were drafted for the discussions. Thematic analysis was used to identify themes in the data. Ethics approval for the study was gained.

STAKEHOLDER ENGAGEMENT

Workers were generally not seen to be adequately engaged in equipment design and development, and were usually only first introduced to new technologies when they were tested or piloted at mines. Usually, indirect feedback was provided to OEMs from operators and maintainers about equipment that was in use. However, it was often not practical or feasible to make changes or retrofit equipment that had already been manufactured. Challenges faced by OEMs included a lack of involvement of and access to mines, along with difficulties in managing individual opinions and preferences. The culture and history of the South African mining industry (SAMI) was a frequently highlighted issue relating to the implementation of new technology, and included aspects relating to leadership, trust, performance and remuneration, skills and training, and the maturity of the organisation. Skills and training aspects included a need for improved technical training, a reduced divide between artisans and operators, and improved change management. Noted benefits of including workers in equipment design and development included improved design, buy-in and ownership, and associated time and cost benefits. Recommendations to improve worker participation included culture transformation, setting up independent forums relating to new technologies in the SAMI, and developing relevant specifications or standards.

STRATEGY

A strategy was drafted for the engagement of workers in OEM design processes in the South African minerals sector. The vision of the strategy is to involve different levels workers from mining companies, including operators, artisans, engineers and managers, with OEMs in the conceptualisation and design of equipment. Human-centred design approaches are considered best practice, for which all stakeholders should be involved in the design process. Requisite processes involve management commitment, the creation of multi-disciplinary teams, effective facilitation, shared understanding of needs, training and development, and iterative design. Culture transformation within the SAMI needs to be addressed for the successful engagement of workers in equipment design. Changes to work structures, systems, processes, teams, skills, leadership, and performance and remuneration systems also need to be considered. Skills and training needs include those of change management, and potentially addressing the divide between operators and artisans. Independent platforms or forums for engagement are recommended, along with neutral facilitators, to discuss and decide on equipment design requirements. This strategy will need to be discussed with stakeholders in the industry, to contribute to guidelines for the engagement of workers in OEM design processes.

CHAPTER 1

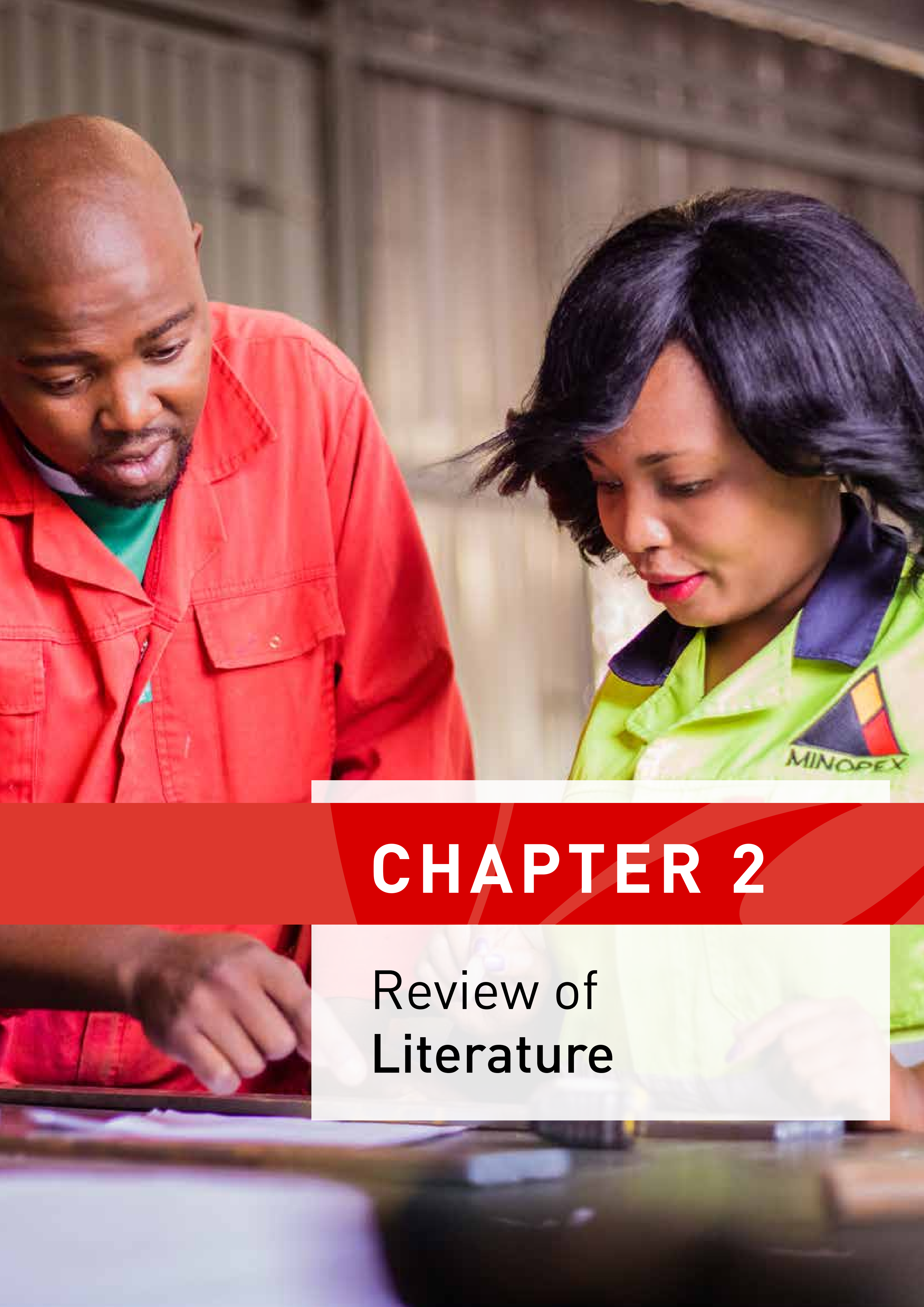
Introduction

Human-centred design and implementation is important for the success of modernisation and mechanisation in mining, in order to improve technology design, and to minimise resistance to change.

The aim of this project is to develop a globally benchmarked strategy for the engagement of workers in Original Equipment Manufacturer (OEM) development processes. The ultimate objectives are to develop a more engaged workforce through involvement in technology design, a sense of ownership by workers, more functional technology, identification of training needs and gaps for skills improvement, and identification of international best practice. The planned study deliverables are as follows:

- Recommendations of best practice relating to worker engagement in OEM development processes
- Identification of approaches, barriers, and enablers to employee engagement in equipment research and development in the South African minerals sector
- Strategy for the engagement of workers in OEM equipment development processes

The project was informed by a review of literature, and data collected during stakeholder engagements assisted to develop the strategy for the engagement of workers during OEM equipment development.



CHAPTER 2

Review of Literature

2.1 INTRODUCTION

2.1.1 OVERVIEW

This literature review intends to inform a globally benchmarked strategy for the engagement of workers in OEMs' development processes. This project takes place in the context of the South African minerals sector, which needs to modernise and adopt the use of new technologies in order to remain sustainable (Jacobs and Webber-Youngman, 2017; Minerals Council South Africa, 2018). Additionally, the sector aims to enhance the capacity of local equipment manufacturers to develop suitable products and technologies for the local and international mining industry; this capacity will address National Development Plan priorities, such as economy and employment, training and innovation, and positioning South Africa in the world (James, 2018; Republic of South Africa, n.d.). This review focuses on approaches to the engagement of workers in equipment design and development processes. Barriers and enablers to worker engagement are also discussed. The literature review includes findings from both local and international research in various industries including the mining sector in South Africa, Australia and the USA, where worker engagement approaches were used in equipment design and development.

2.1.2 MODERNISATION OF THE SOUTH AFRICAN MINERALS SECTOR

There is a current need to modernise the South African minerals sector to make operations safer, healthier, more productive, and sustainable (Minerals Council South Africa, 2018). Modernisation aims to address the challenges facing the industry, which include increased costs, decreased productivity, environmental and social issues, and health and safety issues (Ritchken, 2017; Singh, 2017). Modernisation involves the "innovative implementation, adoption, and advancement of technologies in order to create value and allow the transition towards a more technologically advanced and modernised industry" (Jacobs and Webber-Youngman, 2017, p.638). Modernisation will involve changes to processes, technologies, skill sets, and social and environmental impacts associated with current mining (Singh, 2017). Examples of new technologies include mechanised drilling and blasting equipment, automated or remotely controlled mining equipment, and real- time tracking and monitoring (Deloitte, 2014; Jacobs and Webber-Youngman, 2017; Singh, 2017).

It is noted that for modernisation to be successful, it needs to be addressed in a holistic manner while adopting a systems and people-centred approach (Minerals Council South Africa, 2018). Furthermore, successful and sustainable implementation of new technologies into mines will require addressing people, technology, and process issues (MacFarlane, 2001). People, procedures, environments, and equipment need to interact safely and efficiently (Horberry et al., 2013). Some of the factors that are considered critical for the effective adoption of new technologies include operator acceptance, optimal design of equipment, training and support, human-system integration, and trust in the technology (Gumede, 2018; Lynas and Horberry, 2011).

2.1.3 EQUIPMENT DESIGN, DEVELOPMENT AND IMPLEMENTATION

The implementation of new technologies, including machinery and equipment, in the South African mining industry (SAMI) has been met with varying degrees of success in the past. Barriers to the implementation of new technologies, as listed by MacFarlane (2001), include:

- Premature application of unproven technology
- Resistance to change by the workforce and supervisors
- Fear of job loss as a result of the technology

- Suspicion of management motives in introducing the technology
- Poorly engineered work systems
- Inadequate training or skills to operate the equipment
- New health and safety risks created by the technology or work system
- Poor implementation, planning and control

Lynas and Horberry (2011) noted that reasons for system failures, aside from technical failures, include human-machine interface design, operating procedures, the type of people operating the system, training received, and the ability to physically and mentally cope with the system and system changes. The authors further noted that system redesign must account for the environment in which the equipment operates, the people involved in the process, and be consultative in design with potential operators and engineers.

Ergonomics issues are important in equipment design, as operators will not be inclined to use equipment to its full potential if it is not optimally designed (MacFarlane, 2001). The ergonomics profession assists to address design and operator errors, and to ensure that systems are designed to fit people's capabilities and limitations (Martin et al., 2013; Schutte and James, 2007). The International Ergonomics Association (2019, n.p) states that "Ergonomics (or human factors) is

the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance". Notably, the Mine Health and Safety Act, Section 21(1)(c) states that ergonomics principles must be considered and implemented during the design, manufacture, erection, and installation of any article used at a mine (Republic of South Africa, 1996). Ergonomists can direct processes needed for successful design, and work with designers to enhance the safety, productivity, and sustainability of a product or system (Martin et al., 2013). Martin et al. (2013) further reported ergonomics facets which can be applied to sustainability goals, such as the implementation of total quality management, a sociotechnical systems approach, designing for future users, usability, multifactorial feedback, participation, and change management.

Equipment design can affect the operability or maintainability of mining equipment, and can result in impaired or improved safety and performance (Horberry et al., 2013). Lynas and Horberry (2011) noted that unless technologies are effectively designed, the information that is created could result in overload, distraction or confusion of the operator. Furthermore, workstations with poor ergonomic designs contribute to absenteeism, staff turnover, poor staff retention, and associated financial costs (Sundin et al., 2004). Martin et al. (2013) explained that the design of products influences the behaviour of the consumers or operators, and can drive sustainability, rather than first requiring behaviour change. Martin et al. (2013) stated that design that is most effective achieves all ergonomic, environmental, production, quality, and occupational health standards, and the needs of all the stakeholders. These factors similarly relate to the social, environmental, health and safety requirements of modernisation (Singh, 2017). François et al. (2016) describe various factors that can influence human-machine interface quality. These factors include usability, distraction, and acceptance. Usability refers to how easy interfaces are to use, and include constructs such as learnability, efficiency, memorability, errors, and satisfaction. Distraction could be physical or cognitive. User acceptance includes aspects such as perceived usefulness, perceived ease of use, and attitude (François et al., 2016).

Successful technological change is significantly influenced by employee attitudes or resistance to change (Willis et al., 2004). Technologies that are not accepted are less likely to be used properly, and more likely to be sabotaged by operators (Lynas and Horberry, 2011). Operators adapt to new technologies by positive or negative changes in behaviour, including improved safety or increased risky behaviour (Lynas and Horberry, 2011). MacFarlane (2001) noted that automation will involve different hazards and risk, and will effect work motivation. Lynas and Horberry (2011) added that technology implementation can affect individual outcomes, such as quality of life, job satisfaction, stress and performance. Ownership of the technology or work process by the workforce, and the involvement of operators from early stages of technology design, and in every step of its design and implementation is important (MacFarlane, 2001). Willis et al. (2004) added that people need to be informed about the implementation process, aware of the benefits, consulted about needs, perceptions, attitudes and expectations, and trained and mentored to understand and use the technology optimally.

2.2 WORKER PARTICIPATION IN EQUIPMENT DESIGN AND DEVELOPMENT

2.2.1 BENEFITS OF WORKER PARTICIPATION

It is commonly reported that it is important to engage all stakeholders in design processes (Horberry et al., 2015; MacFarlane, 2001; Martin et al., 2013). End-user involvement is considered important for maintaining safe workplaces and creating adaptive safety cultures (Rost and Alvero, 2018). Rost and Avero (2018) consider personnel at all organisational levels, such as executives, top and mid-level managers, supervisors, and front-line workers (or operators), to be end users. There is acknowledgement that there is a wealth of knowledge at all organisational levels, which has the potential to solve problems and drive improvement in technology or equipment design, if the opportunity and skills are provided (Hattingh and Keys, 2010).

Workers should be involved at all stages of the technology development (Lynas and Horberry, 2011). Vogt and Hattingh (2016) noted that research and development should take place throughout mining projects. Mine workers should be part of the team, and act as co-developers, rather than being given a completed system that they are expected to use (Vogt and Hattingh, 2016). The European Agency for Safety and Health at Work (EU-OSHA, 2012) noted that workers should be informed, instructed, trained and consulted, while full participation involves more than consultation, as workers and worker representatives are further involved in making decisions. Worker participation or involvement is cited to be a critical aspect of a healthy workplace, in which workers and managers collaborate to use a continual improvement process to protect and promote the health, safety and well-being of workers, and the sustainability of the workplace (Burton, 2010). The safety, efficiency, and engagement of workers have been identified as key issues relating to the future of work in mining (Deloitte, 2017).

Worker engagement, in general, is associated with improved organisational problem-solving ability, morale, productivity and profitability, and reduced accidents and absenteeism (Hattingh and Keys, 2010). Improved workforce communication and sense of ownership are also noted benefits (Hattingh and Keys, 2010). Gunningham (2008) noted that worker participation in occupational health and safety usually has better outcomes than one-sided management initiatives. Worker engagement, in general, can be used to predict accident rates, and safety management systems should be designed and implemented to promote and enhance worker engagement (Watcher and Yorio, 2014). Participation of workers and worker representatives has been identified as a key success factor for many effective work environment and health promotion interventions as the employer, workers and worker representatives discuss problems and potential solutions (Burton, 2010). Further to this, the process of worker engagement can result in improved trust between workers and the employer, which would further have positive impacts on the mental health, engagement, and commitment of workers, morale, and the organisational culture (Burton, 2010).

The main benefits of user involvement in design processes, more specifically, have been highlighted in literature (e.g. François et al., 2016; Kujala, 2003), as follows:

- Improved product quality due to better definition of user requirements
- Avoidance of costly features that users do not need or use
- Better acceptance
- Greater understanding of users
- Increased participation in decision-making

The use of human-centred approaches to design has economic and social benefits for users, employers, and suppliers (ISO 9241-210, 2010). The associated benefits include increased productivity and efficiency, reduced training and support costs as a result of equipment being easier to understand and use, increased accessibility for a wider range of people and capabilities, improved user experience and well-being, reduced discomfort, stress, errors and risk of harm, competitive advantage, contribution to sustainability objectives, and improved uptake (Horberry et al., 2015; ISO 9241-210, 2010). ISO 9241-210 (2010) stated that the complete benefits of human-centred design can be determined by accounting for the total life cycle costs of the product or system.

A participative approach encourages sustainability, and can assist designers to get a better understanding of the industry and workplace, and the users to better understand the intent of the designers and how best to use the design features (Martin et al., 2013). It is assumed that greater user involvement would assist to ensure that what is designed is suitable for the users and the environment in which the equipment would be used (Scariot et al., 2012). Participatory approaches further improve the safety, environmental, production, and quality standards of designs, and designs that promote health are also considered to increase productivity (Martin et al., 2013). User involvement would further provide designers with better control of user expectations, and a sense of ownership of what is developed; this commonly results in higher satisfaction and smoother integration of the product designed and the environment where it would be used (Scariot et al., 2012). Motives for engaging users at early stages of product development include the empowerment (and quality of life) of participants, improved efficiency, and improved user acceptance (Lee et al., 2009; Spinuzzi, 2004). Lee et al. (2009) noted that direct contact with users at the early stage of the product development process can result in product improvement and innovation. If various considerations are made early in the design process, it can result in early, and less costly, detection of problems (Sundin et al., 2004). If workers are involved in an issue during the planning stage, this will assist in identifying reasons for taking particular actions, workers can assist with finding practical solutions or with suggesting improvements, and with compliance with the end result (EU-OSHA, 2012).

2.2.2 APPROACHES TO WORKER PARTICIPATION

There are various approaches to worker participation in equipment design and development. Two commonly noted user involvement approaches are user-centred design and participatory design (Lee et al., 2019; Scariot et al., 2012; Spinuzzi, 2004). These approaches, along with others, are discussed further in this section. Participatory ergonomics is also discussed, as it similarly relates to product design, development and implementation.

The term human-centred design can be used as an umbrella term that incorporates approaches such as user-centred, participatory, or ergonomics design (Horberry et al., 2015). ISO 9241-210 (2010, p.vi) focuses on human-centred design for interactive systems, and defines human-centred design as "an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability; and counteracts possible adverse effects of use on human health, safety and performance." A variety of approaches can be used relating to human-centred design in mining (Horberry et al., 2015).

- User-centred design
  Traditional user-centred design approaches require passive objectivity, where researchers (or designers) do not interact with the users (Lee et al., 2019). However, Scariot et al. (2012) define user-centred (or human-centred) design as a collaborative design approach based on user involvement in the development of systems, products, and services. As such, user-centred design allows for direct contact between the designer and the end-users (Scariot et al., 2012). The terms human-centred design and user-centred design are sometimes used interchangeably; however, human-centred design is preferred to emphasize the input of numerous stakeholders (ISO 9241- 210, 2010).

- Participatory design
  Participatory design is "a set of theories, practices and studies that actively involve the end users in the design process to help ensure that the product meets their needs" (Lee et al., 2009, p.4). Participatory design allows for higher levels of user-involvement than user-centred design, from the earliest to the final stages of product development (Scariot et al., 2012). Spinuzzi (2004) stated that in user-centred design, the research is done on behalf of the users, while in participatory design the work is done with the users. Participatory design is usually applied when there are major changes to tools and workflows associated with automation (Spinuzzi, 2004). Participatory design aims to examine tacit or invisible aspects of human activity, through cooperation between the researchers or designers and participants, and attempts to combine participants' tacit knowledge with researchers' more abstract or analytical knowledge (Spinuzzi, 2004). Tacit knowledge refers to implicit rather than explicit knowledge that cannot be easily articulated (Lee et al., 2009; Spinuzzi, 2004). Lee et al. (2009) stated that user-designer collaboration during early stages of the design process can be used to understand users' tacit knowledge and latent needs and transfer them to the design process. Participatory design projects involve design and research, and the methodology is derived from participatory action research (Spinuzzi, 2004). The participatory design process is iterative, as impacts of redesigns are examined incrementally (Martin et al., 2013; Spinuzzi, 2004).

- Other user involvement approaches to equipment design
  Various other related user-involvement approaches are described in literature, including ethnography, contextual design, design for experiencing, and activity-centred design (Kujala, 2003; Lee et al., 2009; Norman, 2005). Norman (2005) supported the concept of activity-centred design, which requires an in-depth understanding of the technology, tools, and reasons for the activities being performed. The design also needs to reflect the possible range of actions, the conditions in which the activity is undertaken, and the constraints of the people using the device (Norman, 2005). Successful devices should fit the requirements of activities, in a manner that is understandable to the people operating the devices (Norman, 2005). Norman (2006) argued that procedures, such as field studies, user observations, and contextual analyses to determine human needs should be performed before the product development process begins; this information is needed to determine the products and projects to pursue. Norman (2006) added that once projects are underway, the research process is constrained by time and resources.

- Participatory ergonomics
  Participatory ergonomics plays an important role in improving the design of mining equipment, and is increasingly cited in work design and workplace improvements for health, safety and quality (Haines et al., 2002; Horberry et al., 2013). Participatory ergonomics has been defined as "the involvement of

people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes to achieve desirable goals" (Haines et al., 2002, p.299). Participatory ergonomics also refers to the involvement of end-users to design, implement, and maintain ergonomics solutions (Rost and Alvero, 2018). Sundin et al. (2004) noted that the focus of participatory ergonomics has often been on improving workplaces and systems, without involving product design. However, as involvement and actions in the early design phase have a large impact on the final product, Sundin et al. (2004) highlighted the need to improve the participatory process for use in the early design process. Horberry et al. (2015) added that while human-centred design processes can be integrated into different design phases, it becomes more costly to effectively apply further into the design process. Sundin et al. (2004) termed a participatory design approach, participatory ergonomics design, where participatory ergonomics input is provided in the design phase.

Motivation for participatory ergonomics includes improved design ideas and solutions, and smoother implementation (Haines et al., 2002). Additionally, participatory ergonomics interventions aim to reduce injury rates, absenteeism, and return-to-work problems (IWH, 2005). The use of participatory ergonomics approaches has been shown to result in improved efficiency, productivity and ergonomics of work processes, and allows for better communication and co- operation in product development processes (Sundin et al., 2004).

Three core elements of a participatory ergonomics approach include ongoing involvement, context-specific involvement, and end-user influence (Rost and Alvero, 2018). The Institute for Work and Health (IWH, 2008) stated that participatory ergonomics programmes involve key players from the workplace to problem-solve, plan, and control work activities. In most participatory ergonomics programmes a team or committee is formed, which usually receives training in ergonomic principles, and uses the knowledge to make improvements (IWH, 2008). A participatory ergonomics framework (the PEF) has been developed to provide clarity and organisation, and also to provide practical guidance on participatory ergonomics programmes (Haines et al., 2002). The nine different dimensions of the PEF, and the corresponding categories, are shown in Table 1. The PEF is considered to be a useful tool at the early stages of project negotiation or of a participatory ergonomics initiative (Haines et al., 2002).

Table 1: The modified participatory ergonomics framework (Haines et al., 2002, p.324)

DIMENSION	CATEGORIES
Performance	Ongoing Temporary
Involvement	Full direct participation Direct representative participation Delegated participation
Level of influence	Group of organisations Entire organisation Department Work group/team
Decision-making	Group delegation Group consultation Individual consultation
Mix of participants	Operators Line management Senior management Internal specialist/technical staff Union External advisor Supplier/purchaser Cross-industry/organisation
Requirement	Compulsory Voluntary
Focus	Physical design/specification of equipment/workplaces/work tasks Designing jobs, teams, or work organisation Formulating policies or strategies
Remit	Problem identification Solution development Implementation of change Process maintenance Set-up/structure process Monitor/oversee process
Role of ergonomics specialist	Initiates and guides process Acts as expert Trains participants Available for consultation Not involved

2.2.3 ENABLERS AND BARRIERS TO WORKER PARTICIPATION

Lynas and Horberry (2011) noted that user-centred design and implementation is required for automated systems to be successful. However, South African mining companies have been slow to embrace a human-centred approach to modernisation (Gumede, 2018). Furthermore, practicing designers are reported to have difficulties in implementing successful user involvement sessions during the product development process (Lee et al., 2009). Facilitators and barriers to participatory ergonomics processes were identified in a systematic review conducted by van Eerd et al. (2010) and were also indicated in IWH (2008). These aspects, which could act as either facilitators or barriers, and ranked in order of frequency at which they were reported, included:

- Support of the intervention among management, supervisors, and workers
- Ergonomic training, knowledge, or abilities
- Resource availability (e.g. time, material, and personnel)
- Creation of a team with all the required members
- Communication
- Organisational training, knowledge, or abilities
- Development and following of a systematic plan or approach
- Participatory ergonomics specialist, leader, or facilitator
- Working relations
- Easy changes to implement
- Workplace climate
- Production requirements
- Personnel turnover at management, supervisor, or worker level
- Awareness of the intervention among management, supervisors, and workers
- The research methodology
- Resistance or ability to change among individuals, workers, or supervisors
- The nature of the work
- The history of intervention attempts

Organisational support, team processes, team building, role definition, role clarity, communication, management commitment, and a supportive culture are necessary for success in participatory interventions (Helali, 2009). Intervention efforts are noted to require senior management leadership, buy-in from all levels, investment in training, and the use of change agents (Hattingh and Keys, 2010). Resistance to change or negative attitudes are further considerations (Helali, 2009). Workers should be committed to the process, and not be coerced to participate (Spinuzzi, 2004). Implementation can also take considerable amounts of time (Hattingh and Keys, 2010). Haines et al. (2002) also identified difficulties in promoting participatory ergonomics, including the (perceived) time and cost, the effort that is required, participant motivation, and embracing non-participatory stakeholders. Limitations of participatory design include the time, resources, and organisational commitment required (Spinuzzi, 2004). Further challenges relating to including users or potential buyers in the product development process include fear of change, concerns over cost of the system, a lack of knowledge of comparative products, or involvement from biased or non-representative participants (Allen et al., 1993). The diverse range of user populations and other stakeholders, and skills gaps are further barriers (Horberry et al., 2015). Horberry et al. (2015) also indicated difficulties in accessing mine sites, the nature of mining being risk averse and conservative, and the amount of time taken for technology development sometimes being longer than the life of the mine. Key drivers of employee engagement, in general, that were identified on platinum mines in South Africa included job design and characteristics, supervision, relationships with co-workers, workplace environment, and human resource development practices (Hlapho, 2015).

2.3 WORKER PARTICIPATION PROCESSES

This section highlights processes that are followed in various worker participation initiatives for product design or workplace improvements. Examples of strategies are provided, followed by a summary of activities that were commonly discussed in the reviewed literature. Participatory programmes and initiatives should be developed to best suit current company needs and culture, and adapted to suit specific workplaces (Hattingh and Keys, 2010; IWH, 2005). Local conditions and cultures should be assessed and incorporated into plans (Burton, 2010). The interventions should be local processes that respond to the particular needs of local people (Helali, 2009). Horberry et al. (2015) summarised principles, processes, and tools for human-centred design in the mining industry, as shown in Table 2. The term human-centred design is used as an umbrella term for worker participation approaches in this report.

Table 2: Essential principles, processes, and tools for mining human-centred design (Horberry et al., 2015, p.2)

Principles ('why' and 'how')	• The design is based on an explicit understanding of the user, their tasks and the environment/use context. • Users and other stakeholders should be involved throughout design and development. Their needs, wants, and limitations are given attention at each stage of the design process. • It fits the equipment, system or interface to the user, not vice versa. • The design is iterative, evolutionary and incremental. • It is driven by user-centred safety evaluation criteria during the design process and for the end product. • A multidisciplinary design team is used, including human factors/usability champions. • The design is integrated with the wider work system organization. • The human-centred design process must be customizable: capable of being adapted to different mine sites conditions.
Processes ('when' and 'where')	• Explore/investigate (understand the need and context of use, and specify user requirements). • Produce/create design solutions based on the exploratory/investigation stage. • Evaluate the design (at all development stages). • Manage the process/feedback information to designers for the next iteration.
Tools ('what')	• To investigate/explore (e.g. ethnographic studies, observations, and task analyses). • To provide input into stages of the design process (e.g. anthropometric datasets, human factors guidelines, or participatory design sessions). • As criteria in the evaluation process of designs (e.g. user acceptance trials, usability audit checklists, or long-term monitoring of the product/system).

The following principles, from ISO 9241-210 (2010), should be followed in design processes:
- The design is based on an explicit understand of users, tasks, and environments
- Users are involved throughout design and development
- The design is driven and refined by user-centred evaluation
- The process is iterative
- The design addresses the whole user experience
- The design team includes multidisciplinary skills and perspectives

De Koker and Schutte (1999), when developing a comprehensive ergonomics strategy for the SAMI, described the steps for the implementation of an ergonomics programme, as follows:
- Define programme goals, priorities and objectives; also define the budgets, resources and limitations
- Select a qualified ergonomics resource to facilitate the achievement of programme goals and objectives
- Conduct a professional ergonomics needs assessment to help with the identification of priority problem areas
- Use the ergonomics resource to train supervisors, safety personnel, and engineers in the principles of ergonomics
- The ergonomics consultant should, together with safety personnel and engineers, conduct systematic workplace need assessments
- Develop and implement practical and cost-effective engineering solutions, where possible, or plan other preventative activities (e.g. adjustment of procedures)
- Evaluate the programme and the impact of the changes that were implemented
- Conduct a cost/benefit analysis of the solutions
- Refine the solutions on an ongoing basis

Van Eerd et al. (2010) listed suggestions relating to participatory ergonomics processes and implementation, which included:
- Create teams with appropriate members
- Involve the right people in the process (e.g. workers, supervisors, and specialists or advisors)
- Define participants' responsibilities (e.g. problem identification, solution development, and implementation of change)
- Make decisions using group consultation (including management and workers)
- Provide ergonomic training to workers, teams, and supervisors
- Address other key facilitators and barriers, including support of the intervention, resources, communication, and organisational training or knowledge

2.3.1. SECURE MANAGEMENT COMMITMENT

Senior management support, commitment, and involvement, is important for the successful implementation and sustainability of participatory programmes (de Koker and Schutte, 1999; Hattingh and Keys, 2010; Helali, 2009; Sundin et al., 2004). Management, and all other levels of workers, need to understand the purpose of the intervention so as to curb resistance to change (Hattingh and Keys, 2010). It is important to obtain commitment and buy-in from the major stakeholders, such as owners, senior managers, union leaders, or informal leaders, from the onset of a programme, as the programme should be integrated into the goals and values of the business (Burton 2010). EU-OSHA (2012) stated that employers need to promote a health and safety culture which supports worker participation, where full participation goes beyond consultation, as it involves workers and worker representatives in making decisions. De Koker and Schutte (1999) added that mutual trust between management and workers is a precondition for successful participatory ergonomics.

2.3.2. CREATE WORKGROUP OR TEAM

Participatory ergonomics teams should be created (IWH, 2005). Participation and accountability are fundamental, and there should be participation from the executive, management, union, supervision, and employee levels (de Koker and Schutte, 1999). Workers affected by the programme and worker representatives should be actively involved in every step of the process (i.e. planning, implementation, and evaluation) (Burton, 2010). Worker involvement is crucial in problem identification, problem-solving, and in the evaluation of corrective actions (Schutte and James, 2007). Rost and Alvero (2018) noted four questions that should be considered in a participatory approach, namely: 1) who will participate, 2) what will they do, 3) when should they be involved in the process, and 4) how will they be involved. Ergonomics problems are best identified and solved in cooperation with those who are most involved in the process (Helali, 2009). Appropriate members include workers, supervisors, and advisors (IWH, 2005). Involvement of mine employees at all stages of the process increases support for the initiative and access to knowledge and experience (Hattingh and Keys, 2010). Helali (2009) reported categories of levels of user involvement: no involvement, symbolic involvement, involvement by advice, involvement by work control, involvement by doing, and involvement by strong control.

An on-going process of regular group discussions enables the exchange of experiences and ideas, to increase efficiency and reliability, and reduce stress and injuries (de Koker and Schutte, 1999). Participants' responsibilities should be defined, and could include problem-solving, developing solutions, and implementing changes (IWH, 2005). A formal agreement with users participating in the design process will assist to clarify expected contributions, and the benefits that would be provided (Scariot et al., 2012). Some of the ways in which workers can get involved is asking questions, raising issues and making suggestions, taking part in surveys or consultation activities and working groups, being involved in equipment trials, and applying knowledge gained in training (EU-OSHA, 2012). Decisions should be made using group consultation (IWH, 2005). One of the key questions highlighted by Deloitte (2017) relating to the future of work in mining was how to engage and communicate with an increasingly diverse group of employees during change processes. Sundin et al. (2004) provided an example of a work group that was formed with representatives from design and production departments, and external specialists. The work group met weekly to discuss problems and design questions, and documentation of the development process was kept (Sundin et al., 2004).

2.3.3. TRAINING AND DEVELOPMENT

Basic introductory training in ergonomics is considered to be a prerequisite for the successful implementation of participatory ergonomics projects (de Koker and Schutte, 1999; IWH, 2005). Learning about technical issues and how to communicate knowledge and experience is also part of the process (de Koker and Schutte, 1999). Business improvement initiatives include developing peoples' skills and mind-sets to allow them to become effective problem solvers (Hattingh and Keys, 2010). Additionally, in general, modernisation of the industry will change the nature of the work that people do, and will require a different skill set in the workforce, as well as an increasing requirement for knowledge, decision-making capability and levels of responsibility (Lynas and Horberry, 2011; Vogt and Hattingh, 2016). Training and selection procedures would be needed for the development of the changing skills and competency requirements (MacFarlane, 2001). MacFarlane (2001) added that skills development should be a collaborative process that is performed with the involvement of OEMs and organised labour.

2.3.4. METHODS AND TOOLS TO SUPPORT THE PARTICIPATORY PROCESS

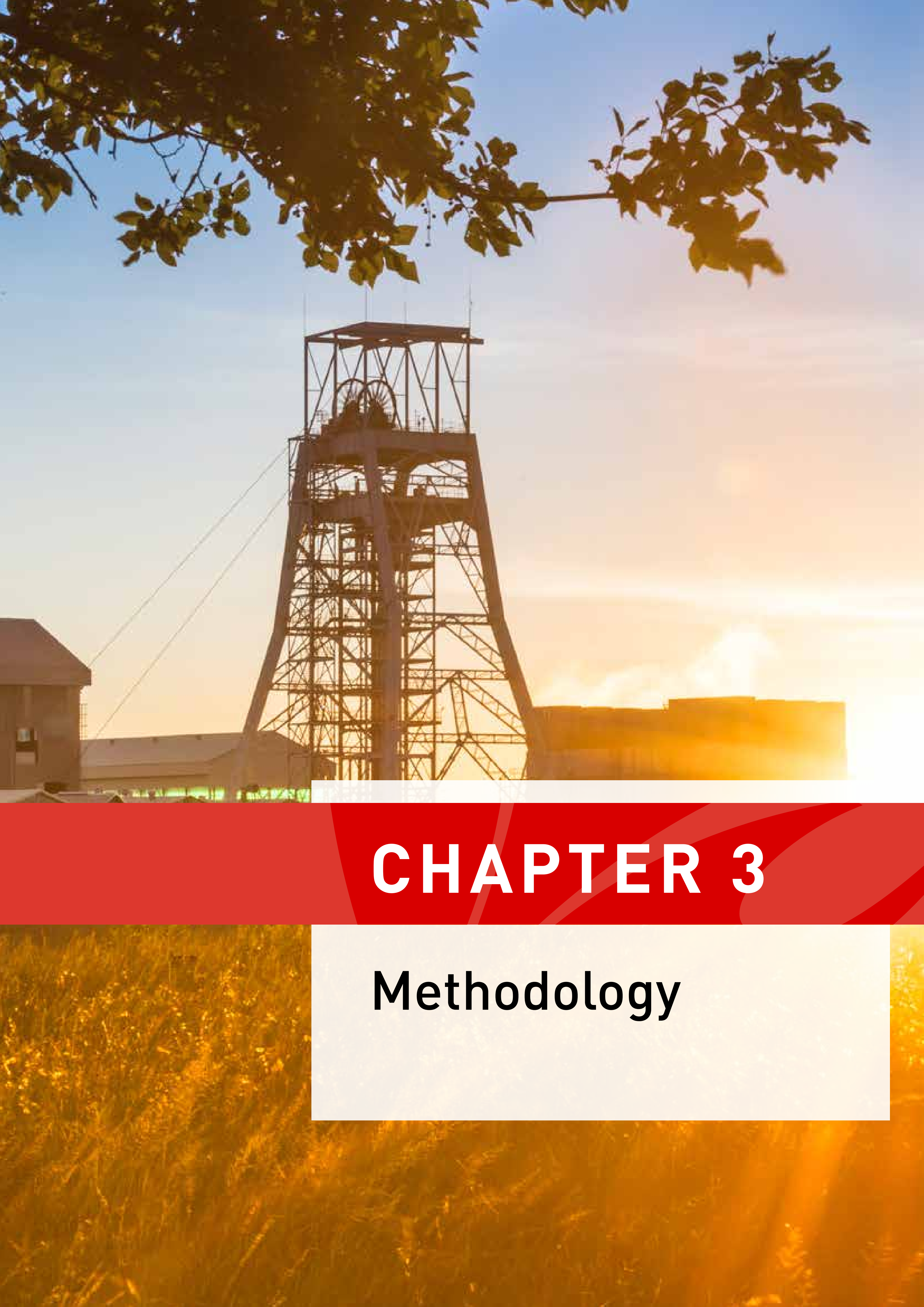
Spinuzzi (2004) described three basic stages in participatory design research, namely the initial exploration of work, discovery processes, and prototyping. In the initial phase, the designers and the users meet, and the technologies, and aspects such as workflow and procedures, are explored. Secondly, in the discovery process, techniques are used to understand and prioritise work organisation and the desired outcome of the project. Finally, prototyping involves iterative shaping of the technology to suit the workplace. The Deming 'Plan-Do-Check-Act' Cycle is often used in problem-solving and to promote continuous improvement in experimentation and implementation (Hattingh and Keys, 2010).

Systematic usability methods or processes are used to inform and adjust designs, and are more important when there are larger gaps between designers and the users, tasks, and context (Nielsen, 2008). A range of models, methods, and tools have been employed in participatory initiatives, and there are different techniques for facilitating communication and the understanding of product designs (Helali, 2009; Sundin et al., 2004). Methods used in participatory design include observations, workshops, focus groups, interviews, organisational games, artefact analysis and prototypes (e.g. Lee et al., 2009; Spinuzzi, 2004). Action checklists have been developed to encourage active participation of workers and employers (Helali, 2009). Participatory methods may involve ergonomics and time analyses, including the assessment of work postures, efficiency, and qualitative and quantitative data (Sundin et al., 2004). These assessments include three-dimensional digital models, physical mock-ups or prototypes, and graphic computer-based simulation and analysis (Sundin et al., 2004). Further approaches include structured conferences, ethnographic methods, theatrical approaches, low-tech simulations, high-tech protoyping, semi-structured games, and post-implementation customisation (Allen et al., 1993). Heuristic evaluation is useful when other methods are difficult to use owing to time or resource constraints, and involves using a small set of evaluators to assess the interface (Allen et al., 1993). However, the methods or techniques used should supplement each other, and be best suited for each development situation (Allen et al., 1993).

Participatory ergonomics methods involve techniques and approaches used for solving workplace and organisational problems, and to conduct working groups (de Koker and Schutte, 1999). Various techniques are used in small group activities to make suggestions for ergonomics improvements, including the cause-and-effect diagram, Pareto diagram, histogram, scatter diagram, control chart, various graphs, check sheet, stratification and full-size or scale mock-ups and simulations (de Koker and Schutte, 1999). Horberry et al. (2013) indicated that the equipment design process should involve a task-based risk assessment process that involves experienced operators and maintainers. The Operability and Maintainability Analysis Technique (OMAT) is an example of a user-engagement process to identify and assess human factors risks in mining equipment design (Horberry et al., 2013).

2.4 CONCLUSION

This literature review highlighted the importance of worker involvement in equipment design and development processes. Different approaches and methods for worker participation, under the umbrella of human-centred design, such as user-centred design, participatory design, and participatory ergonomics, were summarised. Management commitment, the creation of workgroups, and training and development are some of the common themes in these approaches. The processes identified can be used to inform a strategy for the engagement of workers in OEM equipment development processes.



CHAPTER 3

Methodology

3.1 STUDY DESIGN

This was a qualitative study, and data was gathered through interviews and discussions with stakeholders.

3.2 STUDY SAMPLE

The study participants included OEMs and industry experts. Convenience sampling was used to identify and recruit potential participants. The potential participants were identified with the assistance from experts in the sector. A limitation of convenience sampling is that the participants may not be representative of those in the entire industry. Probabilistic sampling was not feasible for this study. However, the findings will provide useful information on the topic and will guide future work.

3.3 DATA COLLECTION TOOLS

Open-ended, semi-structured interview and discussion questions were drafted based on information from the literature reviews and experience and understanding of matters relevant to employee engagement in the South African minerals sector. These questions are attached in Appendix A. The main topics covered in these discussions were 'if and how workers are in engaged with equipment design and development, benefits or barriers to worker engagement, potential training implications, and recommendations to improve worker engagement in OEM development processes.

3.4 DATA COLLECTION PROCEDURES

The study was cross-sectional as data were gathered over relatively short periods of time. Prior to data collection, potential participants were identified. Discussions with the South African Mining Extraction Research and Development Initiative (SAMERDI) programme managers, researchers, and Mining Equipment Manufacturers of South Africa (MEMSA) were held to get suggestions about the most appropriate potential participants and assistance with obtaining relevant contact details. The potential participants were then contacted to be informed about the project, to discuss the study aims and procedures, and to request participation. Necessary permissions were obtained, following which scheduling of data collection took place. Prior to data collection, voluntary informed consent forms were signed. Data collection, in the form of stakeholder engagements then took place. Researchers fluent in local languages were available to assist with data collection, to improve accuracy of responses and interpretation, where necessary. Following collection, data were captured in an electronic format and collated. Themes were identified, and a report was drafted based on the findings. Feedback will be provided to the participants following study completion.

3.5 DATA ANALYSIS

Data were analysed using thematic analysis to identify patterns/themes in the data to inform the strategy for the engagement of workers during OEM equipment development.

3.6 ETHICS APPROVAL

Ethics approval for the study was granted by the CSIR Research Ethics Committee (reference number: 239/2017). The ethics approval letter is attached in Annexure B. According to ethics requirements, the study aims and objectives were to be described in a manner understandable to the participants, participation was voluntary, and informed consent forms were signed by each participant. The data collected in the study will remain confidential, and the names of participating individuals and companies will not be disclosed in project reports. Electronic data will remain securely stored on password protected computers and only accessible to those directly involved in the study.

CHAPTER 4

Stakeholder engagement

4.1 INTRODUCTION

Engagements were held with stakeholders in the SAMI from April to May 2019. These stakeholders included representatives from numerous local OEMs, in positions such as Chief Executive Officer (CEO), Managing Director, and Engineer. The OEM representatives also had relevant experience in the mining industry and research spaces. Interviews were also conducted with other experts in the industry, including those in academia and industry representation in the fields of industrial engineering and behavioural change. These engagements took the form of interviews. A further engagement was held to gather input from the South African Mining Extraction Research, Development and Innovation (SAMERDI) Technical Steering Committee for the Non-Explosive Rock Breaking (NERB) and Mechanised Drill and Blast (MDB) programmes, with involvement from the Advanced Orebody Knowledge (AOK), Longevity of Current Mines (LOCM) programme managers.

This report details the findings from the engagements that were held. The methodology and question guide used for this research is included in the Milestone 3 report ("Data collection tools and methods"). The questions posed included if, and how, workers are engaged in the design or development of equipment in the SAMI, how feedback is incorporated into equipment design, the benefits and hurdles to worker engagement, training or skills implications, and recommendations for improvement. For the purposes of this report, the term 'equipment' has generally been used interchangeably with the terms 'technologies' or 'machines'. The next phase of this project is to draft a strategy based on the findings from the literature review and the stakeholder engagements. The strategy will be presented and discussed with stakeholders, and will further be used to inform guidelines for the engagement of workers in equipment development processes.

4.2 ARE WORKERS ENGAGED IN THE DESIGN OR DEVELOPMENT OF EQUIPMENT THAT IS USED ON MINES?

Workers in the SAMI were not considered to be adequately engaged in the design and development of equipment. While workers were sometimes involved, this was generally not seen to be done in the ideal manner. There was general consensus among the interviewed stakeholders that workers, especially low level workers, were usually not involved in the initial or concept phase of equipment design. For example, one of the stakeholders commented "The input into the design of tools underground has never involved the workers, the user". Often, the workers were only involved in the prototype or piloting phase of implementation – when the technology or equipment was already constructed and physically introduced onto a mine. It was noted that sometimes members of the design team of the OEM had previous mining experience (often at the artisan level), which was helpful to inform the design of equipment to be used in the SAMI.

The term 'worker' needed to be expounded during the course of the research, while considering the different levels of workers at the mines. The terms 'worker' and 'employee' are used interchangeably in this report. It was evident that it is important to consider not only the operators, but also the 'maintainers' ('technicians' or 'artisans'), in equipment design. The term 'end-user', often used interchangeably with the term 'worker', additionally refers to the mining companies, who are the clients or customers, in this case.

Surprisingly, it sometimes appeared that even mining companies were often not involved in the conceptualisation or design of equipment developed for the industry. If this was done, it would usually be with individuals from higher levels of the organisation, such as engineers at the mine and the OEM, and with consultants. Often OEMs had to conceptualise what they expected to be needed by the industry, and then try to motivate the use of the equipment to the industry. However, in other cases the equipment was designed around the needs identified by mines, such as to address specific issues. The concept stages of equipment design usually involved high levels engagements, such as with professionals, designers, product owners, project managers and engineers. Generally, our findings revealed that equipment design in the SAMI is based on what is perceived to be appropriate for the worker, while the workers are not able to give valuable input into the design.

4.3 FEEDBACK MECHANISMS AND RETROFITTING OF EQUIPMENT

In the interviews it was noted that feedback was generally provided from workers, or special project teams, once equipment was piloted at mines. Feedback is also provided to OEMs once the equipment is in use; particularly as the equipment is maintained by OEM service teams. Feedback at the 'version zero' stage is generally more diverse than at the concept stage, and involves engagement with low to high levels of workers at the mines. The stakeholders generally noted that the feedback from the workers was usually indirect; for example, the operators or maintainers would provide feedback to their supervisor, mine engineers or employer, who could then provide this information to the OEM. However, service teams received more direct feedback from the workers, and could relay this information back to design teams in the form of service reports or design recommendations, for example. Feedback relating to equipment maintenance is sometimes gained though formal structures, such as OEM meetings that are held between OEMs and mine personnel, including individuals such as the section engineer, specialist or foreman. OEMs can also directly or indirectly receive information through health and safety meetings that are held on mines. Workshops were another way to get input from worker representatives about factors relating to the design of the equipment. Additionally, researchers or designers sometimes were contacted if mines had complaints or identified problems on existing equipment.

Where possible, the feedback received from these engagements was used to retrofit or customise the equipment. However, the feedback provided generally was used as input towards upgrades or the next versions of the machines. It was not always practical or feasible to retrofit equipment. A stakeholder noted, for example, "There are a lot of nice-to-haves, which people wanted to incorporate or change on the machine, but they are not practical, or it makes it unsafe".

Global (or 'international' or 'multinational') OEMs were discussed, as much of their equipment is in use in the SAMI. International OEMs were not considered to be as able as local OEMs to specifically design for conditions in South Africa. For example, a stakeholder noted that local OEMs would be more able to design technologies that are "appropriate to the type of orebodies, people, skills, and management systems and capabilities we're dealing with". South African conditions are unique in terms of aspects such as the orebodies, and also in terms of social conditions. Social issues include those of labour disputes, job threats, level of skills, attitudes, and mind-sets of workers. One of the local OEM stakeholders, who catered for a differentiated market, noted that their engagements were a bigger factor than for multinational OEMs. However, there were noted cases where equipment from international OEMs had been retrofitted for local conditions, for example, in order to be compatible with safety legislation in South Africa. The use of international versus local OEMs was also pertinent in terms of supply chain issues, including the time and cost of receiving parts for the repair of equipment in the SAMI. Additionally, it was mentioned that innovation of global OEMs was usually ahead of that of local OEMs, as they were driven by global trends, rather than current local issues.

4.4 HURDLES TO WORKER INVOLVEMENT IN EQUIPMENT DESIGN AND DEVELOPMENT

4.4.1 HISTORY AND CULTURE OF THE SAMI

A frequently highlighted reason for the lack of engagement of workers was the historical context of the mining industry in South Africa. Historically, the design of equipment has been considered to be the work of engineers, while input from workers was not considered. Workers were usually expected to "do what they're told." The current mentality in the SAMI was considered to be a hindrance, and it was mentioned that the attitudes in the mining industry do not allow for worker involvement. It appears that attitudes and practices tend to be passed down across generations of managers and workers at mines. It was noted that it might be difficult for those with conventional mining mind-sets to engage with new design paradigms, and make a paradigm shift towards the inclusion of workers. Furthermore, the culture in the SAMI was identified as a reason for failure of the implementation of new technology in the past. Workers in the SAMI have certain expectations and behaviours because of the history of the industry, which may not be compatible with these innovations.

A lack of trust of the motives for the engagement might also be a barrier to the involvement of workers in equipment design. Additionally, there are valid concerns about how technological solutions could replace certain occupations in the mining industry, by reducing the need for manual labour. As such, the engagements about these technologies would not be welcomed. Threats of job displacement will also result in a lack of buy-in or use of equipment that is implemented in mines.

A stakeholder mentioned that often the people responsible for projects regarding the implementation of equipment at mines do not have adequate insight into change management principles. Another stakeholder indicated that change management relating to new technologies in the SAMI is done haphazardly. It was also noted that appropriate support from elsewhere in the organisation was important for successful implementation. It was indicated that there is diversity among mining houses, as some companies are eager to adopt new technologies, while others are resistant to this change (e.g. because of cost constraints, life of mine etc.). These differences were attributed to the maturity level of the mining houses, and to the strategic direction taken by organisations, even at executive levels. Another stakeholder mentioned, however, that even within the same mining company, some mines work very well, but others do not.

4.4.2 PERFORMANCE AND REMUNERATION

From the engagements that were held, it was evident that it was not possible to discuss mechanisation in the industry without considering performance and reward. The performance measurement system would need to change in a modernised mine environment to be compatible with the changes in how the mine is operated. There is complexity in rewards for interlinked roles of the operators, artisans and product specialists; there could be conflict rather than synchronicity between the jobs that revolve around the same piece of equipment. Current measures and incentives in the SAMI were not perceived to encourage operators to be involved in the maintenance of equipment. For example, operators might not want to stop using the equipment so that the artisan can maintain it, as it will affect their short-term productivity and the associated remuneration, but this could lead to increased breakdowns in the future. Workers might not want to be engaged with the development of new technologies due to uncertainty around how remuneration will be impacted, and because it could hinder the attainment of bonuses while designing and trialling new systems. Furthermore, a stakeholder noted "People are not rewarded for innovation. So why should anybody bother? …There's very little room for being creative, because the antithesis of that is safety." Another reason relating to the measurement and reward system that was mentioned about why operators were not encouraged to be more involved in technical aspects of equipment design was because it was perceived that if operators had a better understanding about how the equipment worked, they could potentially override safety mechanisms to improve their production levels.

4.4.3 MINING COMPANY INVOLVEMENT

Gaining access to mines to engage with workers and to test equipment was a hurdle in OEM equipment development processes. Involvement of mining companies is important for the successful implementation of technologies. Some of the stakeholders noted that it was difficult to get information or access mines if one did not have inside contacts at mining houses, such as if they had worked in the mines previously. Reduced funding for research and development in the mining industry in the past few decades was a reason cited for a lack of involvement of mining companies in equipment development processes.

Cost implications of incorporating worker feedback are another consideration. The OEM might have high costs but not receive returns during the development and testing phases, while mines do not want to lose production while testing new equipment. There are also cost implications for the mines and OEMs for training workers to use and repair new equipment. It is also more difficult to control the process of equipment development if this is not conducted internally to the OEM. OEMs might also not be willing to invest significant amounts in equipment development, if there are no guarantees that it will be accepted by the industry and bring a return. It was difficult for OEMs to develop costly innovations for the future, as it was not known if there would be buy-in from the industry. Moreover, cost constraints in the industry can result in cheaper, but less ergonomic or user-friendly, components being used in equipment designed for use in the SAMI.

4.4.4 PROBLEM PRIORITISATION

The effectiveness and use of feedback between the workers and the OEM regarding equipment design and use needs to be considered. Commonly this information is 'filtered' by the employer. Communication breakdown could occur in the process, because of the lack of direct communication with the workers. A challenge with obtaining indirect feedback is that information can get lost along the way. However, this process could also assist the OEMs to identify the most critical aspects to address. It might be difficult to manage all the information that is received, and to satisfy everyone. Additionally, some matters might be difficult to address. The time taken for this process might also not be easily defined. A lack of continuity and turnover of mining staff (e.g. engineers) was another potential problem. A stakeholder noted that sometimes feedback on recommended changes was driven by a certain individual at a mine, but when they left the mine the person who replaced them had different ideas and requests. A further challenge relates to the use of third-party suppliers of systems used in OEM equipment. It could be difficult to involve and manage user feedback into these systems, as they are developed independently from the OEM. This lack of up-front feedback further results in retrospective design upgrades.

Another challenge in engaging with workers in the concept stage of a design is the difficulty of engaging with concepts or ideas, rather than a tangible product. The understanding of workers could also be limited, so they might not be able to adequately consider equipment beyond their experience. It was noted that it was easier to engage with higher level stakeholders in this phase, but that industry standards that are relevant to the local workforce would be important to inform appropriate design.

4.5 BENEFITS OF WORKER INVOLVEMENT IN EQUIPMENT DESIGN AND DEVELOPMENT

4.5.1 IMPROVED EQUIPMENT DESIGN

It was considered to be important for OEMs to receive input from the industry about what to design, and how they would like equipment to be designed. Input from individuals across high and low levels in the organisation, and worker experience was considered to be beneficial in the design of equipment. If there were higher levels of engagement with the end-users, the equipment would be better designed. This improved design would make it easier to use and to repair. Improved design would help to ensure that the equipment continues to operate effectively at the mines. Operators were considered to be the ones who knew the most about the use of the equipment, because they are the ones that use it throughout long shifts across the mining cycle. They were also the ones who had the most practical knowledge about the working environment. It was noted, for example, that operator input would assist to identify what would or would not work in the mining environment, and to highlight numerous considerations that the designer might not think of. It was considered helpful to engage with workers with many years of experience, and a stakeholder noted "So if you…give them new equipment, you must listen to them, because they sit with that knowledge and that experience". Examples were provided of short- comings in design of equipment for use by women in mining, as equipment was generally designed for male physiques. Other examples where worker input is required included ergonomic aspects such as visibility, posture, seating and control layouts. Aspects such as how equipment could be misused or abused, or how short-cuts could be taken, should also be considered in equipment design. The process of involving workers would help to identify and resolve these issues. The maintainers or artisans also need to be considered in equipment design; equipment needs to be designed so that it is serviceable, such that it is easy to check and not dangerous to maintain. Improved design would further help to address issues including burnout and absenteeism of the workers.

4.5.2 BUY-IN AND OWNERSHIP OF EQUIPMENT

Engaging with workers was seen to be an important mechanism to gain buy-in and a sense of ownership of the equipment by the workers. Involving workers early on in the equipment development process could help them to understand the benefit of the equipment, and to accept it faster. A reason for failure of new equipment that was implemented in mines was that people were not involved early on in the process. Stakeholders mentioned that if the operator does not like the equipment, or if it is difficult to use, the equipment often gets broken or it is not used. A stakeholder commented that "The operator has no role in the decision-making at all… So their only input really is, if they don't like it, make sure it doesn't work". Others mentioned that the workers might not deliberately break the equipment, but they might not have an incentive to make it work either. Workers with a greater sense of ownership were seen to take better care of the equipment. This further has cost implications, as equipment is expensive to fix when it breaks.

4.5.3 TIME AND COST IMPLICATIONS

Gaining user input into the design of equipment up-front was considered to reduce the time taken to complete the innovation and to save money relating to the costs of redesign. Although some more time will be required in the initial stages of equipment design, it is understood that it is usually more costly to redesign equipment, than it is to develop it correctly in the first place. Another stakeholder mentioned that gaining feedback from the end-users could assist to reduce upfront costs, as it will inform the design. Improved user involvement in equipment design was also considered to give the OEMs a competitive edge. The stakeholders noted that it would be helpful to have engagements with workers before the equipment has already been implemented at mines, as it is difficult and costly to make changes to the equipment once it has already been manufactured. It was often too costly and time-consuming to incorporate changes from feedback received into equipment prototypes. Sometimes it is not possible to effectively retrofit equipment; as such, product evolution occurs and new versions of the equipment are developed to combat shortcomings in the previous version. Adaptation of workers to numerous different versions of equipment can further result in confusion and also safety risks relating to the changes. Additionally, it was reported that if the use of equipment failed in a particular situation, then it was sometimes abandoned entirely. It also affects the credibility of the equipment and the OEM, if it was not designed correctly up-front. Improved engagements will also help to reduce the time to market, so that all the requirements can be met in initial versions of the equipment.

Additionally, as a result of the cost-implications of changes in the design of equipment once it has already been implemented, workers are sometimes required to use the equipment despite barriers or ineffective design; this can result in workers 'making a plan' or retrofitting the equipment themselves to make it more useable. Furthermore, if machines are difficult to fix when they break down, it will lead to a loss of production. Additionally, OEMs would face costs relating to adapting equipment if there are problems with it, and maintaining the equipment. Conversely, if machines are designed with the proper input, they would be easier to inspect, maintain and repair. These improvements would reduce downtime and result in improved equipment availability and production.

4.6 SKILLS AND TRAINING MATTERS

Training is generally provided when new equipment is introduced onto a mine. This training occurs at different levels, and includes training for operators and technical or engineering staff. One of the OEMs noted that they trained facilitators on the mine to internalise the training, and support buy-in and longevity of the project. The training sometimes takes place on surface, or only takes place underground were the equipment is installed, depending on the need or situation. Training manuals are also generated by OEMs. Competency is evaluated in both written and practical tests. The length of the training might depend on the familiarity of the workforce with similar types of equipment, and the length of training should be considered in relation to the time taken for workers to engage with and adapt to the technology. Simulators are sometimes used for training people on how to use equipment or machines. If people are properly trained it would help to ensure that the equipment is used appropriately.

The stakeholders discussed aspects relating to literacy levels, experience, and technical skills in the SAMI. It is feasible that those with higher levels of literacy could engage quicker with the use of new equipment. Basic literacy was considered to be important with the use of new technologies, as the equipment is often electronic and requires being able to read the screens and understand the displays. It could also be difficult for workers with lower levels of literacy to understand and engage with new concepts or ideas. Additionally, those with higher levels of literacy might feel more able and willing to provide input and feedback. It was noted that literacy and learnability levels differed between individuals, mining methods used, and geographical location.

The levels of experience of both workers and OEMs were also mentioned. It was noted that having engineers with vast experience in the design team helps to inform the design, as they have a good understanding of the mining environment and the work that is done. A lack of experience in technical and design skills in South Africa is a potential challenge, and some of the interviewed stakeholders alluded to a lack of technical colleges and training in South Africa. For this reason, it was noted that there is a high reliance on artisans from neighbouring countries such as Zimbabwe and Zambia. A stakeholder also noted that workers in Zimbabwe, compared to in South Africa, appeared more interested in understanding how equipment worked, which could relate to workplace culture. It was noted that capability and education systems need to be in place before mines transition to increased use of technology. Furthermore, a divide between operators and maintenance teams was commonly highlighted, and was further linked to the culture, hierarchy, and remuneration practices in the mines. Reducing the divide between the people using the equipment and those that repair it would help to reduce problems, for example, so that the operators would be more likely to report problems with the equipment so that it can be repaired.

The adoption of new technologies in the SAMI could provide opportunities for the development of new skills for workers of all levels, including those who are highly qualified and experienced. A shift in skills included those associated with a progressive shift towards more mechanised, rather than labour-intensive, work. There could likely be an increased need towards knowledge- based, manufacturing or maintenance, and electronics-related skills. The stakeholders also noted that the skills of mine managers would also need to change in order to adapt to increased mechanisation. It was noted that there is a gap between the 'old-school' and modern ways of thinking of managers. It was also mentioned that the younger generation of workers differed from the older generation of workers; the younger workers tend to be better educated and included more people from the local communities rather than migrant labour. It was noted that the younger generation tends to want to 'work smart' rather than work hard. This factor could be an opportunity for involving these workers in new technologies. A number of the interviewed stakeholders mentioned that the most important skills required for the adoption of new technologies related to mitigating and managing change. Skills and preparedness were considered to be important. These skills were associated with the culture in the SAMI, which was related to the mentality surrounding conventional, labour intensive work. It was noted that it would take time for the workforce to get used to and understand mechanised mining (e.g. particularly for those in conventional gold and platinum mines). Another of the stakeholders, when noting that workers in other countries have degrees to operate equipment, stated "I imagine a degree would help. But…personally, I think the reason that operators don't develop the necessary skills, is because of the culture in a mine that does not allow them to develop the necessary skills."

4.7 RECOMMENDATIONS TO IMPROVE THE PARTICIPATION OF WORKERS IN EQUIPMENT DESIGN AND DEVELOPMENT

4.7.1 BETTER ENGAGEMENT OF WORKERS IN EQUIPMENT DESIGN AND DEVELOPMENT

The stakeholders generally agreed that workers should be better involved in equipment design and development. It would be worthwhile if workers were involved from the initial stages of design so that ideas can be discussed and issues better identified from the start. If workers are involved before the equipment has been manufactured and installed, then it is easier and less expensive for changes to be made. The use of simulations or mock-up designs could assist with visualisation of the concepts that are proposed. At the onset, the affected parties should be identified, which could include the managers, supervisors, and users of the technology. Ideally, everyone would work together, while the manager or supervisor would support or drive the implementation. Understanding of the perceptions and needs relating to the adoption of the technology of these parties will be necessary.

4.7.2 CULTURE TRANSFORMATION

It is evident that it is not possible to design and implement equipment without considering the impact holistically. Aspects that need to be considered include structures, measures used, organisational culture, team compositions, and skills. Work schedules were also noted to change with the use of new technologies. Workplace culture incorporates aspects such as leadership buy- in, workplace relationships, teamwork, performance and reward. Management or leadership was noted to determine the willingness to innovate at mines. Reference was made to the need for 'Maverick' leadership in order to change from the conventional way things are done in the SAMI. Changes in relationships between management, unions and the workforce would also need to be made as mines modernise. The teams of workers will also need to be reconstituted with the introduction of new technologies, scheduling and ways of working, along with ensuring the teams have the skills that are required. With the adoption of technologies in the SAMI, it will also be necessary to consider performance and reward systems, or how the benefits to the workers could be structured. A stakeholder noted that with new innovation, the performance culture will need to move away from that used with conventional mining. More holistic incentive mechanisms (e.g. profit-sharing or quality bonuses, rather than 100% production bonuses) will need to be considered to drive the most appropriate behaviour.

The culture of the mining industry needs to be addressed to better engage workers in equipment design. It will be necessary to build better levels of trust between the different stakeholders. Improved communication between the workers, managers, and the OEMs would help. This should be done in a structured manner. The needs of the affected individuals need to be considered in terms of health, safety, job security and sustainability of the industry. Tangible ways in which these needs could be addressed, and a clear definition of benefits that could result from the process, should then be provided. It was suggested that workers should be familiarised with the process of being engaged in equipment design procedures using non-threatening technologies. The stakeholders also noted that one should consider the teams where the equipment is trialled, as the workers might be hesitant to use technologies that could reduce production while it is being tested. A lack of buy-in could result if workers resent the new technology and the increased attention that could result from it. Additionally, when equipment is trialled, it should not be in the worst or most difficult areas of the mine, as this would increase the chances of it being abandoned.

4.7.3 PLATFORMS FOR ENGAGEMENT

The need for platforms or forums for engagement about the adoption of equipment in the SAMI were frequently noted as a recommendation. These platforms could be within mining companies, or external to these companies. A neutral platform for OEMs and other stakeholders to engage would be a valuable mechanism. Having a network to access and engage with individuals in mining companies would assist OEMs to develop equipment that will benefit the SAMI. Some of the stakeholders noted that there was no party who was really guiding the imminent transition to mechanisation in the SAMI. Others noted that recently developed structures of the Mandela Mining Precinct (MMP) and MEMSA had a potentially important role to play in coordinating research and development in the SAMI. One stakeholder mentioned that although there were structures in place (such as at mining houses) to engage about equipment development, there is a need for improved consensus. It was suggested that the structures would need to examine different themes, or problems that are faced, for which the relevant stakeholders could be identified and included. These platforms would need to be effectively governed, to ensure that there are no issues such as anti-competitiveness.

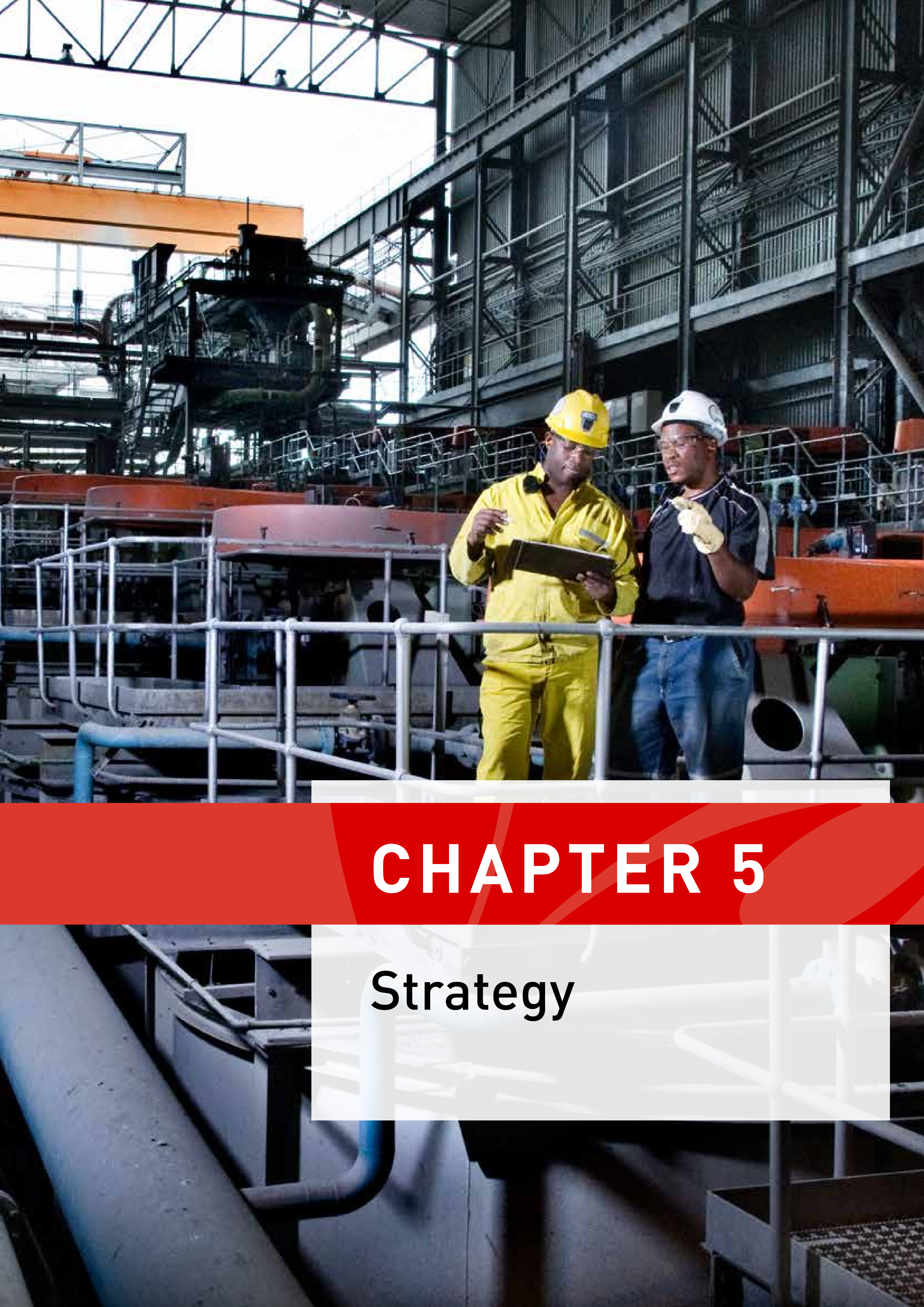
The need for an external, neutral or independent champion or facilitator for these platforms or workshops was commonly mentioned in the interviews. One of the stakeholders noted that a good facilitator could help to "find synergies amongst all of these different ways of thinking". The stakeholders cautioned against opinion-leaders or those with predetermined or fixed ideas, in favour of creating more inclusivity in finding solutions for problems. The challenge of including workers and their superiors in the same workshop was also noted, as workers might be afraid to challenge the opinions of senior personnel.

The stakeholders noted that input from the mining industry would help OEMs know what to design for the future of the SAMI, rather than only focussing on addressing sort-term issues. Collaboration to agree on specifications for design from the mining industry would be helpful. If OEMs received specifications from mining companies, it would also lead to fewer changes in scope, which can be costly and time-consuming. Furthermore, formulating industry norms, standards or rules to govern the design of equipment would help to provide parameters for designers or OEMs in which to work. These include, for example standardised guidelines relating to physical postures, visibility, vibration, cockpit designs, and the layout of controls. Many current standards or guidelines that are used are based on international norms, and might not align to the South African workforce or conditions. It is important to have standards that are up to date and relevant for the local workforce. These rules should not be too stringent, so as to allow for product differentiation. These standards could assist to provide a system to work from so that prior research, experience and learnings relating to equipment development can be formalised to improve the design of equipment developed in the industry in the future, which will save time in research and development, and reduce the costs relating to retrospective redesign. Additionally, it was mentioned that the development of a guideline on change management and engagement in the SAMI would be beneficial. A stakeholder noted that a framework or guidelines for how to develop innovations, and introduce and implement them into the SAMI, would be beneficial. The framework could consider aspects of what is needed, funding mechanisms, and who or what would be involved. New models of partnerships, or contracting, between OEMs and mines in the development of equipment were also mentioned.

4.8 CONCLUSION

Data gathered from the stakeholders during the course of this research provided insight into the level of engagement of workers in equipment development processes. Related benefits and challenges were identified. Recommendations for implementation in the sector included improved engagement of workers in initial phases of equipment design, culture transformation, an independent platform to coordinate equipment development in the SAMI, and the development of specifications, standards, and frameworks for engagement. A strategy for the engagement of workers in equipment development processes will be drafted and discussed with further stakeholders in the SAMI. The intention of this strategy is to improve both the design and the ownership or buy-in of equipment, through improved worker engagement.

The findings in this report represent the views of the stakeholders that participated in the study. Many of the comments made by different individuals reflected similar findings, which supported the concept of data saturation. However, more input from a more diverse range of stakeholders is warranted prior to finalisation of the industry strategy and guidelines for the engagement of workers in equipment development processes. In particular, further input is warranted from both mining company and union representatives. Government stakeholders should also be involved. It is also recommended that future work on this topic involves the workers themselves, while community stakeholders should also be considered.



CHAPTER 5

Strategy

5.1 INTRODUCTION

The purpose of this document is to outline a draft strategy for the engagement of workers in OEM design and development processes in the South African minerals sector. This draft strategy draws on research findings from a review of local and international literature and engagements with stakeholders. Work planned for the 2019/2020 financial year involves that to discuss and refine the strategy, with the input of a range of stakeholders, including mining companies, workers, and worker representatives. This work will contribute to the development of a guideline on including employees in equipment design in the South African mining sector.

5.1.1 AIM OF THE STRATEGY

Improved engagement of workers in equipment design is known to result in more functional technology and improved user acceptance and ownership (Hattingh and Keys, 2010; MacFarlane, 2001). Employee attitudes and resistance to change are barriers to the implementation of new technologies, while worker participation enhances buy-in and also helps to improve trust between the employer and employees (Burton, 2010; Willis et al., 2004). Worker participation in equipment design helps to improve product quality in terms of operability and maintainability, and has further health, safety, productivity and sustainability benefits (Burton, 2010; Horberry et al., 2013; Martin et al., 2013; Rost and Alvero, 2018). Furthermore, the associated social and financial benefits of involving workers from the onset have been highlighted in literature and in engagements held with stakeholders in the SAMI (Horberry et al., 2015; ISO 9241-210, 2010).

The vision of this strategy is to engage workers from the concept stage of equipment design, through to product manufacture and evaluation. The need for this strategy stems from the need to modernise the minerals sector in South Africa.

5.1.2 CONTEXT

As indicated in the review of literature, the South African minerals sector needs to modernise to remain sustainable. Modernisation aims to address challenges faced by the industry and to make mining operators safer, healthier and more productive (Minerals Council South Africa, 2018; Ritchken, 2017; Singh, 2017). Modernisation refers to innovation and the use of new technologies and may involve increased use of mechanisation and automation (Jacobs and Webber-Youngman, 2017). Modernisation will require changes to processes, technologies, skill sets, and will need to address the social and environmental impacts of mining (MacFarlane, 2001; Singh, 2017).

The South African Mining Extraction Research Development and Innovation (SAMERDI) strategy was an input to the 2015 Mining Phakisa, with the aim "to maximise the returns of South Africa's mineral wealth through collaborative, sustainable research, development, innovation of mining technologies in a socially, environmentally and financially responsible manner that is rooted in the wellbeing of local communities and the national economy" (Singh, et al., 2017, p11). The MMP was launched in response to industry needs, with the intention of enabling a research and development community to work together on related subjects in the same space. The Mining Equipment Manufacturing Cluster of South African (MEMSA) was also established, to help position South African mining manufacturers as competitive, innovative, and transformative suppliers to local and global markets (Singh, et al., 2017).

5.1.3 DEFINITIONS

At the outset of this report, it is necessary to define certain terms for improved clarity. The term 'strategy', firstly, refers to a plan of action. In this case the strategy refers to a plan of action to involve workers in OEM equipment development processes. Based on the findings from engagements that were held to inform the development of this draft strategy, it was evident that it was necessary to elaborate on the term 'worker'. For this project, the term worker incorporates employees and end-users of the equipment, including both operators and artisans. The term further incorporates workers from all levels of the mining company, including managers, engineers, supervisors and mine workers.

5.2 PARTICIPATION OF WORKERS IN EQUIPMENT DESIGN

Best practice in terms of approaches and processes for worker participation in equipment design and development processes have been recorded in local and international literature. Human- centred design is recommended, and includes user-centred, participatory and ergonomics design processes (Horberry et al., 2015). It is important to engage all stakeholders in the design process (Horberry et al., 2015; MacFarlane, 2001; Martin et al., 2013). In particular, workers should be involved in all stages of equipment design, development, implementation and evaluation (Burton, 2010; Hattingh and Keys, 2010; Horberry et al., 2015; MacFarlane, 2001). Furthermore, workers should act as co-developers and be involved in decision-making, and not only in consultation (EU- OSHA, 2012; Vogt and Hattingh, 2016).

From engagements that were held with mining industry stakeholders, it was evident that there is a lack of engagement of workers in equipment design. There generally appeared to be some level of engagement between managers, including engineers, at mining companies, and OEMs during equipment conceptualisation. However, a lack of access to mine sites, or differences in opinion regarding equipment needs, were barriers relating to worker engagement at this stage. Lower level workers, including operators and artisans, were usually only engaged with new equipment once it was trialled or piloted at the mines. Generally, these workers could provide indirect feedback to the OEMs about the design of the equipment. However, it was often too costly or time- consuming for changes in equipment to be made at this stage. It is recommended that steps are taken to better involve all workers in equipment design and development in the SAMI to improve equipment design and improve acceptance and ownership.

Recommended processes for worker engagement in equipment design and development have been identified. A systematic, holistic approach is required (Minerals Council South Africa, 2018). Potential barriers and enablers should also be considered (van Eerd et al., 2010). At the onset to the project, it is necessary to define the scope of work, which includes the users, tasks and the environment in which the equipment will operate (Horberry et al., 2015; ISO 9241-210, 2010). The solution needs to be customised to local conditions and cultures (Burton, 2010; Hattingh and Keys, 2010; Helali, 2009; IWH, 2008). It is also necessary to assess the resources (e.g. human and equipment) required and available (de Koker and Schutte, 1999). Management commitment needs to be secured, and it is evident that organisational support is vital (Helali, 2009; Hattingh and Keys, 2010). The next step is the creation of multidisciplinary teams with representative members (Horberry et al., 2015; IWH, 2008; van Eerd et al., 2010). It is important to identify a good leader or facilitator for the process (de Koker and Schutte, 1999). Requisite training, knowledge and abilities within the team are important for the success of the project (IWH, 2008). Training should be provided, where necessary, such as to gain a common understanding the purpose of the intervention, on ergonomics criteria, and how to provide appropriate feedback (de Koker and Schutte, 1999; Hattingh and Keys, 2010). The equipment should then be discussed, and solutions developed (de Koker and Schutte, 1999; van Eerd et al., 2010). Numerous potential methods for participatory design have been described in literature (e.g. de Koker and Schutte, 1999; Helali, 2009; Horberry et al., 2015; Lee et al., 2009; Spinuzzi, 2004; Sundin et al., 2004). The design process should be iterative, and therefore evaluation and refining of the solutions should take place (Hattingh and Keys, 2010; Horberry et al., 2015; Martin et al., 2013; Spinuzzi, 2004).

Relationships, trust, and good communication are important components in this process. These factors link to the need to have a supportive workplace culture. This basic process for worker engagement has been illustrated in Figure 1.

External factors:
- Workplace culture, communication, leadership and trust.
- Work systems and structure

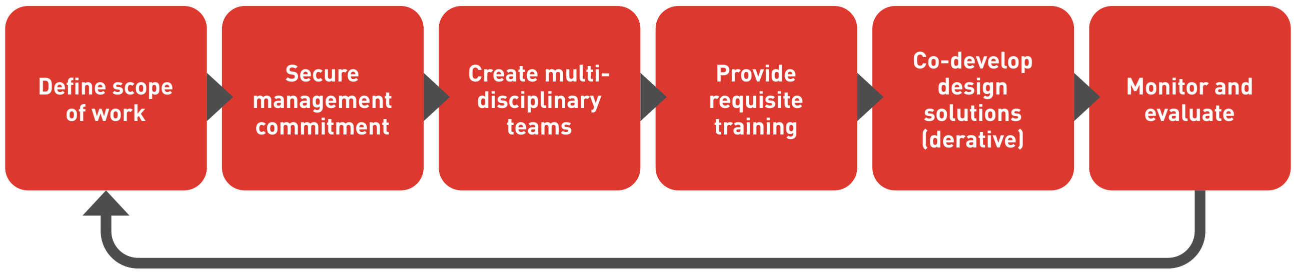


Figure 1: Recommended process for engaging workers in equipment design

An inclusive, underlying change management process should be implemented to support the engaging of workers in equipment design. In deciding on an appropriate change management approach, Hiatl (1998) identified the following approach as best practice for change management, which is common to many best practice change management models:
- Identify what will be changed/improved
- Use an inclusive process to arrive at a solid business case
- Plan for the change
- Provide resources and use data for evaluation
- Communication
- Monitor and manage resistance, dependencies, and budgeting risks
- Celebrate success
- Review, revise and continuously improve

The Minerals Council South Africa supports the Mining Industry Occupational Safety and Health (MOSH) adoption process for leading practices, as a best practice approach. This process relates to practices in terms of high-risk issues like dust, transport and machinery, falls of ground and noise. There are three distinct phases in terms of the adoption process, namely: identify the leading practice, document the leading practice, and facilitate widespread adoption. The process for adoption is underpinned by a change management process (Malatji and Stewart, 2016). This study has not investigated an underlying change management model and process. However an applicable change management process becomes important for engaging workers in equipment design.

Importantly, this project has links with other projects that are currently being conducted in the SATCAP programme, including that relating to the review and modification of the MOSH process for a change management protocol relevant to the adoption of new technology in the context of modernisation. The outcomes of this project should be considered in relation to the engagement of workers in OEM design and development processes.

5.3 CULTURE TRANSFORMATION

Research conducted by SAMERDI work teams indicated workplace culture to be a major barrier to engaging workers in equipment design processes. This finding was related to the history of the SAMI. It is evident that there is a lack of trust between workers and management in mines. With increased technological innovation, there are also increased threats of job replacement, which contributes to this lack of trust in management motives. The impact of workplace maturity was highlighted, along with differences in 'old' and 'new' ways of thinking. The important role played by leadership was frequently highlighted. As modernisation of the mining industry will change aspects including work systems, teams, skills required, and performance and remuneration, these matters will need to be addressed. A culture change is required before workers can be adequately involved in equipment design and development processes. The following issues should be considered in this regard:

- Leadership;
- Trust;
- Work structure and teams;
- Performance and remuneration systems; and
- Education, training and experience.

5.4 TRAINING AND SKILLS IMPLICATIONS

Modernisation and the introduction of new technologies into mines will provide opportunities for new skills to be developed. Those involved in teams to design and develop new equipment should be trained in ergonomics principles. Improved change management awareness and skills are recommended for all levels of industry stakeholders. Additionally, higher levels of technical training will assist with addressing future needs in the industry. Training to reduce the divide between the operators of equipment and those that maintain the equipment is also recommended. Furthermore, the education system of the country will need to be assessed and adapted to fit with industry needs and increased technological innovation.

5.5 PLATFORMS FOR ENGAGEMENT

Industry forums are recommended to inform equipment needs and design in the SAMI. It will be necessary for all stakeholders to be involved in discussing issues facing the mining industry, and to reach an agreement on the needs and concerns relating to modernisation of the sector. These stakeholders would include mining companies, organised labour, researchers and industry experts, and constituents from governing bodies such as MEMSA, the Minerals Council South Africa, the Department of Mineral Resources (DMR), Mining Qualifications Authority (MQA) and the Mine Health and Safety Council (MHSC). New models of partnership between stakeholders, including OEMs and mining houses, may be required. It is recommended that an independent platform be developed to coordinate these engagements, and a neutral facilitator should be appointed to chair these sessions. This platform could potentially be based at the MMP and coordinated by SAMERDI partners or MEMSA. These platforms could be used to reach agreements on specifications for new technologies, and the development of standards and guidelines. Different forums or workshops would need to be set up in order to discuss different matters or equipment. The need and context of each engagement will be determined, and the relevant stakeholders should be identified and invited. A stakeholder database and platform for engagement will be a valuable mechanism to support collaboration. Trust amongst industry partners can be built by understanding and addressing the needs of each stakeholder. Workers will need to be familiarised with the processes involved in equipment conceptualisation and design, and it is recommended that this familiarisation process takes place with equipment that is not likely to be a perceived threat to job security.

The Earth Moving Equipment Safety Round Table (EMESRT) working group has developed engagement processes which could be emulated in the SAMI (EMESRT, 2018). The EMESRT approach involves industry-level engagement with OEMs, to better understand operational and maintenance issues from a customer/user perspective. The EMERST engagement process has been arranged around eight design philosophy categories, namely: access and working at heights; tyres and rims; exposure to harmful engines; fire; machine operation and control; health impacting factors; manual tasks; and confined spaces and restricted work areas. Work is also conducted with other stakeholders, including third-party suppliers, researchers, and industry associations. EMESRT has further developed the Operability Maintainability Assessment Technique (OMAT), which involves engaging users with a structured task-based methodology, and the EMESRT Design Evaluation for Earth moving Equipment Procurement (EDEEP) process (EMESRT, 2012 and 2018).

5.6 CONCLUSIONS

Improved worker engagement in OEM equipment design processes will help to improve acceptance, ownership, equipment design, quality, health, safety and productivity. Recommendations of approaches and processes to follow in involving workers in equipment design processes have been provided in this document. Additionally, numerous methods are available to support human-centred design processes (Maguire, 2001).

A platform to discuss equipment needs and design processes for the South African minerals sector should be set up. The platform, as recommended, should allow for participation, engagement and inclusion of OEMs, unions, mine employees and mine leadership, and other identified stakeholders. It is also recommended that aspects relating to culture transformation, skilling and training, and change management be addressed in order for modernisation initiatives to be successful.

Recommendations for future work involve the review of the draft strategy by relevant stakeholders, for validation, and then the development of a guideline for the involvement of employees in equipment design.

The assessment of a pilot or case study relating to the engagement of workers in equipment developed is also recommended. SATCAP 2019/2020 research work on developing a guideline to engage employees in equipment design will conduct a case study towards practical recommendations.

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Annexures

ANNEXURE A: INTERVIEW/FOCUS GROUP DISCUSSION GUIDE

- Are workers engaged in the conceptualisation, design or development of equipment that is used on mines?
  - If so, how is this done?
  - If not, why not? What could be changed to encourage OEMs to engage workers, or to enable worker participation?
- Which levels or groups of workers are involved in equipment development?
- At what stage are the different levels of workers introduced to equipment that is developed locally or globally?
- Is equipment designed or retrofitted to fit the local workforce, their tasks, and the environment? If so, how is this done?
- How do the different levels of workers give feedback regarding the design and effectiveness of new technology, and how is this feedback integrated into equipment development?
- If applicable, what training is provided when workers are involved in equipment development or adoption?
- Are there opportunities for new skills to be developed as mines adopt new technologies?
- What hurdles or challenges are faced (e.g. by mining companies and OEMs) with the involvement of workers in these development processes?
- What are the benefits of involving workers in equipment research and development?
- What do you recommend should be done to improve the participation workers in equipment design and development?

ANNEXURE B: ETHICS CLEARANCE

CSIR
our future through science

CSIR Research Ethics Committee
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05 December 2018

Dear: **Mr Navin Singh**

Extension of the validity of the previously approved Protocol: **The South African Mining, Extraction, Research, Development and Innovation (SAMERDI) Programme.**

This is to confirm that the ethical approval validity for this Protocol that has since expired has been extended for another year. The reference number of this research project is **REF: 239/2017.**

This approval of the extension is granted under the condition that:

1. The researcher remains within the procedures and protocols indicated in the proposal, as well as the additions made to the procedures and protocols as indicated in the responses submitted to the questions of the REC, particularly in terms of any undertakings made and guarantees given.
2. The researcher notes that **any deviations to the approved project/protocol must be submitted to the REC for approval before implementation**.
3. The researcher remains within the parameters of any applicable national legislation, institutional guidelines and scientific standards relevant to the specific field of research.
4. This **approval is valid for one calendar year from the date of this letter.**
5. The researcher submit bi-annual progress reports to the REC
6. The researcher immediately alert the REC of any adverse events that have occurred during the course of the study, as well as the actions that were taken to immediately respond to these events.
7. The researcher alert the REC of any new or unexpected ethical issues that emerged during the course of the study, and how these ethical issues were addressed. If unsure how to respond to these unexpected or new ethical issues as they emerge, the researcher should immediately consult with the REC for advice.
8. The researcher submit a short report to the REC on completion of the research in which it is indicated (i) that the research has been completed; (ii) if any new or unexpected ethical issues emerged during the course of the study; and if so, (iii) how these ethical issues were addressed.

We wish you all of the best with your research project.

Kind regards

Prof WA Hoffmann

(CSIR REC Chair)

Ms Brenda Mapunya

(CSIR REC Secretariat)