MANDELA MINING PRECINCT
MINDS FOR MINES

Guideline:
Inclusion of stakeholders in equipment design and development in the South African mining sector

science & innovation
Department: Science and Innovation
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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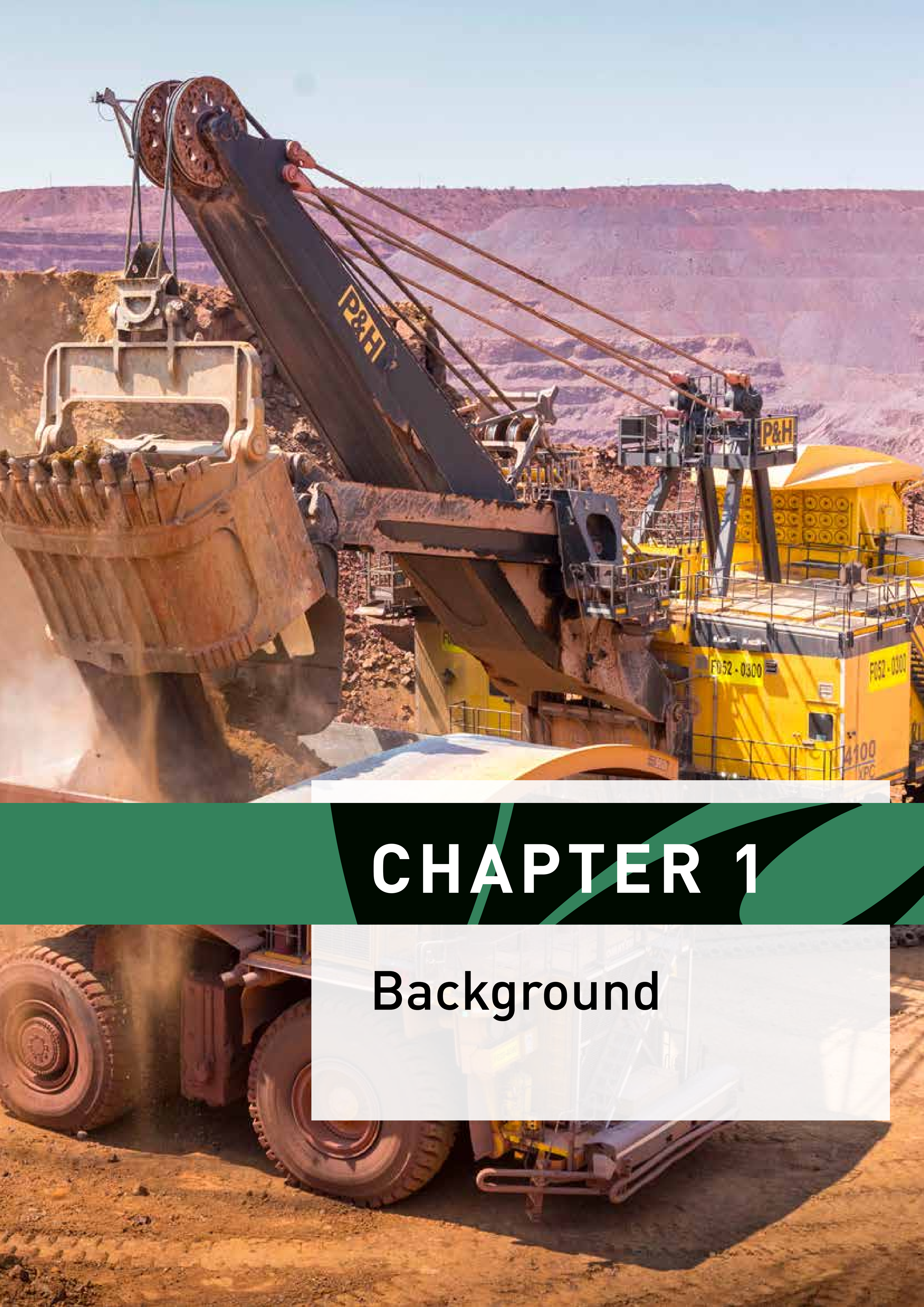

CHAPTER 1

Background

The Mandela Mining Precinct commissioned a project to develop a guideline for the inclusion of stakeholders in equipment design and development processes, in the context of the modernising mining sector in South Africa. For the purposes of this guideline, a stakeholder is a party that has an interest in a mining company and can either affect or be affected by the business (mining operations). At a typical mining operation, stakeholders include the board of directors, all management levels, frontline supervisors, all employees (workers), organised labour (unions), contractors, service providers, government (particularly the Department of Mineral Resources and Energy), other mining companies, communities surrounding the mine, non-governmental organisations and local authorities. Additionally, in this guideline, original equipment manufacturers (OEMs) generally refer to local, rather than international, equipment manufacturers. The project was funded by the Department of Science and Innovation (DSI), as part of the Successful Application of Technology Centred Around People (SATCAP) programme, in support of the South African Mining Extraction Research, Development and Innovation (SAMERDI) strategy. The project was conducted by the Council for Scientific and Industrial Research (CSIR), in collaboration with Enterprises University of Pretoria (EUP). The project comprised Work Package 3 "People-centric modernisation" for the 2020-21 financial year.

1.1 SUMMARY OF PROJECT AIM AND OBJECTIVES

The aim of the project was to support people-centric mining modernisation through stakeholder inclusion in equipment design and development. The research objectives were:

- To understand the benefits and shortcomings of stakeholder inclusion in equipment design and development;
- To gain insight into the (current and best practice) process for inclusion of employees in equipment design, applicable for mining modernisation; and
- To develop a guideline for worker inclusion in equipment design and development, applicable for mining modernisation.

1.2 SUMMARY OF RESEARCH FINDINGS

1.2.1 BENEFITS OF INCLUSION IN EQUIPMENT DESIGN AND DEVELOPMENT

Early involvement of the workforce was recommended for improved inputs into equipment design before it is developed. Mutual social and economic benefits of inclusion in equipment design and development were identified for mining companies, OEMs and workers. These benefits included:

- Improved health, safety and wellbeing;
- Improved insight from workers about practical applications and design requirements;
- Improved ownership, acceptance and uptake;
- Early, and less costly, detection of problems;
- Improved product quality;
- Improved effectiveness, efficiency, and productivity;
- Improved user satisfaction, accessibility and sustainability;
- Reduced time to market;
- Increased demand for equipment (competitive advantage);
- Opportunities for reskilling; and
- Reduced downtime and support costs.

1.2.2 BARRIERS TO INCLUSION IN EQUIPMENT DESIGN AND DEVELOPMENT

Several gaps relating to the inclusion of stakeholders in equipment design and development were evident. For example, a gap between theory and practice in terms of employee inclusion in equipment design and development was noted. While inclusion has been shown to improve aspects such as product quality and buy-in, there was limited participation of stakeholders throughout the equipment design and development process in the South African mining sector. It was noted that in cases where the equipment development was driven by the mining industry ("market pull"), there was usually more involvement from mining company management, than if there were a "technology push". Workers or employees (end-users) were usually only involved when the equipment was being rolled out or trialled at the mine. A knowledge gap was identified between the designers or manufacturers and the end-users. Further gaps or related barriers to worker inclusion in equipment design and development processes were identified during this research, and included:

- A lack of resources (e.g. time, budget, material and personnel);
- Challenges releasing workers (mining industry employees) for inclusion in equipment design and development;
- Logistic constraints;
- Challenges managing requirements of numerous stakeholders;
- Lack of a systematic plan or approach;
- Lack of integrated systems thinking;
- Lack of technical and design skills;
- Inadequate communication;
- Intellectual property (IP) and legislative concerns;
- Organisational culture or climate;
- Attitudes or mindsets of mines, OEMs and workers;
- Lack of acceptance (i.e. resistance to change);
- Dealing with perceptions and engaging people to obtain buy-in at all levels;
- Concerns about the impact (e.g. job losses and skills requirements); and
- Lack of appropriate change management strategy.

1.2.3 ESSENTIAL ELEMENTS IN THE DESIGN AND DEVELOPMENT PROCESS

Meanwhile, factors that were considered necessary in the equipment design and development process were identified, including:

- Understanding of the users, tasks and environment (i.e. system context);
- Addressing the whole user experience;
- Specifications of user and organisational requirements;
- Needs analysis (through consultation);
- Cost-benefit analysis;
- Stakeholder participation early and throughout the design and development process;
- Multi-disciplinary skills and perspectives;
- Designing the equipment to be easy to use, fit for purpose, and fit to the user;
- Understanding of regulations or legislative framework;
- Iterative design (i.e. feedback, evaluation and re-design);
- Systematic, step-by-step design process;
- Systems mapping and integration;
- Skills development; and
- Effective change management.

It was evident that the approach to stakeholder inclusion in equipment design and development needs to be customised based on the context of use, and would depend on factors such as the type of equipment, mine, company and manufacturer. A human-centred systems design approach was identified as good practice for stakeholder inclusion in equipment design and development.

1.2.4 IMPACTS OF COVID-19 ON INCLUSION IN EQUIPMENT DESIGN AND DEVELOPMENT

During the project, effects of the COVID-19 pandemic, relating to stakeholder inclusion in equipment design and development were cited. These included:

- A highlighted need for a human-centred systems approach to assessment and management of the COVID-19 pandemic;
- Increased use of online or remote communication platforms;
- Restrictions in access to mines for trialling and testing of new equipment;
- Reduced focus on research and development;
- Businesses closing down and job losses in the mining sector, including the mining supply chain (e.g. in manufacturing);
- Delays in the supply of international materials or products for equipment development; and
- A highlighted need for improved skills in mining to maintain the equipment.

CHAPTER 2

Recommended guideline for stakeholder inclusion in equipment design and development

This section details the recommended guideline for stakeholder inclusion in equipment design and development in the South African mining sector. The purpose of the guideline is to provide a framework to support mining companies, equipment manufacturers, and workers, which can be used to enhance the inclusion of all mining industry stakeholders in equipment design and development processes. The guideline contains a voluntary process to follow in equipment design and development, which would be customised to suit the particular context. It is important to note that this process might be better suited for interventions that are driven by industry ("demand-pull") than from developers or manufacturers ("technology-push") as a result of the nature of these processes and ease of access to stakeholders for participation. Although it might be difficult to fully implement all elements of the guideline in a technology-push scenario, full implementation of all elements of the guideline will catalyse sustainable assimilation of technology in the South African mining sector.

The recommended guideline that was developed for the project is shown in Table 1 and will be described further in this document. Figure 1 illustrates the basic model for the guideline. These illustrations depict the suggested process to follow during the design and development process relating to the inclusion of stakeholders, and particularly workers or employees. The use of job grading levels can be made as a method to ensure buy-in from all levels of employees in the process. Examples of methods that can be used to facilitate the process are also provided. The approach taken in the development of this guideline is of human-centred design, which is considered good practice in industry internationally. In particular, ISO 9241:210 (Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems) and ISO: 9241:220 (Ergonomics of human-system interaction — Part 220: Processes for enabling, executing and assessing human-centred design within organisations) were used as the basis for the reference to the human-centred design approach, principles and processes. These documents can be consulted for more detailed information relating to requirements and recommendations for human-centred design.

Five basic stages are proposed in the recommended guideline, namely: Demand analysis; Product specifications; Equipment design and development; Demonstration, pilot, review and refinement; and Adoption. The dotted lines in Figure 1 refer to an example of loops to reflect on whether the requirements of previous steps have been adequately met. This type of verification should take place for each step in the guideline. Notes relating to each of the steps are as follows:

- Demand analysis: The guideline is initiated by various forms of changes/drives in the environment (i.e. regulatory requirements, best practice developments, production methodology changes, etc.);
- Product specifications: This stage focuses on technical specifications that need to align to best practice, regulatory requirements, Safety, Health, Environment and Quality (SHEQ) specifications and other technical requirements around human-centred design;
- Equipment design and development: There is a focus on the development of a technical guideline for users, which is aligned to best practice and the development of a prototype;
- Demonstration, pilot, review and refinement: User interaction is evaluated and ergonomics factors evaluated in the use of the equipment. Digital/physical interfaces are evaluated during this step;
- Adoption: Adoption would be either per operation (if economically viable), per company, per commodity, or for sector. Business cases would have had to be used as a basis for this (see step 1).

The descriptions, sub-processes, and potential methods for each step, are indicated in Table 1. Factors underpinning the guideline are also incorporated, and include the need for loop learning, and change management throughout the process.

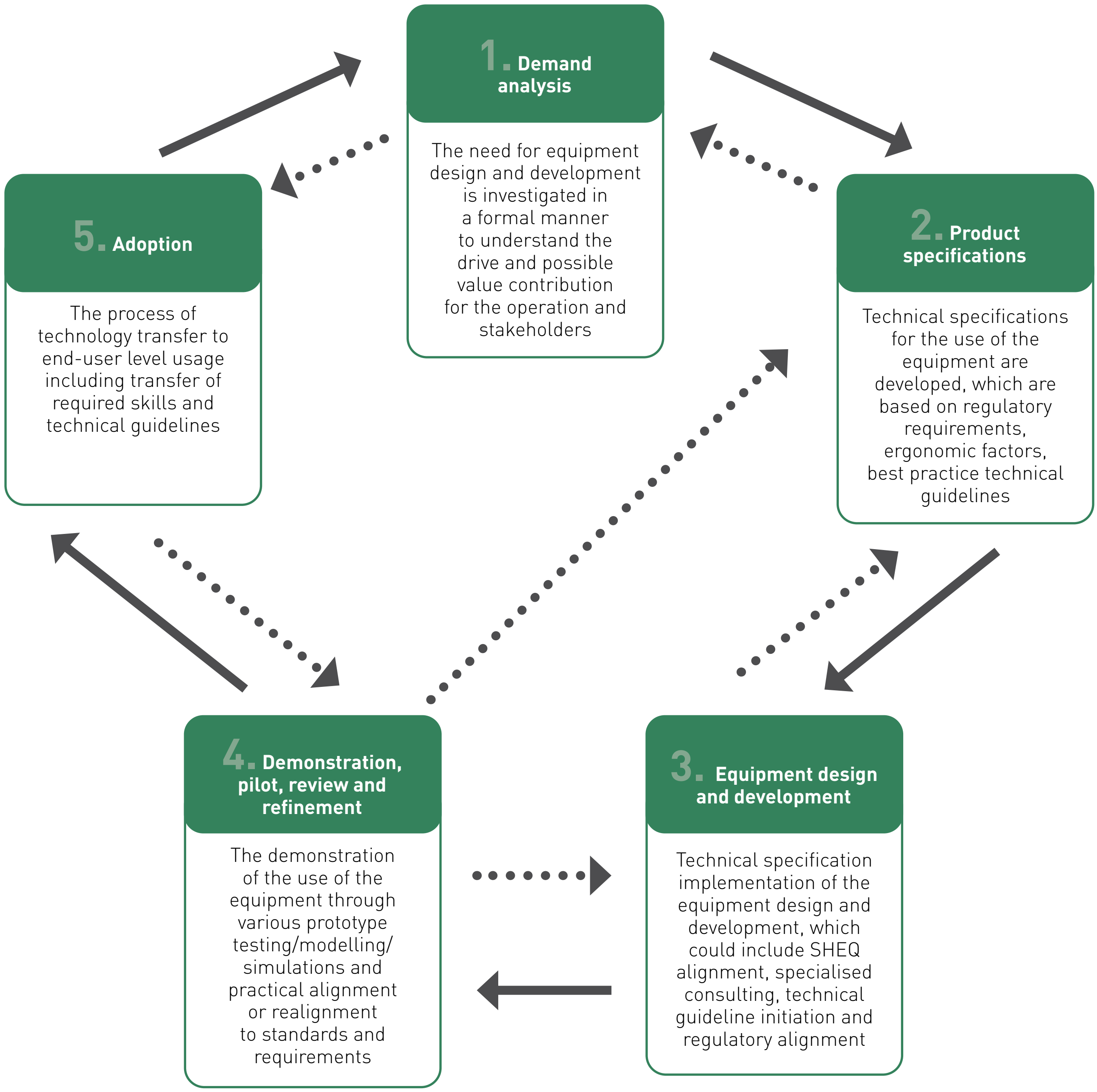

Figure 1: Recommended process model for stakeholder inclusion in equipment design and development in the South African mining sector

Table1: Recommended guideline for stakeholder participation in equipment design and development for the South African mining sector

STEP TITLE	1. DEMAND ANALYSIS	2. PRODUCT SPECIFICATIONS	3. EQUIPMENT DESIGN AND DEVELOPMENT	4. DEMONSTRATION, PILOT, REVIEW AND REFINEMENT	5. ADOPTION
Description	The need for equipment design and development is investigated in a formal manner to understand the drive and possible value contribution of the operation and stakeholders	Technical specifications for the use of the equipment are developed, based on regulatory requirements, ergonomic factors, best practice technical guidelines	Technical specification implementation of the equipment design and development, which could include SHEQ alignment, specialised consulting, technical guideline initiation and regulatory alignment	The demonstration of the use of the equipment through various prototype testing/modelling/ simulations and practical alignment or realignment to standards and requirements	The process of technology transfer to end-user level usage including transfer of required skills and technical guidelines
Process Underpin	1.1. Business case 1.2. Context of use definitions (scenarios of use), which include the technical, physical, social, cultural, and organisational environments 1.3. Stakeholder identification 1.4. SHEQ Analysis 1.5. Organisational impact assessment	2.1. Technical specification determination 2.2. Regulatory analysis 2.3. Environmental analysis 2.4. Ergonomic factor analysis 2.5. Best practice benchmarking	3.1. Concept development 3.2. Technical specification analysis 3.3. SHEQ requirement inclusion 3.4. Specialised technical development and inputs 3.5. Projections and modelling	4.1. Prototyping and organisation practical testing (mock-up trials) 4.2. User testing, feedback and alignment (if required) 4.3. Further technical guideline development 4.4. Verification and validation	5.1. Skills transfer 5.2. Technology transfer to user 5.3 Application / commissioning and review
Methodology (Examples)	• Brainstorming • Benchmarking best practice • Idea generation methods • Field studies • Surveys • Observations • Technical steering committee establishment and inputs provided • Environmental analysis • Cost-benefit analysis • Role play • Context diagram	• Benchmarking • OEM specification • Regulatory specifications • Ergonomic guidelines • Focus group discussions • Surveys • Desktop study	• Organisational prototyping • Design guidelines and standards • Virtual reality (VR) design and projections • Lead user analysis • National/ international modelling	• Model run • Broader simulations • Projections (scenario, production, financial, other) • Physical demonstration (prototype concept and site/mock-up demonstration) • VR and simulations	• Skills transfer • User and technical guideline distribution and implementation • Standard operating procedures implemented • Post-delivery support • Refer to change guideline • Communication strategies rolled out

Possible Stakeholders Involved	• Driver: industry / mine management • Lead: OEMs • Mine technical services (e.g. engineering, safety, production) • Support services at mines (e.g. ICT, training, HR, OHS, finance, procurement, legal) • External consultants (e.g. SHEQ, technical designer, programmers) • Indirect input from the workforce from all job grades (e.g. operators, artisans, supervisors, miners, shift bosses) • Labour representatives (if relevant) • Regulator (if relevant) • Etc.	• Industry / mine management, including technical and support services • OEMs • External consultants • Suppliers (if relevant) • Labour representatives • Workforce • Regulator (if relevant) • Etc.	• OEMs • Industry / mine management, including technical and support services • External consultants (if relevant) • Suppliers • Labour representatives • Workforce (direct participation) • Regulator (if relevant) • Etc.	• OEMs • Industry / mine management, including technical and support services • External consultants (if relevant) • Suppliers (if relevant) • Labour representatives • Workforce (direct participation) • Regulator • Communities • Etc.	• OEMs • Industry / mine management, including technical and support services • External consultants (if relevant) • Suppliers (if relevant) • Labour representatives • Workforce (direct participation) • Regulator • Communities • Etc.
Underpinning Factors	Loop Learning (single, double and triple loop), including hazard analysis Change Management (monitoring and evaluation – communication strategies) Impact on Jobs and Skills Requirements				

Loop learning serves as a continuous improvement tool where gaps and lessons learnt are identified at each stage of the process, for subsequent development and implementation of an action plan to close the identified gaps. Loop learning within the guideline refers to the theory of organisational learning that takes place. Loop learning also closely relates to project management success and contributes to greater success in project implementation (McClory et al., 2017). The loop learning theory thus applies to the project management approach to equipment design. The aim of including loop learning was to ensure that the guideline is aligned to best practice principles of project management as well as ensure that there is continuous feedback into the various steps in the guideline. Jaaron and Backhouse (2017) state that loop learning is an activity that contributes to creating knowledge. This knowledge is then utilised to realign practices, specifications, guidelines, prototypes, etc. Loop learning can in essence be described as a methodology to create feedback spirals so that the project, or organisation, can learn from the activities undertaken (Carless, 2019).

Change management processes also should be followed within the design, development, and implementation of equipment. The guideline for stakeholder inclusion in equipment design and development can be implemented in alignment with change management processes, such as that developed by Stanz et al. (2020). This change management guideline was developed as part of a SATCAP project and based on the Mining Occupational Safety and Health (MOSH) Leading Practice Adoption System. The five stages of the change processes are the following:

- Identification;
- Planning;
- Documentation;
- Demonstration; and
- Adoption.

There is alignment between the change guideline and guideline for stakeholder inclusion in equipment design and development. For example, both processes involve specifying the need for the intervention (i.e. change intervention or equipment development), stakeholder identification and engagement, and phases involving demonstration and adoption. Change management processes should be considered throughout equipment design and development. The guideline for stakeholder inclusion in equipment design and development more specifically focuses on equipment design and development activities and methods that can be used to support these processes.

CONCLUSION

This recommended guideline informs methods and processes for the improved participation of stakeholders in equipment design and development in the mining sector in South Africa. A human-centred systems design approach is recommended. Additionally, processes running in parallel with equipment design and development are needed to enable to address the identified barriers and enable successful people-centric modernisation of the mining industry.