Safety in Mines Research Advisory Committee

Final Report

Ergonomics of mining machinery and transport in the South African mining industry

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Executive Summary

As a practice, ergonomics applies human-system interface technology to the analysis, design, standardisation and control of systems to improve safety, health, comfort and productivity. A major goal of ergonomics is to minimise design-induced human error.

Local and international safety statistics indicate that ergonomic factors underlie many of the accidents occurring in mines, and could impact negatively on the effective and efficient operation of mining machinery and transport systems.

Against this background, a study was conducted to assess the ergonomics of a number of mining machines and transport systems to identify the ergonomics-related hazards that could impact on the operators' ability to work safely and efficiently.

Cabin ingress and egress proved to be a problem in many of the machines and vehicles assessed, especially in the case of the haulage trucks. In most cases, the steps provided were too high and too far from the ground level, so that the act of mounting the vehicle created strain on the operator.

Inadequate cabin space, controls in the wrong location and information displays that are difficult to read resulted in operators/drivers adopting awkward postures. These awkward postures, particularly if they are adopted repeatedly or over prolonged periods, may cause discomfort and fatigue, and increase the risk of musculoskeletal disorders.

Most of the haulage trucks and utility vehicles have open cabs with an unrestricted view to the front and sides of the machinery. However, the sideways sitting orientation influenced the operator's dynamic viewing field. Although this appeared to be overcome by head and eye movements, the frequency of such movements would cause fatigue. For the mining machines with cab canopies, such as roof bolters and drill rigs, forward viewing to the ground was severely limited. Blind spots at the corners of the enclosed cabs also restricted the visual angles.

The seats in the older vehicles assessed were in a poor, and in some instances in an unserviceable, condition. Where newer seats had been provided, the seat-adjustment controls were found either not to be used by the driver or not to be in working order.

Typical shortcomings observed with regard to displays included poor positioning of displays, incorrect labelling, no labelling or, if labels were present, they were dirty and illegible. As far as controls are concerned, the positioning and configuration of controls on some of the vehicles were not optimal in terms of ergonomics requirements and presented a safety hazard.

The observed occupational health and safety risks resulting from ergonomics-related factors can be ascribed predominantly to workstation designs based on anthropometric data that are not entirely suitable for the South African user population.

As far as could be established, there is no standard dedicated to underground mining machinery and transport systems. However, a number of international standards that deal with general requirements for earth-moving equipment are available and could, together with appropriate anthropometry, be used as a basis for the design of mining machinery and transport systems.

From an ergonomics point of view, improvements aimed at reducing the risk of the musculoskeletal disorders and worker fatigue associated with the cabin design of mining machinery and transport systems will depend heavily on the availability of anthropometric data pertaining to the user population in the South African mining industry, both male and female. Current information on the body dimensions of South African mine workers is rather dated and covers only male mine workers.

In view of the importance of this information in the design of the operator workstations (the 'operator space envelope') of mining equipment, and mining tasks in general, it is recommended that studies be carried out to determine the functional anthropometry (i.e. those body dimensions that are essential for the design of workstations) of South African mine workers (both male and female).

The latest South African anthropometric data are based on a representative sample of males and females from an SANDF survey. It is recommended that a small sample representative of the mine worker population be measured for the critical anthropometric variables used in workstation design and specification, in order to verify whether indeed the military data are applicable to the mining community.

It is recommended that a concerted effort be made to upgrade the seats of mining machinery and transport systems. Seat maintenance programmes and the training of operators to adjust their seats properly to meet their personal requirements are indicated.

It is further recommended that the steps and handrails on existing mining machinery and transport systems be inspected and modified, if necessary, to provide the operator with the required three-point support for safe access and exit.

The possibility of making practical modifications and retrofits to improve the driver's visual field should be investigated. The aim of effective modifications or retrofits would be to eliminate visual obstructions and to improve illumination in the driver's primary visual field by ensuring that the driver's position will optimise visibility. The design of the supports for the cab canopy must also not impair visibility.

Because of the limitations of cab designs, which are influenced mainly by the height of the mine tunnel, visual field can be improved by:

- Providing a height-adjustable seat so that the 95th percentile can adopt a low-sitting configuration to improve the visual field.
- Repositioning existing equipment and lights mounted on top of the forward frame that obscure the driver's vision to the front.
- Lowering the fenders to minimise visual obstruction.
- Investigating the possibility of using a video camera to help the driver to spot personnel on foot or obstacles at the front and rear right corners of the vehicle, and for turning into corners that are on the opposite side of the cab.
- Totally redesigning the cab's position, size and orientation on the vehicle. This will, however, only be practical with major rework or for new mining machinery designs.

These recommendations may have a cost implication. However, the improved visibility would result in improved safety and comfort for the driver, and also in improved productivity and fewer vehicle accidents.

Future designs of mining machinery should consider eliminating the sideways sitting orientation as substantial advantages with regard to viewing angles, driving accuracy and effectiveness can be obtained from forward-facing and rearward-facing driving positions.

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1. Introduction

Ergonomics is the science and practice of designing systems to fit people. As a science, it involves the study of human performance capabilities, limitations and other characteristics to develop human system-interface technology in the form of ergonomic design principles, guidelines and specifications.

A useful concept in understanding the occupational application of ergonomics is that of an 'ergosystem'. An ergosystem consists of three primary interacting components, namely human, machine or technology, and environment. In a basic human-machine interface, the operator and 'machine' are in a closed loop, connected by displays and controls. 'Machine information' is converted into 'operator information' via displays, and controls act as transducers to allow the operator to change a system's state. Feedback to the operator system comes via displays and via the interaction with the controls. When the output characteristics of each of the above match the input characteristics of the other, it is referred to as a user-system fit or as a successful human-machine interface (Kroemer and Grandjean, 1997)

As a practice, ergonomics applies human-system interface technology to the analysis, design, standardisation and control of systems to improve safety, health, comfort and productivity. The application of sound ergonomic principles in the design of the human-machine interface will minimise design-induced human error (Kroemer *et al.,* 1996), and also eliminate significant occupational health and safety risks. In the workplace the application of ergonomics aims to promote health, efficiency and well being of workers.

It has been argued that the ideal is for ergonomics principles to be followed in the design of equipment and systems. Practice has always fallen short of this ideal. This implies that the ergonomics issues are introduced primarily after problems have been experienced during operation of equipment or systems under actual working conditions. In tasks where ergonomics principles were not employed from the outset, or perhaps improperly employed, risk factors may exist. These risk factors may eventually become apparent as precursors to poor work performance, unsafe work practices and occupational injuries or illnesses.

Ergonomics principles are habitually employed at two distinct levels: the so-called micro-ergonomics level, at which individual tasks and the design of the operator's place of work (workstation) are considered in terms of worker safety and productivity; and the macro-ergonomics level, at which ergonomic principles are incorporated into management strategy and the overall business plan of the organisation.

Ergonomic workstation design, based on engineering anthropometry and occupational biomechanics, can play a major role in reducing many risk factors associated with occupational injury (Grandjean, 1982). Anthropometry literally means 'the measurement of humans' and focuses on the measurement of bodily features such as shape and size (Herron, 2001). Engineering anthropometry is the effort to apply such data to workstations, equipment and tools to enhance the efficiency, safety and comfort of the worker. In the context of workstation design, engineering anthropometry is employed to develop design parameters or dimensions for such a design (Das, 2001).

The application of anthropometry to design employs what is known as 'methods of limits' to establish boundary conditions (American Bureau of Shipping, 1998). In essence, it defines the 'limiting user'; if that individual is accommodated, it follows that the majority of the population, who are less demanding in their requirements, will be accommodated as well.

For any body dimension, the 5^{th} percentile value indicates that 5% of the population will be equal to or smaller than that value and 95% will be larger. Conversely, the 95^{th} percentile value indicates that 95% of the population will be equal to or smaller than that value and that 5% will be larger. Therefore, the use of a design range from the 5^{th} to the 95^{th} percentile values will theoretically provide coverage for 90% of the user population for that dimension.

In general, there are four major ergonomics design principles:

- *Design for the smallest:* This principle applies primarily to forces and reach distances.
- *Design for the largest:* This principle applies primarily to clearances, such as escape hatches, walkways and ceiling heights.
- *Design for the average:* This principle applies to operator positions that are not adjustable (e.g. fixed-height tables and work surfaces).
- *Design for the range:* This principle is applied to determine the amount of adjustability that should be built into such things as variable workstation seats (forward-aft and up-down).

An ergonomically designed workstation attempts to achieve an optimum compromise between the variable anthropometry of the targeted operator population and the physical size and layout of the workstation components. Factors considered include spatial accommodation, posture, reaching abilities, clearance and interference with body segments, field of vision, available strength of the operator, and biomechanical stress.
In reality, it is often found that workstations are designed in an arbitrary manner with little attention being paid to the anthropometric measurements of and biomechanical abilities of the anticipated user population. The situation is further aggravated by the lack of usable design parameters or dimensions (Das and Grady, 1983).

2. Objective of study

Local and international safety statistics indicate that ergonomic factors underlie many of the accidents occurring in mines, and could impact negatively on the effective and efficient operation of mining machinery and transport systems. Section 21 (1)(c) of the Mine Health and Safety Act requires designers and manufacturers of mining equipment and machines to ensure that their products comply with ergonomic principles.

The objective of the study was to conduct an ergonomics evaluation of the mining machinery and transport systems generally used in mining. This evaluation will be based on the consideration of the complete ergonomics system to identify the ergonomics-related hazards that could impact on the operators' ability to work safely and efficiently. The information on the current ergonomics hazards related to mining machinery and transport systems was used to identify ergonomics interventions and the potential of these interventions to promote the safety, health, efficiency and well-being of the workers. The need for further ergonomics investigations and product development was also be investigated.

3. Ergonomics evaluations

3.1 Methods

The ergonomics assessments of mining machinery and equipment were conducted at nine mines, two quarries and at manufacturers' or suppliers' premises to determine the physical characteristics of the mining machinery and transport systems that could affect the efficiency of operation and the safety of the operator. The assessments consisted of inspections to identify potential ergonomics-related hazards in the design and operations. In cases where obvious ergonomics-related risks were identified, further dimensional evaluations were

performed. Operators and supervisors were also interviewed to obtain information and other data not apparent during walk-through observations.

Typical ergonomics aspects of the mining machinery assessed at the operator's workstation are shown in Figure 3.1, and their descriptions are presented in Table 3.1.

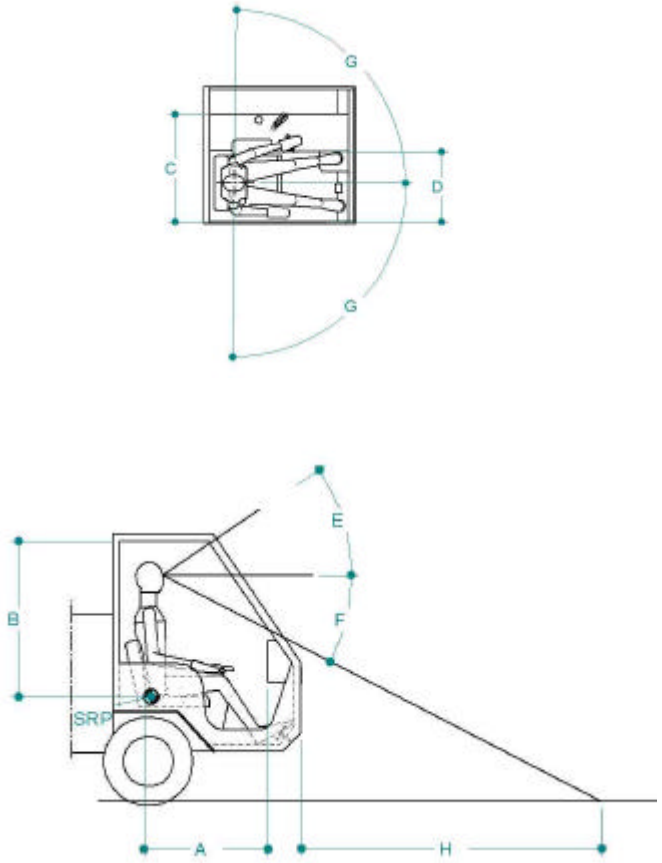

Figure 3:1: Typical ergonomics aspects of mining machinery for the operator's workstation

Table 3.1: Description of the primary ergonomics aspects at the operator's workstation

Reference	Description
-	Seat dimensions
A	Leg clearance (forward horizontal distance from the SRP* to the cab panel)
B	Head clearance (vertical distance from the SRP* to the cab roof line)
C	Lateral shoulder space inside the cab
D	Lateral leg room (the space around the feet)
E	Eye view above 0? horizontal
F	Eye view below 0? horizontal
G	Eye view to either side
H	Distance obscured in front of the vehicle

***SRP = the point of reference where the three axes intersect between the seat base and the seat backrest.**

Detailed results of the dimensional evaluation of the mining machinery and transport systems are presented in Appendix 1. The risk factors identified are given in Table 3.2.

3.2 Results and discussion

The major ergonomics-related risks resulting from inadequate design considerations are given in Table 3.2 and are discussed below. Relatively minor risk factors, such as poor work organisation, noise and thermal stresses are not discussed. Where applicable, possible interventions to mitigate the major risks are also identified.

Table 3.2: Summary of ergonomics-related problem areas that pose a health or safety risk

Machine	Access	Cab space	Driving position	Seats	Controls	Displays	Field of view
Haul truck 1	v	v	v	v		v	v
Haul truck 2	v	v	v				
Haul truck 3	v		v	v	v	v	v
Haul truck 4			v	v	v	v	
Haul truck 5	v		v				v
LHD 1	v		v				v
LHD 2	v		v		v	v	v
LHD 3			v				
LHD 4	v	v	v				v
LHD 5	v		v				v
LHD 6							
Roof bolter drill rig 1			v		v	v	
Roof bolter drill rig 2			v		v	v	v
Roof bolter drill rig 3		v	v	v	v	v	v
Rock scaler	v	v			v	v	v

Table 3.2 - continued

Machine	Access	Cab space	Driving position	Seats	Controls	Displays	Field of view
Utility vehicle 1			v	v	v		v
Utility vehicle 2	v	v	v	v	v	v	v
Utility vehicle 3	v		v	v	v	v	v
Utility vehicle 4	v	v	v	v	v	v	v
Utility vehicle 5	v	v	v	v	v		v
Utility vehicle 6	v						
Roof bolter 1	v				v		
Roof bolter 2	v	v			v	v	
Coal shearer							v
Shuttle car 1	v		v		v	v	v
Shuttle car 2	v		v		v	v	v
Mechanical loader							v
Drill platform	v						

3.2.1 Accessibility

Foot steps and handrails on the side panels to facilitate entry were not consistently applied to the cabin designs. Cabin ingress and egress proved to be a problem in 68% of the machines and vehicles assessed, especially in the case of the haulage trucks. In most cases, the steps provided were too high and too far from the ground level, so that the act of mounting the vehicle created strain on the operator. The rigid nature of some of the steps fitted to vehicles also posed a safety risk as the operator could lose his or her footing or grip on a handhold. Many operators complained about the difficulty of getting into the cabin.

When the cabin of a mining machine or vehicle is placed high above the ground, steps and handrails must be provided to assist in both the mounting and dismounting processes. It is not sufficient to place these devices wherever there is a convenient attachment point. The first step from the ground must be reachable for the shortest expected user(380mm), and at least two handholds must be accessible to this person while he or she is still on the ground. The positioning of each succeeding step and its associate handhold must be planned in such a way that the user's final entry into the machine or vehicle will be compatible with sitting in the seat. Handholds and steps must be planned to conform to the natural 'climb pattern'. Usually a person cannot hold and step from the same side without swinging. Both ladder rungs or steps and handrails must have non-skid or non-slip surfaces, and handrails should be placed on both sides (Woodson *et al.,* 1992).

It is interesting to note that the handrails fitted to most of the newer mining machines to facilitate entering and exiting from the cab were frequently not used because of their awkward positions.

3.2.2 Cabin layout, design and orientation

Poor cabin design, in many cases the result of not considering the body dimensions of the user population (as is the case in the present study), forces operators into awkward postures. The workspace inside the operator's cab was generally restrictive for the 95th percentile South African male to drive the vehicles comfortably. Clearance for the head, legs and feet was insufficient in 32% of the vehicles assessed.

Inadequate cabin space, controls in the wrong location and information displays that are difficult to read resulted in operators/drivers adopting awkward postures. These awkward postures, particularly if they are adopted repeatedly or over prolonged periods, may cause discomfort and fatigue, and increase the risk of musculoskeletal disorders.

In 70% of the machines and vehicles assessed, the orientation of the cabin requires the operators to twist in order to look sideways, upwards or downwards to see what they are doing or where they are going. This will accentuate discomfort arising from the lower back or neck regions. In addition, it causes a safety hazard because of the masking or obstruction of vision by various parts of the machines.

3.2.3 Field of view

Haulage trucks and utility vehicles have open cabs with an unrestricted view to the front and sides of the machinery. However, the sideways sitting orientation (such as in the case of Utility vehicle 1, for example) influences the operator's dynamic viewing field. Although this appeared to be overcome by head and eye movement, frequent head and eye movement would cause fatigue. For the mining machines with cab canopies, such as roof bolters and drill rigs, forward viewing to the ground is severely limited. Blind spots at the corners of the enclosed cabs also restrict the visual angles.

For the LHDs, the 5th percentile operator in the driving posture is incapable of seeing the ground. A driver between the 5th percentile and the 95th percentile cannot see a 5th percentile South African male standing upright and entering the path of the vehicle within approximately 15 m of the obscured area in front or to the rear of the vehicle from the seated position – this has serious safety implications.

In 80% of the vehicles, the rear view is severely restricted to the extent that the operators lean backwards outside the cab.

The importance of an unobscured view when operating mining machinery and transport systems is obvious. It is therefore vital to limit the masking that is caused by various parts of the machines. An international standard entitled *Earth-moving machinery – Operator's field of view* (ISO 5006) that specifies acceptable visibility criteria is available to assist in this regard.

3.2.4 Seats

The seats in the older vehicles assessed were in a poor and, in some instances, in an unserviceable, condition. Where newer seats have been provided, the seat-adjustment controls were found either not to be used by the driver or not to be in working order.

The dimensions of the seats fitted in most of the newer machines were found to be acceptable for the design population. Most of the seats have lap belts fitted. The lap belts were, however, found to hinder quick access to belt-worn self-contained self-rescuers.

Optimum seat design should provide adequate support for the operator while he or she is working or driving. The seat should not place any unnecessary stress on any part of the body and should encourage optimum posture, allowing for comfort, efficiency and minimal muscle fatigue. People vary markedly in size and this range must be allowed for in the dimensional specifications of chairs and seats. In order to accommodate 95% of the target user population, some adjustability can be incorporated into the design, for example, seat height, backrest angle, and fore and aft adjustments. Adjustments should be easy to achieve for any user in the seated position.

When seats are not maintained or replaced on a regular basis, they can add to the vibration problems because seat suspension systems deteriorate over time. Seats that 'bottom out' or cannot be adjusted adequately for all users may cause serious injury.

Newer machines were fitted with polyurethane seating systems with T-shaped backrests. The T-shaped seat takes into consideration the use of a cap lamp battery and self-contained self-rescuers.

Figure 3.2.4: Seat with T-shaped backrest

3.2.5 Displays and controls

Typical shortcomings observed with regard to displays include poor positioning of displays, incorrect labelling, no labelling or, if present, the labels were dirty and illegible. As far as controls were concerned, the positioning and configuration of controls on 60% of the vehicles were not optimal in terms of ergonomics requirements and presented a safety hazard. In some instances, crucial controls such as emergency stops were obscured or out of comfortable reach. Controls of which inadvertent activation or deactivation could have serious consequences were seldom guarded.

The points of interchange of information from the operator to the machine and from the machine to the operator are of paramount importance to ensure safe and efficient operations. Two of these interfaces are of particular importance in mining machinery and transport systems, namely the displays and controls. Displays provide feedback to the operator about the status of the machine or the behaviour of the whole system. Controls, on the other hand, are used by the operator to provide inputs affecting the system. Any breakdown in this interface as a result of poor ergonomics design could potentially be catastrophic.

A display conveys information to the human sensory organs by some appropriate means. In man-machine systems, the display is usually a visual presentation of dynamic processes. It provides a positive indication of the state of the equipment, such as ‘ready’, ‘running’, ‘not running’, or ‘out of tolerance’.

Visual displays should be labelled to convey the basic information needed by the operator and the information displayed should be clear, concise and consistent, following standards and conventions that are clear to the operator. General guidelines in this regard are available in Van Tonder and Schutte, 2002. The display of the instrument face should preferably be perpendicular to the operator’s normal line of sight, but should not be more than 45º from the perpendicular to the normal line of sight. (The normal line of sight is the line running from the viewer’s eye to the object and is 15º below horizontal due to the natural downward tilt of the head.)

Primary displays, consisting of emergency displays, displays requiring frequent use or displays requiring precise reading, should be located within the operator’s immediately readable field of view. Secondary displays and those not requiring accurate reading should be located within the operator’s easily readable view.

Control actuators should be labelled to convey the information needed for proper identification and utilisation. Adequate spacing should be provided between control actuators to ensure that manipulation of the one will not inadvertently affect the others. Control actuators should be placed so that simultaneous operation of two control actuators will not require crossing or interchanging of the operator's hands.

Coding is also important when dealing with displays and controls and refers to the use of size, shape, colour or texture to assist with the identification of states and control functions. Several coding methods may be combined to achieve maximum identification and differentiation.

Colour coding is most effective when a specific meaning can be attached to the colour, and the colour is used consistently with the associated meaning. Cultural expectations should be considered when colour coding. Coding by size, shape or texture is useful when controls are to be identified without the use of vision.

4. Equipment design standards

As far as could be established, there is apparently no standard dedicated to underground mining machinery and transport systems. However, a number of international standards that deal with general requirements for earth-moving equipment are available.

These standards include:

- European Standard BS EN 474-1: *Earth-moving machinery – Safety*
- International Organization for Standardization ISO 2860: *Earth-moving machinery – Minimum access dimensions*
- International Organization for Standardization ISO 3411: *Earth-moving machinery – Human physical dimensions of operators and minimum operator space envelope*
- International Organization for Standardization ISO 5006: *Earth-moving machinery – Operator's field of view*
- International Organization for Standardization ISO 6682: *Earth-moving machinery – Zones of comfort and reach for controls*
- International Organization for Standardization ISO 7096: *Earth-moving machinery – Laboratory evaluation of operator seat vibration*.

All of these standards are available from the South African Bureau of Standards.

5. Ergonomics guidelines: mining machinery and transport systems

A number of guidelines for the ergonomically acceptable design of mining machinery and transport systems are presented in Table 5.1. The guidelines are based on the anthropometric data of the South African population to ensure the accommodation of the 5th percentile to the 95th percentile male and female user. Other guidelines are derived from national, international, commercial and military standards.

Table 5.1: Ergonomics guidelines for mining machinery and transport systems

Parameter	**Range of values**	**Preferred**
ACCESS		
Surface to entrance-level height	380 mm - 500 mm (maximum)	380 mm
Entrance level to cab floor-line	0 mm – 200 mm	0 mm
Entrance width	500 mm – 760 mm	760 mm
Entrance level to roof line		1 300 mm (minimum)
Handrails:		
? length	150 mm – 300 mm	200 mm
? diameter	25 mm – 32 mm	32 mm
? hand clearance between the retaining surface and the inner surface of the handrail		76 mm
? hand clearance area surrounding the handrail		76 mm
? centre of handrail to ground	1 000 mm-1 470 mm	1 250 mm

OPERATOR'S WORKSTATION		
? leg clearance (forward horizontal distance from SRP to cab panel)	910 mm – 1 000 mm	1 000 mm
? head clearance (vertical distance from SRP to roof line)	Erect seated stature of the 95th percentile male South African +100 mm	1 100 mm
? shoulder clearance (dynamic elbow/abducted arm space, the minimum width of the cab)	875 mm – 1 000 mm (minimum)	910 mm
? leg room (lateral space around the feet on the cab floor-line)	690 mm – 900 mm	880 mm

Table 5.1 (Continued):

SEATING		
Type	Cushioned seat with backrest that can accommodate the personal protective equipment, no sharp edges	T-shaped backrest
Vertical adjustment range from recommended midrange	0 mm – 40 mm up and down	80 mm
Horizontal adjustment to the fore and aft positions	150 mm – 200 mm	180 mm
Seat base:		
? cushion thickness	25 mm – 50 mm	38 mm
? width	485 mm – 510 mm	
? depth	420 mm – 445 mm	
? height (SRP to cab floor-line)	300 mm – 550 mm	350 mm
Slope towards the SRP	5? - 8?	
Seat backrest:		
? height (from SRP)	300 mm – 650 mm	600 mm
? width	480 mm – 510 mm; 200 mm minimum only in area where provision for personal protective equipment at waist level is required for T-shaped backrest	485 mm
Angle from vertical plane	6.5° - 30?	
Arm rest:		
? SRP to top surface of the armrest		235 mm
? width	50 mm – 120 mm	75 mm
? length	210 mm – 300 mm	220 mm
Spacing (inside dimensions)	480 mm – 510 mm	500 mm

CONTROLS		
Forward reach distance (from SRP to hand controls in the most forward seat position for the 5th percentile person and in the most rear seat position for the 95th percentile South African male	Forward seat position: 180 mm – 330 mm Rear seat position: 350 mm – 500 mm	
Vertical distance from SRP to the hand controls	300 mm – 380 mm	320 mm
Hand levers:		
Clearance area around the control	76 mm	76 mm
Clearance – front		75 mm
? minimum length of hand control portion	115 mm – 150 mm	150 mm
? hand control diameter	25 mm – 32 mm	32 mm
Diameter of push-button controls	13 mm – 19 mm	19 mm
Force activation of lever hand controls	200 N (maximum)	150 N
Force activation of push buttons	0.26 N – 4.5 N	1 N

Table 5.1: (Continued)

Parameter	Range of values	Preferred
CONTROLS		
Foot pedals:		
Distance from SRP to bottom of foot pedals	690 mm – 860 mm	700 mm
Angle of foot pedals	< 30?	20?
Width and depth of foot pedals	75 mm x 100 mm	
Force of activation of foot pedals	200 N 300 N	210 N
Clearance between pedals (must allow sufficient space to avoid inadvertent application or sufficient space to pass a boot in between the pedals)	50 mm or 150 mm	50 mm

INSTRUMENTS:		
Label placement	Above or below the controls	Above the controls
Label type		Symbols
Alphanumeric characters and displays		
? width	70% of the height	
? height	5 mm (minimum)	5 mm
Viewing distance from eye reference point	330 mm – 630 mm	400 mm
Viewing angle from centre axis	0? - 65?	0? - 45°
Orientation of display from normal line of vision	?45?and 90??	60?

VISIBILITY		
Eye view above 0? horizontal		15?
Eye view below 0? horizontal		30?
Eye view to either side		90? / 90?
Distance obscured in front of the vehicle		1 500 mm (max.)

ENVIRONMENTAL FACTORS		
Noise	Hearing protection >85 dB	Enclosed cab <65 dB
Vibration		Attenuation of vibration must be handled by seat, vehicle suspension and damping material to reduce exposure to vibration (ISO 2631-1:1997)

6. Conclusions

Operators of mining vehicles have a range of conditions to contend with and often have less well-designed cabs and seats than their road transport counterparts. Inadequately sized cabs situated in inappropriate locations on the vehicle, and with poorly designed displays and controls, compound the stresses placed on the operators.

An added problem in underground mines is that many mining machines and vehicles may not have suspension systems of any kind. This shortcoming, together with a lack of appropriate seat suspension and having to travel on poorly maintained roads and uneven surfaces, could result in operators being exposed to unacceptable whole-body vibration levels. All these factors, in conjunction with other physical stresses typical of the mining environment, such as noise and poor visibility, can make vehicle operation unnecessarily tiring at best and hazardous to health and safety at worst.

The observed occupational health and safety risks resulting from ergonomics-related factors can be ascribed predominantly to workstation designs based on anthropometric data that are not entirely suitable for the South African user population.

Internationally available standards could, together with appropriate anthropometry, be used as a basis for the design of mining machinery and transport systems.

7. Recommendations

From an ergonomics point of view, improvements aimed at reducing the risk of the musculoskeletal disorders and worker fatigue associated with the cabin design of mining machinery and transport systems will depend heavily on the availability of anthropometric data pertaining to the user population in the South African mining industry, both male and female. Current information on the body dimensions of South African mine workers is rather dated (Schoeman *et al.,* 1981) and only covers male mineworkers.

In view of the importance of this information in the design of the operator workstations (the ‘operator space envelope’) of mining equipment, and mining tasks in general, it is recommended that studies be carried out to determine the functional anthropometry (i.e. those body dimensions that are essential for the design of workstations) of South African mine workers (both male and female).

The latest South African anthropometric data are based on a representative sample of males and females from an SANDF survey. It is recommended that a small sample representative of the mine worker population be measured for the critical anthropometric variables used in workstation design and specification, in order to verify whether indeed the military data are applicable to the mining community.

It is recommended that a concerted effort be made to upgrade the seats of mining machinery and transport systems. Seat maintenance programmes and the training of operators to adjust their seats properly to meet their personal requirements are indicated.

8. References

American Bureau of Shipping. 1998. Guidance notes on the application of ergonomics to marine systems. New York: ABS.

Das, B. 2001. Ergonomic workstation design. In: Karwowski, W. (Ed.), International Encyclopaedia of Ergonomics and Human Factors. London: Taylor & Francis, pp 911-920.

Das, B. and Grady, R.M. 1983. Industrial workplace layout design: An application of engineering anthropometry. *Ergonomics* 26:433-447.

Grandjean, E. 1982. Fitting the Task to the Man: An Ergonomics Approach (3rd ed.). London: Taylor & Francis.

Herron, R.E. 2001. Anthropometric databases. In: Karwowski, W. (Ed.), International Encyclopaedia of Ergonomics and Human Factors. London: Taylor & Francis, pp 191-192.

Kroemer, K.H.E. and Grandjean, E. 1997. Fitting the Task to the Man: A Textbook of Occupational Ergonomics (5th ed.). London: Taylor & Francis, pp 157-176.

Kroemer, K., Kroemer, H. and Kroemer-Elbert, K. 1996. Ergonomics: How to Design for Ease and Efficiency. Englewood Cliffs: Prentice Hall, pp 67-68.

Van Tonder, J.A. and Schutte, P.C. 2001. Ergonomics. In: Guild *et al.*, (eds) Handbook of Occupational Health Practice in the South African Mining Industry. Safety in Mines Research Advisory Committee, Johannesburg, pp315-337.

Appendix 1: Results of dimensional evaluation

Dimensional evaluations were carried out on a range of mining machinery at the various types of mines or at the specific manufacturers' or suppliers' premises to determine the physical characteristics of the mining machinery and transport systems that could affect the efficiency of operation and the safety of the operator

Typical ergonomics aspects of the mining machinery assessed at the operator's workstation are shown in Figure 1.1, and their descriptions are presented in Table 1.1

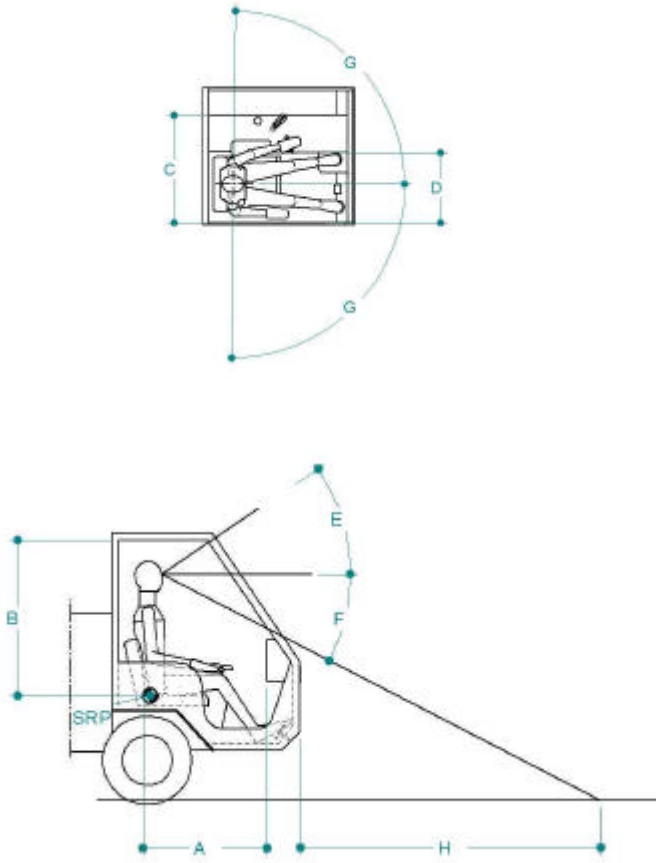

Figure 1.1: Typical ergonomics aspects of mining machinery for the operator's workstation

Table 1.1: Description of the primary ergonomics aspects at the operator's workstation

Reference	Description
-	Seat dimensions
A	Leg clearance (forward horizontal distance from the SRP* to the cab panel)
B	Head clearance (vertical distance from the SRP* to the cab roof line)
C	Lateral shoulder space inside the cab
D	Lateral leg room (the space around the feet)
E	Eye view above 0? horizontal
F	Eye view below 0? horizontal
G	Eye view to either side
H	Distance obscured in front of the vehicle

*SRP= the point of reference where the three axes intersect between the seat base and seat backrest.

HAULAGE TRUCK 1

Figure 1.2: Haulage Truck 1

Table 1 2: Evaluation of Haulage Truck 1

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	400 mm (inadequate)
	Entrance step height from the ground	600 mm (too high)
Clearances inside the cab		
	Canopy	None
	Canopy to seat height	N/A
	Shoulder width	Restrictive
	Knee clearance from SRP to front wall panel	750mm (adequate)
SEATING		
	Seat type	ISRI bucket type with a backrest
	Seat material	Vinyl
	Seat base dimensions (WxD)	470x500 mm (adequate)
	Seat backrest dimensions (WxH)	470x550 mm (adequate)
	Seat surface height from the cab floor	590 mm (too high)
	Restraint system	Lap belt fitted not utilised
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 300 with a knob ? 55 (acceptable)
Display panel and instruments layout		Lack of labeling
VISIBILITY		
	Operators field of view	Rear viewing was limited

Access

The surface to entrance-level height was above the recommended height for easy entry into the cab for the 5th percentile male South African.

Seating

The seat base is not height-adjustable. The seat has armrests which would provide the required arm support when driving the vehicle. However, it was found that the armrests were not utilised. Also, the operator placed a cushion on the seat base to provide additional comfort. The seat width was slightly too narrow to accommodate the 95th percentile male South African. The seat base was too high from the cab floor for a comfortable sitting posture for the 5th percentile male South African.

The configuration of the driver's cab was of such a nature that the driver had to adopt a sideways sitting orientation. The driver rotated his neck over his left shoulder when driving the vehicle forward. When reversing the vehicle and during the tipping process, the operator rotated his trunk >30^{o} towards the right so that he could align the vehicle and see the tipping process. This is an unacceptable driving posture.

Controls and displays

All the controls were within the reach envelope and visual field of the seated 5th percentile to 95th percentile male South African. Labelling of the controls and instruments is lacking (see Figure 1.3).

Figure 1.3: Lack of instrument labelling

Visual field

Forward and side viewing was excellent, except when reversing the vehicle and during the tipping process.

HAULAGE TRUCK 2

Figure 1.4: Haul Truck 2

Table 1.4: Evaluation of Haul Truck 2

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	450 mm(inadequate)
	Entrance step height from the ground	600 mm(too high)
Clearances inside the cab		
	Canopy (if fitted)	YES (Airconditioned cab)
	Height of canopy roof ceiling to SRP	1000 mm (adequate)
	Shoulder width	Adequate
	Knee clearance from SRP to front wall panel	750 mm (adequate)
SEATING		
	Seat type	Air suspension, bucket type chair with a backrest
	Seat material	Vinyl
	Seat base dimensions (WxD)	470x500 mm (adequate)
	Seat backrest dimensions (WxH)	470x550 mm (adequate)
	Seat surface height from the cab floor	590 mm (too high)
	Restraint system	Lap belt fitted
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel lever	? 55 (acceptable)
Display panel and instruments layout		Symbols used
VISIBILITY		
	Operators field of view	Rear viewing camera and a VDU are fitted in the cab to aid rear viewing

Access

The surface to entrance-level height was above the recommended height for easy entry into the cab for the 5th percentile male South African.

Seating

The air suspension seat, with height and horizontal adjustment mechanisms, fitted in the vehicle was acceptable. The chair is also fitted with armrests and a lap belt restraint system. The seat width was slightly too narrow to accommodate the 95th percentile male South African. The seat base was too high from the cab floor for a comfortable sitting posture for the 5th percentile male South African.

The configuration of the driver's cab was of such a nature that the driver has to adopt a sideways sitting orientation. The driver rotated his neck over his left shoulder when driving the vehicle forward. This induced a sustained twisted neck posture when the driver faced towards the direction of the vehicle's movement.

Controls and displays

All the controls were within the reach envelope and visual field of the seated 5th percentile to 95th percentile male South African. Symbols are used for the identification of the controls and instruments. The layout of the primary controls and instruments is shown in Figure 1.5. The biomechanical force required to activate the controls appeared to be within acceptable limits.

Figure 1.5: Layout of primary controls and instruments

Visual field

The operator's forward and front visual field was excellent from the seated position. A video camera is fitted on the rear frame of the vehicle and a monitor is fitted inside cab, which helps the driver to see at the rear of the vehicle when reversing it. The rear-viewing system fitted in the vehicle was found to be useful and suitable for the task. The design of the cab and sitting configuration would not enable proper rear viewing from the seated posture without the aid of the video camera.

HAULAGE TRUCK 3

Table 1.6: Evaluation of Haul Truck 3

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	N/A
	Entrance step height from the ground	410 mm(acceptable)
Clearances inside the cab		
	Canopy	None
	Height of canopy roof ceiling to SRP	N/A
	Shoulder width	Adequate
	Knee clearance from SRP to front wall panel	Adequate
SEATING		
	Seat type	Bucket type chair with a backrest
	Seat material	Vinyl
	Seat base dimensions (WxD)	470x500 mm (adequate
	Seat backrest dimensions (WxH)	470x550 mm (adequate)
	Seat surface height from the cab floor	400 mm (acceptable)
	Restraint system	Lap belt fitted
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 300 with a knob ? 55 (acceptable)
Display panel and instruments layout		Lack of labeling
VISIBILITY		
	Operators field of view	Restricted rear and operator's back view

Access

The height between the surface and the first step was within the recommended height for easy entry into the cab for the 5th percentile to the 95th percentile male South African. However, not all the vehicles had the step fitted on the wheel mudguard. The handrails required for three-point contact for easy access were not available on most of the vehicles. It was observed that, as a result, access to the driver's workstation was not easy.

Seating

The seat base is not height-adjustable. The seat width was too narrow to accommodate the 95th percentile male South African. The seat base was too high from the cab floor for a comfortable sitting posture for the 5th percentile male South African. The feet of the 5th percentile operator cannot be comfortably placed on the cab floor. As a result, the operator would sit on the edge of the seat and this is an unstable position for controlling a moving vehicle.

The configuration of the driver's cab is such that the driver adopts a sideways sitting orientation. This induces a sustained twisted neck posture when facing towards the direction of the vehicle's movement. When reversing the vehicle at the tipping point, the operator leans backwards and rotates his trunk >30^{o} towards the right so that he can align the vehicle and see the tipping process. This is an unacceptable driving practice according to the Mine Health and Safety Act, 1996 (Regulation 18.2.1).

Controls and displays

All the controls were within the reach envelope and visual field of the seated 5th percentile to the 95th percentile male South African. Labelling of the controls and instruments was lacking. The biomechanical force required to activate the controls was not determined. The drivers, however, complained of the need to exert excessive force when turning the steering wheel.

Visual field

The forward and side visual fields were excellent for normal forward driving. The visual field from the seated posture to the rear when reversing and during the tipping process is restricted.

HAULAGE TRUCK 4

Figure 1.6: Haul Truck 4

Table 1.7: Evaluation of Haul Truck 4

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	600 mm (acceptable)
	Entrance step height from the ground	430 mm (acceptable)
Clearances inside the cab		
	Canopy	YES
	Height of canopy roof ceiling to SRP	1050 mm(adequate)
	Shoulder width	Adequate
SEATING		
	Seat type	Bucket type chair
	Seat material	Breathable fabric material with foam padding
	Seat base dimensions (WxD)	480x500 mm (adequate)
	Seat backrest dimensions (WxH)	440x530 mm (adequate)
	Seat surface height from the cab floor	460 (acceptable)
	Restraint system	Lap belt fitted
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 430 with a knob ? 30 (acceptable)
Display panel and instruments		Inconsistent labeling of the control
VISIBILITY		
	Operators field of view	Good

Access

The height between the surface and the first step was within the recommended height for easy entry into the cab for the 5th percentile to the 95th percentile male South African. The vehicles have steps fitted on the wheel mudguard. Handrails are fitted which enable three-point contact for easy access (see Figure 1.7).

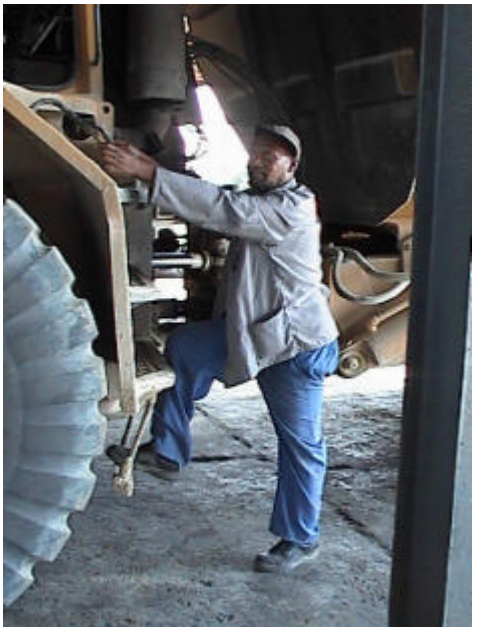

Figure 1.7: Three-point contact for easy access

Seating

The seat has a horizontal adjustment mechanism. The dimensions of the seat would accommodate the 5th percentile to the 95th percentile male South African. The height of the seat base from the cab floor is within the acceptable limit for a comfortable sitting posture for the operators.

The configuration of the driver's cab is such that the driver faces forwards, adopting a typical driver sitting orientation for a motor vehicle. When reversing the vehicle, the operator uses the rear-view mirrors.

The fabric used for the seat covers is not suitable for mining machinery. As shown in Figure 1.8, tear and wear is quite high. Also, maintenance of the fabric in a mining operation would be difficult.

Figure 1.8: Unsuitable seat fabric for mining machinery

Controls and displays

All the controls were within the reach envelope and visual field of the seated 5th percentile to 95th percentile male South African. Labelling of the controls and instruments was inconsistently applied. As shown in Figure 1.9, some of the controls have labels above the actual control and some have labels below the actual control. The biomechanical force required to activate the controls appeared to be within the acceptable limit.

Figure 1.9: Inconsistent labelling of the controls

Visual field

The forward and rear visual fields appeared to be good for the normal forward driving.

HAULAGE TRUCK 5

Figure 1.10: Haul Truck 5

Table 1.8: Evaluation of Haul Truck 5

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	600 mm (acceptable)
	Entrance step height from the ground	600 mm(too high)
Clearances inside the cab		
	Canopy	YES
	Height of canopy roof ceiling to SRP	1250 mm(adequate)
	Shoulder width	Adequate
	Knee clearance from SRP to front wall panel	
SEATING		
	Seat type	Bucket type chair with a headrest and armrests
	Seat material	Polyurethane material
	Seat base dimensions (WxD)	500x500mm (acceptable)
	Seat backrest dimensions (WxH)	470x500mm (adequate)
	Headrest dimensions (WxH)	255x220mm (acceptable)
	Seat surface height from the cab floor	450 mm (acceptable)
	Restraint system	Lap belt fitted
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 430 with a knob ? 45 (acceptable)
Display panel and instruments		Symbols used for labeling the controls
VISIBILITY		
	Operators field of view	Good

Access

Access was through the front of the vehicle. The vehicle has steps and handrails fitted on the front frame and guardrails are fitted around the wheel mudguards. The handgrips would enable three-point contact for easy access and the guardrails provide protection when entering the cab. However, the distance between the surface and the first step was slightly too high for easy entry into the cab for the 5th percentile male South African.

Seating

The configuration of the driver's cab is such that the driver faces forward adopting a typical motor vehicle sitting orientation. When reversing the vehicle, the operator uses the rear viewing mirrors.

The seat has a horizontal adjustment mechanism. The dimensions of the seat would accommodate the 5th percentile to the 95th percentile male South African. The height of the seat base from the cab floor was within the acceptable limits for a comfortable sitting posture for the drivers.

The polyurethane material used for covering the seats was suitable for mining machinery (see Figure 1.11).

Figure 1.11: Suitable seat material for a mining machine

Controls and displays

All the controls were within the reach envelope and visual field of the seated 5th percentile to the 95th percentile male South African. The symbols used for labelling the controls and instruments were recognisable (see Figure 1.12). The biomechanical force required to activate the controls appeared to be within the acceptable limits.

Figure 1.12: Symbols used for labelling the controls

Visual field

The forward and rear visual fields appeared to be good for normal forward driving.

LHD 1

Figure 1.13: LHD 1

Table 1.9: Evaluation of LHD 1

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	550 mm (adequate)
	Entrance step height from the ground	655 mm (too high)
Clearances inside the cab		
	Canopy	Yes
	Height of canopy roof ceiling to SRP	940 mm (adequate)
	Shoulder width	Adequate
	Knee clearance from SRP to front wall panel	1040 mm (adequate)
SEATING		
	Seat type	Bucket type chair with a backrest and headrest
	Seat material	vinyl
	Seat base dimensions (WxD)	520x450 mm (adequate)
	Seat backrest dimensions (WxH)	450x450 mm (adequate
	Headrest dimension (WxH)	330x170 mm (acceptable)
	Seat surface height from the cab floor	620 mm (too high)
	Restraint system	Lap belt fitted
CONTROLS AND DISPLAYS		
Steering mechanism	Steering lever and a joy stick	? 300 with a knob ? 55 (acceptable)
Display panel and instruments layout		Lack of labeling
VISIBILITY		
	Operators field of view	Restricted view at the operator's back

Access

The surface to entrance-level height was above the recommended height for easy entry into the cab for the 5th percentile male South African.

Seating

The seat base was height-adjustable and had armrests for supporting the arms. The seat width was adequate for accommodating the 5th percentile to the 95th percentile male South African.

The configuration of the driver's cab is such that the driver adopts a sideways sitting orientation. He rotates his neck over his left shoulder when driving the vehicle forward. This induces a sustained twisted neck posture when facing towards the direction of the vehicle's movement. When he reverses, the cab canopy creates blind spots.

Controls and displays

All the controls were within the reach envelope and visual field of the seated 5th percentile to the 95th percentile male South African. The design and location of the primary controls prevents accidental activation.

Visual field

Forward and side viewing was restricted by the cab canopy. From the seated posture, the visual field to the rear is severely restricted.

LHD 2

Figure 1.14: LHD 2

Table 1.10: Evaluation of LHD 2

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance step height from the ground	745 mm (too high)
Clearances inside the cab		
	Canopy	None
	Height of canopy roof ceiling to SRP	N/A
	Shoulder width	Adequate
SEATING		
	Seat type	Bucket chair type (ill state of repair)
	Seat material	vinyl
	Seat base dimensions (WxD)	520x450 mm (adequate)
	Seat backrest dimensions (WxH)	450x370 mm (adequate)
	Seat surface height from the cab floor	600 mm (too high)
	Restraint system	None
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 370 (acceptable)
Display panel and instruments layout		Lack of labeling
VISIBILITY		
	Operators field of view	Restricted view at the operator's back

Access

There is no specific provision for access to the cab. The operator enters the cab through the left side of the vehicle over the ledge of the cab. The foot pedals are located within the cab entrance area and partially obstruct access. The surface to ledge-level height was above the recommended height for easy entry into the cab for the 5th percentile to the 95th percentile male South African.

Seating

The configuration of the driver's cab is such that the driver adopts a sideways sitting orientation. The driver rotates his neck over his left shoulder when driving the vehicle forward. This induces a sustained twisted neck posture when facing towards the direction of the vehicle's movement.

Controls and displays

All the controls were within the reach envelope and visual field of the seated 5th percentile to the 95th percentile male South African. Labelling of the controls and instruments was lacking and the biomechanical force required to activate the controls was not determined.

Visual field

Forward and rear viewing from the driver's seated position was excellent for normal driving. When reversing, the visual field in the front (right-hand side) and to the rear from the seated position was severely restricted.

LHD 3

Figure 1.15: LHD 3

Table 1.11: Evaluation LHD 3

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	640 mm (adequate)
	Entrance step height from the ground	490 mm (acceptable)
Clearances inside the cab		
	Canopy	YES
	Height of canopy roof ceiling to SRP	1020 mm (adequate)
	Shoulder width	600 mm (inadequate)
	Knee clearance from SRP to front wall panel	890 mm (adequate)
SEATING		
	Seat type	Bucket chair type
	Seat material	vinyl
	Seat base dimensions (WxD)	370x450 mm (inadequate width)
	Seat backrest dimensions (WxH)	470x520 mm (adequate)
	Restraint system	None
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 350 (acceptable)
Display panel and instruments layout		Symbols used
VISIBILITY		
	Operators field of view	Restricted view at the operator's back

Access

The surface to entrance level height was easy for entry into the cab for the 5th percentile to the 95th percentile male South African.

Seating

The seat base was height-adjustable and had armrests for supporting the arm. The seat width would not accommodate the 95th percentile male South African.

The configuration of the driver's cab is of such a nature that the driver adopts a sideways sitting orientation. The driver rotates his neck over his left shoulder when driving the vehicle forward. This induces a sustained twisted neck posture when facing towards the direction of the vehicle's movement. When reversing, the cab canopy creates blind spots.

Controls and displays

All the controls were within the reach envelope and visual field of the seated 5th percentile to the 95th percentile male South African. Symbols are used for the identification of the controls and instruments. Activation of the controls appeared to be easy.

Visual field

Forward and rear viewing from the driver's seated position was excellent for normal driving. When reversing, the visual field to the front and rear from the seated posture is severely restricted by the cab's blind spots.

LHD 4

Figure 1.16: LHD 4

Table 1.12: Evaluation of LHD 4

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	400 mm (inadequate)
	Entrance step height from the ground	500 mm (acceptable)
Clearances inside the cab		
	Canopy	YES (semi-canopy)
	Height of canopy roof ceiling to SRP	N/A
	Shoulder width	975 mm (adequate)
	Knee clearance from SRP to front wall panel	650 mm (adequate)
SEATING		
	Seat type	Bucket chair type
	Seat material	vinyl
	Seat base dimensions (WxD)	500x450 mm (acceptable)
	Seat backrest dimensions (WxH)	500x450 mm (acceptable)
	Restraint system	None
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 350 (acceptable)
Display panel and instruments layout		Symbols are used
VISIBILITY		
	Operator's field of view	Front and back view restricted

Access

The configuration of the cab is of such a nature that access is through the front, towards the articulating frame of the bucket. It was observed that the clearance space around the entrance into the cab depends on the position in which bucket has been parked. For instance, if the front frame was turned more to the right, the clearance around the entrance was sufficient for the driver to get into the cab. With the normal straight parking of the bucket, the entrance clearance was found to be restrictive considering that the driver wears a cap lamp battery and personal protective equipment, which would require more space for easy access. As a result, the driver was observed stepping onto the bucket frame and then stepping directly inside the cab.

The surface to entrance-level height was comfortable for entry into the cab for the 5th percentile to the 95th percentile male South African.

Seating

The configuration of the driver's cab is such that the driver adopts a sideways sitting orientation. The driver rotates his neck over his left shoulder when driving the vehicle forward. This induces a sustained twisted neck posture when facing towards the direction

of the vehicle's movement. When reversing, the front-right corner of the cab canopy creates blind spots.

A bucket-type seat is fitted. The dimensions of the seat base are adequate for accommodating the 5th percentile to the 95th percentile male South African.

Controls and displays

The foot pedals are located within the cab entrance area, which partially obstructs access. All the controls were within the reach envelope and visual field of the seated 5th percentile to the 95th percentile male South African. Symbols are used for identification of the controls and instruments. Activation of the controls appeared to be easy.

Visual field

Forward and rear viewing along the driver's seated position was excellent for normal driving. When reversing, the visual field to the front from the seated position is severely restricted by the cab's blind spots.

LHD 5

Figure 1.17: LHD 5

Table 1.13: Evaluation of LHD 5

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	400 mm (inadequate)
	Entrance step height from the ground	344 mm (acceptable)
Clearances inside the cab		
	Canopy	YES (fully enclosed cab with air conditioner system)
	Height of canopy roof ceiling to SRP	N/A
	Shoulder width	975 mm (adequate)
	Knee clearance from SRP to front wall panel	650 mm (adequate)
SEATING		
	Seat type	T-shaped backrest chair type
	Seat material	Polyurethane
	Seat base dimensions (WxD)	480x400 mm (adequate)
	Seat backrest dimensions (WxH)	480x420 mm (adequate)
	Seat surface height from the cab floor	380 mm (acceptable)
	Restraint system	Lap belt fitted
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 350 (acceptable)
Display panel and instruments layout		Symbols are used
VISIBILITY		
	Operator's field of view	Operator's view was excellent

Access

The configuration of the cab is of such a nature that access is through the front, towards the articulating frame of the bucket. It was observed that the clearance space around the entrance into the cab depends on the position in which the bucket is parked. For instance, if the front frame was turned more to the right, the clearance around the entrance was sufficient for the driver to get into the cab. For normal straight parking of the bucket, entrance clearance was found to be restrictive considering that the driver wears a cap lamp battery and personal protective equipment, which would require more space for easy access.

The surface to entrance-level height provided easy entry into the cab for the 5th percentile to the 95th percentile male South African. Handrails are fitted and provide the required three-point contact for safe access to the cab (see Figure 1.18).

Figure 1.18: Three-point contact for easy access

Seating

The configuration of the driver's cab is such that the driver adopts a sideways sitting orientation. The driver rotates his neck over his left shoulder when driving the vehicle forward. This induces a sustained twisted neck posture when facing towards the direction of the vehicle's movement.

A mechanical suspension seat with a polyurethane T-shaped backrest is fitted. The seat has an adjustable weight suspension for comfort, and the T-shaped backrest provides vertical and lateral support of the spine to an operator wearing rescue and battery packs. The dimensions of the seat base are adequate for accommodating the 5th percentile to the 95th percentile male South African.

Controls and displays

All the controls were within the reach envelope and visual field of the seated 5th percentile to the 95th percentile male South African. The layout of the controls is such that accidental activation is prevented. The leather-like covering of the steering wheel and transmission control provides comfortable hand grips. Activation of the controls appeared to be within acceptable limits. Symbols are used for the identification of the controls and instruments (see Figure 1.19).

Figure 1.19: Layout of the controls/displays and labelling

Visual field

Forward and rear viewing from the driver's seated position was excellent for normal driving. The cab canopy has large windows, which give all-round visibility (see Figure 1.20).

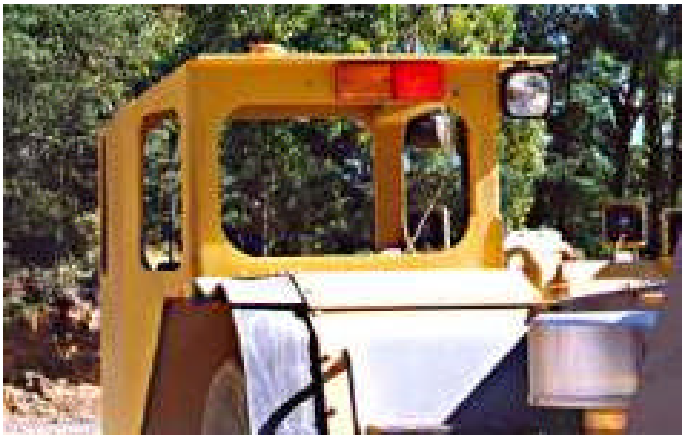

Figure 1.21: Improved all-round visibility

LHD 6

Figure 1.22: LHD 6

Table 1.14: Evaluation of LHD 6

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	600 mm (adequate)
	Entrance step height from the ground	550 mm (too high)
Clearances inside the cab		
	Canopy	YES
	Height of canopy roof ceiling to SRP	1350 mm (adequate)
	Shoulder width	Adequate
	Knee clearance from SRP to front wall panel	Adequate
SEATING		
	Seat type	Bucket type chair
	Seat material	Breathable fabric material
	Seat base dimensions (WxD)	500x480 mm (acceptable)
	Seat backrest dimensions (WxH)	480x530 mm (acceptable)
	Seat surface height from the cab floor	400 mm (acceptable)
	Restraint system	Lap belt fitted
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 430 with a knob ? 30 (acceptable)
Display panel and instruments		Symbols used for labeling the control
VISIBILITY		
	Operators field of view	Very Good

Access

The configuration of the cab is such that access is through the left or right side of the cab. The surface to entrance-level height was within acceptable limits for the 5th percentile to the 95th percentile male South African.

Handrails are fitted and provide the required three-point contact for safe access to the cab (see Figure 1.23).

Figure 1.23: Three-point contact for easy access

Seating

The configuration of the driver's cab is such that the driver faces forward, adopting a typical motor vehicle sitting orientation. When reversing the vehicle, the operator uses the rear-view mirrors.

The seat has a horizontal adjustment mechanism. The dimensions of the seat would accommodate the 5th percentile to the 95th percentile male South African. The height of the seat base from the cab floor was within the acceptable limits for a comfortable sitting posture for the drivers.

Although the aesthetics and design of the seat, shown in Figure 1.24, appear impressive, the fabric used to cover the seat is unsuitable for mining machinery because of the need for maintenance, and high tear and wear problems

Figure 1.24: Unsuitable seat fabric for a mining vehicle

Controls and displays

All the controls were within the reach envelope and visual field of the seated 5th percentile to the 95th percentile male South African. The steering column is adjustable forwards and backwards, and the layout of the controls is such that accidental activation is prevented. The steering wheel and transmission control provide a comfortable hand grip. Activation of the controls appeared to be within acceptable limits. Symbols are used for identification of the controls and instruments (see Figure 1.25).

Figure 1.25: Layout of the controls/displays

Visual field

Forward and rear viewing from the driver's seated position was excellent for normal driving. The cab canopy has large windows, which give all-round visibility (see Figure 1.26).

Figure 1.26: Improved visibility around the cab

ROOF BOLTER AND DRILL RIG 1

Figure 1.27: Roof bolter/drill rig 1

Table 1.15 Evaluation of Roof bolter/drill rig 1

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	500 mm (adequate)
	Entrance step height from the ground	400 mm (acceptable)
Clearances inside the cab		
	Canopy	YES
	Height of canopy roof ceiling to cab floor (drilling position)	1500 – 2260 mm (acceptable)
	Height of canopy roof ceiling to cab floor (driving position)	700 – 1460 mm (acceptable)
	Shoulder width	Adequate
	Knee clearance from SRP to front wall panel	800 mm (adequate)
SEATING		
	Seat type	Bucket chair type
	Seat material	vinyl
	Seat base dimensions (WxD)	470x500 mm (adequate)
	Seat backrest dimensions (WxH)	470x550 mm (adequate)
	Seat surface height from the cab floor	400 mm (acceptable)
	Restraint system	None
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 350 (acceptable)
Display panel and instruments layout		Lack of labeling
VISIBILITY		
	Operators field of view	Restricted view at the operator's back and when driving the vehicle

Access

The operator enters the cab through either the left or right side of the vehicle. The distance from the surface to the step was within the recommended height for easy entry into the cab for the 5th percentile to the 95th percentile male South African. Handrails are fitted and provide the required three-point contact for easy access to the cab.

Seating

The configuration of the driver's cab is such that the driver adopts a sideways sitting orientation. The driver stoops and rotates his neck over his left shoulder when driving the vehicle forward. This induces a sustained twisted neck posture when facing towards the direction of the vehicle's movement. The operator stands in front of the drill rig controls during normal mining operations.

Controls and displays

All the controls were within the reach envelope and visual field of the seated 5th percentile to the 95th percentile male South African. However, the distance between the control levers would be inadequate for manipulation of the controls if the operator was required to wear protective gloves when operating the vehicle (see Figure 1.28).

Figure 1.28: Layout of the control levers

Labelling of the controls and instruments was lacking.

Visual field

The visual field during the mining operations was excellent. This was achieved by a height-adjustable cab with open sides. Forward viewing from the driver's seated position was severely restricted when driving the vehicle from one section of the mine to another because of the complexity of the cab configuration and the mine's tunnel height limitations.

ROOF BOLTER AND DRILL RIG 2

Figure 1.29: Roof bolter/drill rig 2

Table 1.15: Evaluation of Roof bolter/drill rig 2

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	750 mm (adequate)
	Entrance step height from the ground	400 mm (acceptable)
Clearances inside the cab		
	Canopy	YES
	Height of canopy roof ceiling to cab floor (drilling position)	1500 – 2260 mm (acceptable)
	Height of canopy roof ceiling to SRP (driving position)	700 – 1460 mm (acceptable)
	Shoulder width	Adequate
	Knee clearance from SRP to front wall panel	800 mm (adequate)
SEATING		
	Seat type	Bucket chair type
	Seat material	vinyl
	Seat base dimensions (WxD)	470x500 mm (inadequate width)
	Seat backrest dimensions (WxH)	470x550 mm (inadequate width)
	Seat surface height from the cab floor	400 mm (acceptable)
	Restraint system	None
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 350 (acceptable)
Display panel and instruments layout		Symbols used
VISIBILITY		
	Operators field of view	Restricted view when driving

Access

The operator enters the cab through either the left or right side of the vehicle. The distance from the surface to the step level was within the recommended height for easy entry into the cab for the 5th percentile to the 95th percentile male South African. Handrails are fitted and provide the required three-point contact for safe access to the cab.

Seating

The configuration of the driver's cab is such nature that the driver adopts a sideways sitting orientation when driving the vehicle. The configuration of the cab and the complexity of the machine render the driving task very difficult. Because the cab canopy is height-adjustable between 700 and 1 460 mm from the SRP, the lowest setting of the cab would induce awkward body postures. The driver adopts a stooped and rotated neck posture when driving the vehicle. Sustained stooped and rotated neck postures are undesirable and induce fatigue. During the normal production mining processes, the driver operates the vehicle whilst standing (see Figure 1.29). The seat provided in the vehicle is only used when driving the vehicle. The dimensions of the seat were adequate for accommodating the 5th percentile to the 95th percentile male South African.

Controls and displays

All the controls were within the reach envelope and visual field of the 5th percentile to the 95th percentile male South African. However, the distance between the control levers was inadequate for manipulation of the controls whilst wearing protective gloves.

Labelling of the controls and instruments was lacking.

Visual field

The visual field during the mining production processes was excellent. This was achieved by a height-adjustable cab with open sides (see Figure 1.29). Forward viewing from the driver's seated position was severely restricted because of the complexity of the cab configuration and mine's tunnel height restrictions.

ROOF BOLDER AND DRILL RIG 3

Figure 1.30: Roof bolter/drill rig 3

Table 1.16: Evaluation of Roof bolter/drill rig 3

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	520 mm (adequate)
	Entrance step height from the ground	300 mm (acceptable)
Clearances inside the cab		
	Canopy	YES
	Height of canopy roof ceiling to cab floor (drilling position)	1660 – 2560 mm (acceptable)
	Height of canopy roof ceiling to SRP (driving position)	800 – 2050 mm (acceptable)
	Shoulder width	Adequate
	Knee clearance from SRP to front wall panel	800 mm (adequate)
SEATING		
	Seat type	Bucket chair type
	Seat material	vinyl
	Seat base dimensions (WxD)	470x500 mm (acceptable)
	Seat backrest dimensions (WxH)	470x550 mm (acceptable)
	Seat surface height from the cab floor	400 mm(acceptable)
	Restraint system	None
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 350 (acceptable)
Display panel and instruments layout		Symbols used
VISIBILITY		
	Operators field of view	Restricted view when driving

Access

The operator enters the cab through either the left or right side of the vehicle. The distance from the surface to step level was within the recommended height for easy entry into the cab for the 5th percentile to the 95th percentile male South African. Handrails are fitted and provide the required three-point contact for safe access to the cab.

Seating

The configuration of the driver's cab is such that the driver adopts a sideways sitting orientation when driving the vehicle. The configuration of the cab and the overall complexity of the machine make driving very difficult. Because the cab canopy is height-adjustable between 800 and 2 050 mm from the SRP, the lowest setting of the cab would induce awkward body postures. The driver would adopt a stooped posture and rotate his neck over his left shoulder when driving the vehicle. A sustained twisted neck posture induces fatigue.

The driver is required to stand when operating the vehicle during the normal production mining processes. However, as shown in Figure 1.31, the operator uses a drum as a makeshift seat in order to get relief from a static standing posture, which is undesirable and harmful to the operator's musculoskeletal system.

Figure 1.31: Makeshift seat

Controls and displays

All the primary controls were within the reach envelope and visual field of the 5th percentile to the 95th percentile male South African. However, the distance between the control levers, as shown in Figure 1.32, would be inadequate for manipulation of the levers if the operator is required to wear protective gloves when operating the vehicle.

Figure 1.32: Awkward layout of the control levers

Labelling of the controls and instruments was lacking.

Visual field

The visual field during the mining production processes was excellent. This was achieved by a height-adjustable cab with open sides. Forward viewing from the driver's seated position was severely restricted because of the complexity of the cab configuration and mine's tunnel height restrictions.

ROCK SCALER

Figure 1.33: Rock Scaler

Table 1.17: Evaluation of Rock Scaler

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	810 mm (adequate)
	Entrance step height from the ground	540 mm (too high)
Clearances inside the cab		
	Canopy	YES
	Height of canopy roof ceiling to SRP (driving position)	1080 mm (adequate)
	Shoulder width	Adequate
	Knee clearance from SRP to front wall panel	1140 mm (adequate)
SEATING		
	Seat type	Bucket chair type
	Seat material	vinyl
	Seat base dimensions (WxD)	470x500 mm (adequate)
	Seat backrest dimensions (WxH)	470x550 mm (adequate)
	Seat surface height from the cab floor	130 mm (acceptable)
	Restraint system	Lap belt
CONTROLS AND DISPLAYS		
Steering mechanism	Treadle type	N/A
Control dimensions		
	Control levers	? 30 (acceptable)
Display panel and instruments		Labeling is lacking
VISIBILITY		
	Operators field of view	Restricted view when driving

Access

The operator enters the cab through either the left or right side of the vehicle. The distance from the surface to step level was slightly too high for easy entry into the cab for the 5th percentile male South African. There are no handrails to provide the required three-point contact for easy access to the cab.

Seating

The configuration of the driver's cab is such nature that the driver's seat is located at the centre of the cab and the driver faces towards the direction of the vehicle's movement when driving it forward. The operator adopts straight leg postures when activating the treadle foot pedals. The driver's postures when operating the vehicle and manipulating the controls were found to be awkward and make the driving task very difficult.

The dimensions of the seat were adequate for accommodating the 5th percentile to the 95th percentile male South African.

Controls and displays

A treadle steering mechanism is used for controlling the vehicle's direction of movement. The layout of the levers is such that the operator has to stretch out his arms and sustain his grasp of the control levers when performing the required mining processes. The operator's postures were undesirable for the application of force. Repetitive treadle movements of the feet induce strain on the operator's ankles and lower leg muscles.

A hand-brake lever, which in some of the vehicles is located far behind the SRP, was found to have been repositioned in some of the vehicles to the location shown in Figure 1.34. The location of the hand-brake lever interferes with effective utilisation of the restraint system, as well as with the cap lamp battery or self-rescuer pack.

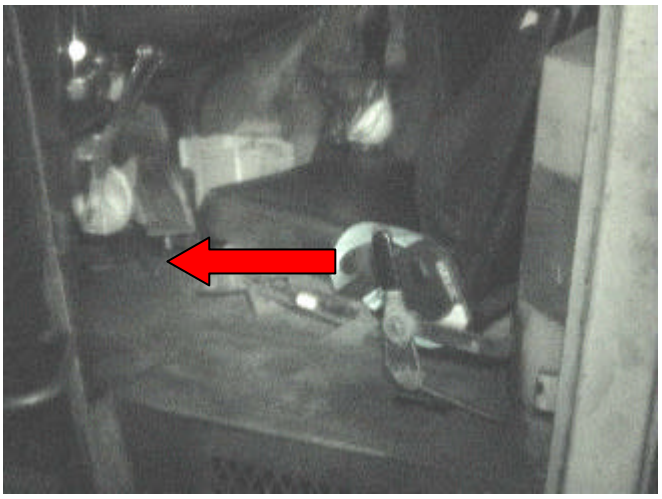

Figure 1.34: Location of the hand-brake lever

Labelling of the controls and instruments was lacking.

Visual field

The visual field during the mining processes was restrictive due to the design and configuration of the cab which took into consideration primarily the inherent physical hazards of the task.

UTILITY VEHICLE 1

Figure 1.35: Utility vehicle 1

Table 1.19: Evaluation of Utility vehicle 1

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	1500 mm (adequate)
	Entrance step height from the ground	600 mm (too high)
Clearances inside the cab		
	Canopy	YES (FOP/ROP)
	Height of canopy roof ceiling to SRP (driving position)	900 mm (inadequate)
	Shoulder width	1360 mm (adequate)
	Knee clearance from SRP to front wall panel	690 mm (adequate)
SEATING		
	Seat type	Bucket chair type
	Seat material	vinyl
	Seat base dimensions (WxD)	430x400 mm (inadequate depth)
	Seat backrest dimensions (WxH)	430x400 (inadequate height)
	Seat surface height from the cab floor	130 (acceptable)
	Restraint system	Lap belt
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 330 (acceptable)
Display panel and instruments		Label and symbols used
VISIBILITY		
	Operators field of view	Good

Access

The operator enters the cab through the left side of the vehicle. The height from the surface to the step level was easy for entry into the cab for the 5th percentile male South African. However, the location of the handrail on the front support frame of the canopy would not provide the required three-point contact for easy access to the cab. As a result, the operator would normally enter to the cab by holding onto the seat backrest.

Seating

The configuration of the driver's cab is such nature that the driver adopts a sideways sitting orientation. The driver rotates his neck over his left shoulder when driving the vehicle forward. This induces a sustained twisted neck posture when facing towards the direction of the vehicle's movement.

A bucket-type seat is fitted. The dimensions of the seat base would not comfortably accommodate the 95th percentile male South African.

Controls and displays

The location of the foot pedals, towards the right in relation to the centre of the operator's seat and the vehicle's steering wheel, forces the operator to rotate his trunk towards the left. The horizontal angle of the foot pedals was also too high for effective activation of the pedals. The operator's foot position would induce strain to the ankle and lower leg muscles.

The position of the control lever, shown in Figure 1.36, is too far for ease of manipulation. The operator would have to stretch out his arm and keep it there unsupported for a period longer than three minutes. This posture would induce shoulder strain and fatigue. The layout of the instrument panel is such way that some the instruments are obstructed by the steering wheel.

Figure 1.36: Awkward location of the control lever

Label and symbols are used for identification of the controls and instruments. These were found to be acceptable.

Visual field

The forward and front visual field from the operator's seated posture was good. The rear visual field when a personnel carrier 2 510 mm long and 1 900 mm high was fitted would be restrictive.

UTILITY VEHICLE 2

Figure 1.37: Utility vehicle 2

Table 1.20: Evaluation of Utility vehicle 2

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	N/A
	Entrance height from the ground to a foot step	620 mm (too high)
	Entrance height from the ground to the ledge of the cab	1120 mm (too high)
Clearances inside the cab		
	Canopy	None
	Shoulder width	Adequate
	Knee clearance from SRP to front wall panel	600 mm (inadequate)
SEATING		
	Seat type	Bucket chair type
	Seat material	vinyl
	Seat base dimensions (WxD)	470x500 mm (acceptable)
	Seat backrest dimensions (WxH)	470x550 mm (acceptable)
	Restraint system	None
CONTROLS AND DISPLAYS		
Steering mechanism	Steering levers	? 30 (acceptable)
Display panel and instruments		Labeling is lacking
VISIBILITY		
	Operators field of view	Restricted view when driving

Access

The design of the cab does not provide a specific entrance point and its configuration is such that the operator could enter the cab through either the left or right side of the vehicle. The operator steps onto the ledge of the cab and then places one foot directly onto the cab floor. The entrance landing area is obstructed by the seat if accessed through the right-hand side, and is obstructed by the foot pedals if accessed through the left-hand side. Also, the distance from the surface to the entrance level was too high for easy entry into the cab for the 5th percentile male South African without handrails.

Seating

The configuration of the driver's cab is such nature that the driver adopts a sideways sitting orientation. The driver rotates his neck over his right shoulder when driving the vehicle forward. The twisted neck posture is sustained for long periods when facing towards the direction of the vehicle's movement.

A bucket type seat is fitted. However, this seat was in a poor state of repair.

Controls and displays

The location of the foot pedals in a recess in the cab floor limits the space for proper positioning of the feet. As a result, the operator rests his foot between the pedals (see Figure 1.38).

Figure 1.38: Resting of the foot between the pedals

The control levers for raising and lowering the bucket are located too far for ease of reach and manipulation of the controls (see Figure 1.39). The operator stretches out his arm and sustains it unsupported for a period longer than three minutes. The operator also has to rotate his trunk and neck towards the right to see the bucket lifting/lowering process. These postures are undesirable and would induce shoulder and neck strain.

Figure 1.39: Awkward location of the control lever

The instrument panel is laid out in such a way that some the instruments cannot be read from the operator's seated position. Labelling of the controls and instruments was lacking.

Visual field

The operator's visual field was restricted due to the cab design and configuration.

UTILITY VEHICLE 3

Figure 1.40: Utility vehicle 3

Table 1.21: Evaluation of Utility vehicle 3

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	640 mm (adequate)
	Entrance step height from the ground	530 mm (too high)
Clearances inside the cab		
	Canopy	None
	Shoulder width	600 mm (inadequate)
	Knee clearance from SRP to front wall panel	890 mm (adequate)
SEATING		
	Seat type	Bucket chair type
	Seat material	vinyl
	Seat base dimensions (WxD)	470x500 mm (adequate)
	Seat backrest dimensions (WxH)	470x550 mm (adequate)
	Restraint system	None
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 300 (acceptable)
Display panel and instruments		Labeling is lacking
VISIBILITY		
	Operators field of view	Restricted view when driving

Access

The operator enters through the left side of the cab. The distance from the surface to the entrance level was too high for easy entry into the cab for the 5th percentile male South African. The location of the seat within the entrance area makes it difficult to enter the cab without the handrails that would provide the required three-point contact for easy access to the cab.

Seating

The configuration of the driver's cab is such that the driver adopts a sideways sitting orientation. The driver rotates his neck over his left shoulder when driving the vehicle forward. The twisted neck posture is sustained for long periods when the driver is facing towards the direction of the vehicle's movement. The space inside the cab (600 mm) is inadequate and would not enable free body posturing. The bucket-type seat that is fitted in the vehicle was in a poor state of repair.

Controls and displays

All the controls were within the easy reach envelope and visual field of the 5th percentile to the 95th percentile male South African. However, the limited space inside the cab renders manipulation of these controls awkward due to the restrictions on free movement of the operator's limbs.

Labelling of the controls and instruments was lacking.

Visual field

The operator has a severely restricted visual field due to the design of the cab. He is not able to see the ground in front of the vehicle without leaning out of the cab.

UTILITY VEHICLE 4

Figure 1.41: Utility vehicle 4

Table 1.22: Evaluation of Utility vehicle 4

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	N/A
	Entrance step height from the ground	625 mm (too high)
Clearances inside the cab		
	Canopy	None
	Shoulder width	600 mm (inadequate)
	Knee clearance from SRP to front wall panel	600 mm (inadequate)
SEATING		
	Seat type	Bucket chair type
	Seat material	vinyl
	Seat base dimensions (WxD)	470x500 mm (acceptable)
	Seat backrest dimensions (WxH)	470x550 mm (acceptable)
	Restraint system	None
CONTROLS AND DISPLAYS		
Steering mechanism	Steering lever	? 30 (acceptable)
Controls dimensions		
	Accelerator pedal (WxL)	90x300 mm (acceptable)
	Brake pedal (WxL)	100x265 mm (acceptable)
Display panel and instruments		Labeling is lacking
VISIBILITY		
	Operators field of view	Restricted view

Access

The design of the cab does not provide a specific entrance point. It is configured in such a way that the operator could enter the cab through either through the left or the right side of the vehicle. The operator steps onto the ledge of the cab and then places one foot directly onto the cab floor-line. The entrance landing position is obstructed by the seat if the cab is accessed through the right side, and obstructed by the foot pedals if it is accessed through the left. Also, the distance from the surface to the entrance level was too high for easy entry into the cab for the 5th percentile male South African without handrails.

Seating

The configuration of the driver's cab is such that the driver adopts a sideways sitting orientation. The driver rotates his neck over his right shoulder when driving the vehicle forward. The twisted neck posture is sustained for long periods when the driver is facing towards the direction of the vehicle's movement. The bucket-type seat that is fitted in the cab was in a poor state of repair.

Controls and displays

The location of the foot pedals in the cab floor limited the space for proper positioning of the feet. As a result, the operator would have to lean slightly backwards in order to gain foot leverage when activating the foot pedals. This posture is undesirable for the application of biomechanical force. Figure 1.42 shows the typical posture adopted by the operator when activating the controls.

Figure 1.42: Typical posture when activating controls

The instrument panel is located and laid out in such a way that some of the instruments cannot be read from the operator's seated position. Labelling of the controls and instruments was lacking and the biomechanical force required to activate the controls was not determined.

Visual field

The vehicle was evaluated when it did not have a cassette fitted. Forward and rear viewing in the driver's seated position was excellent for normal driving. The visual fields to the front left corner and to the rear from the seated position are severely restricted due the cab configuration.

UTILITY VEHICLE 5

Figure 1.43: Utility vehicle 5

Table 1.23: Evaluation of Utility vehicle 5

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	900 mm (adequate)
	Entrance step height from the ground	420 mm (acceptable)
Clearances inside the cab		
	Canopy	YES
	Height of canopy roof ceiling to SRP (driving position)	850 mm (inadequate)
	Shoulder width	Adequate
	Knee clearance from SRP to front wall panel	930 mm (adequate)
SEATING		
	Seat type	Bucket chair type
	Seat material	vinyl
	Seat base dimensions (WxD)	470x500 mm (acceptable)
	Seat backrest dimensions (WxH)	470x550 mm (acceptable)
	Seat surface height from the cab floor	130mm (too low)
	Restraint system	Lap belt
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel	? 400 (acceptable)
Display panel and instruments		Symbols used
VISIBILITY		
	Operators field of view	Restricted view when driving

Access

The operator enters through the left side of the cab. The low cab profile makes entry into the cab difficult despite the fact that the height from the surface to the entrance level was

within easy reach for the 5th percentile to the 95th percentile male South African and despite the fact that the handrails fitted provide the required three-point contact for access to the cab.

Seating

The configuration of the driver's cab is such that the driver's seat is located at the centre of the cab and the driver faces towards the direction of the vehicle's movement when driving it forward. The driver's leg postures when activating the foot pedals were awkward because of the low height of the seat mounting.

The dimensions of the seat were adequate for accommodating the 5th percentile to the 95th percentile male South African.

Controls and displays

The controls were not easily accessible from the operator's seated positions. As shown in Figure 1.44, the operator has to stretch out his arm in order to operate the gear lever.

Figure 1.44: Stretched-out arm

Symbols are used for identification of the instruments. All the symbols used are nationally and internationally recognisable (see Figure 1.45).

Figure 1.45: Layout and labelling of the instrument panel

Visual field

The visual field during the mining processes would be restrictive due to the design and configuration of the cab.

UTILITY VEHICLE 6

Figure 1.46: Utility vehicle 6

Table 1.24: Evaluation of Utility vehicle 6

ITEM	DESCRIPTION	COMMENTS
OPERATORS' WORKSTATION		
Access		
	Entrance width	810 mm (adequate)
	Entrance height from the ground	1060 mm (too high)
	Entrance height from the ground to a foot step	270 mm (acceptable)
Clearances inside the cab		
	Canopy	None
	Shoulder width	Adequate
	Knee clearance from SRP to front wall panel	1140 mm (adequate)
SEATING		
	Seat type	T-shaped backrest
	Seat material	Polyurethane
	Seat base dimensions (WxD)	480x400 mm (acceptable)
	Seat backrest dimensions (WxH)	480x420 mm (acceptable)
	Seat surface height from the cab floor	450 mm (acceptable)
	Restraint system	Lap belt
CONTROLS AND DISPLAYS		
Steering mechanism	Steering wheel with a handle knob	? 420 (knob ? 30) (acceptable)
Display panel and instruments		Symbols used
VISIBILITY		
	Operators field of view	Good

Access

The operator enters through either the left or right side of the cab. The location of the seat, approximately 1 500 mm from the surface, causes access problems due to the limitation of the tunnel height and obstructions in the tunnel, such as pipes and cables.

The height from the surface to the foot step provides easy entry into the cab for the 5th percentile to the 95th percentile male South African as long as the handrails, which provide the required three-point contact for safe access, are maintained.

Seating

The configuration of the driver's cab is such nature that the driver's seat is located at the centre of the cab and the driver faces towards the direction of the vehicle's movement when driving it forward. The space inside the cab is adequate for the driver to move his legs. This was because the vehicle does not have any foot controls; all the controls are hand-operated.

A mechanical suspension seat with a polyurethane T-shaped backrest is fitted. The seat is height-adjustable and horizontally adjustable. The T-shaped backrest provides vertical and lateral support of the spine to an operator wearing rescue and battery packs. The dimensions of the seat base are adequate for the accommodation of the 5th percentile to the 95th percentile male South African.

Controls and displays

All the controls were within the arm reach envelope of the seated 5th percentile to the 95th percentile male South African. Activation of the controls appeared to be easy. Symbols are used for identification of the instruments. The layout of the controls and instruments was acceptable (see Figure 1.47).

Figure 1.47: Layout of the controls and instruments

Visual field

The forward and rear viewing was excellent due to the overall height of the driver's seat position from the ground.