

Guidance Document

G182 Ergonomic considerations for the design and development of a rolling stock operator's cab

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1 Purpose and Scope

- 1.1 The purpose of this document is to provide ergonomics support for the development of the cab environment of new rolling stock.
- 1.2 Many of the requirements, current issues and possible improvements are outputs of the assessments associated with the 'Human Factors in Cab Design' analysis commissioned by London Underground (LU) and undertaken by Human Engineering Ltd (HEL). Further detailed requirements and recommendations are given from various sources based on ergonomics best practice.
- 1.3 The recommendations have been grouped into a series of sections broadly based upon the key systems and equipment within the cab.
- 1.4 The document is not intended as the definitive guide to all human factors issues associated with cab design, but is intended to provide a series of pragmatic requirements and recommendations that will assist designers in developing future train cabs.
- 1.5 This Guidance Document replaces G-182 A1

2 Introduction

2.1 Aim

- 2.1.1 The aim of this document is to provide systems designers with an overview of the ergonomic issues that shall be considered within the train operator's cab when designing future rolling stock vehicles.
- 2.1.2 The document is intended to provide a series of best practice guidelines based upon the results of a detailed analysis of each of the 9 different rolling stocks utilised on the London Underground (LU) infrastructure.

2.2 Objectives

- 2.2.1 The following objectives have been developed in order to support the aforementioned aim:
 - a) To provide an overview of ergonomics principles.
 - b) To provide overall cab requirements and the associated human factors issues of the Train Operator (TO) and Instructor Operator (IO).



Note: For the purposes of this document, the term 'operator' will be used to describe the person controlling the train, whether a Train Operator or Instructor Operator, unless otherwise stated.

2.3 Document Structure

2.3.1 The document has been split into a series of sub-sections and appendices to aid the user in navigation through the document and finding the desired information.

- *Section 2:* Provides an introduction explaining the aims, objectives and lifecycle of the document.
- *Section 3:* Provides an overview of general ergonomics principles to enhance the reader's understanding of applying ergonomics throughout the design process.
- *Section 4:* Provides guidelines on the physical workspace within the cab including thoroughfare, design of the operator's console and seating requirements.
- *Section 5:* Focuses on the external visual requirements of the operator. This includes design guidelines for the structure of the cab and window features to ensure the operator has visibility of external information sources (e.g. signals, PTI equipment) from within the cab.
- *Section 6:* Details the ergonomic design principles that should be applied when identifying the optimum layout of controls and displays within the cab.
- *Section 7:* Provides guidelines on maintaining appropriate environmental conditions within the cab to ensure factors such as the temperature, lighting, noise and vibration do not have an adverse effect on the health, comfort and performance of the operator.
- *Section 8:* Provides guidelines on the use of communication systems/equipment within the cab, for example, the cab radio.
- *Section 9:* Identifies factors in cab design that directly influence the vigilance of the operator, with guidelines for eliminating such factors.
- *Section 10:* Identifies storage requirements for handheld equipment (e.g. radios) and personal belongings within the cab to ensure they do not obstruct the tasks to be completed within the cab.
- *Section 11:* Provides requirements for access and egress including; movement around the cab, boarding/alighting from the cab and escape routes via the cab in the event of an emergency detrainment.
- *Appendix A:* Provides tables of anthropometric data with graphical representation of human body dimensions.
- *Appendix B:* Provides information on the appropriate use of colour for displays and controls.
- *Appendix C:* Provides a specification for the design of controls i.e. size, resistance, functionality etc.
- *Appendix D:* Provides examples of possible gauge designs.
- *Appendix E:* Provides Human Factors Process

Statements that are perceived as best practice principles have been formatted in **bold** and are viewed as goals that the train cab designers should strive to achieve. All other text should be considered as explanatory supporting information.



The following appendices detail all of the human factor issues associated with each line generated during Task Analysis and Issue Capture Workshops carried out in the development of this guidance document. These are available as separate documents upon request to the Capital Programmes Directorate, Head of Engineering:

- *Appendix F:* Bakerloo Line Human Factors Issues
- *Appendix G:* Central / Waterloo & City Line Human Factors Issues
- *Appendix H:* Jubilee Line Human Factors Issues
- *Appendix I:* Northern Line Human Factors Issues
- *Appendix J:* Piccadilly Line Human Factors Issues

2.4 Document Lifecycle

2.4.1 Other Standards

LU standards (e.g. Platform Train Interface (PTI), in-cab Closed Circuit Television (CCTV) (1-150 Telecommunications and OPO CCTV and G-150) and manual of good practice should be referred to when appropriate, and take priority over the best practice guidance within this document.

3 Ergonomics principles

3.1 Overview

3.1.1 The purpose of this section is to provide an overview of general ergonomics principles to enhance the reader's understanding of applying ergonomics throughout the design process.

3.1.2 Task Analysis

3.1.2.1 At each stage of the design of a new cab consideration shall be given to the tasks to be carried out efficiently and safely by the driver. The aim of the task analysis is to gain an understanding of the different tasks and activities that a driver has to carry out to operate a train effectively and safely.

3.1.2.2 Through the identification of the task requirements by task analysis, the end user (driver) requirements shall be established.

3.1.3 Demanding Scenarios

Demanding scenarios are a series of operational scenarios which can be used by the supplier to demonstrate that the train design is fit for purpose i.e. that the design can fulfil the tasks which would be required of it in any operational scenario. Relevant stakeholders identify and agree on the set of high level demanding scenarios, which are then elaborated upon to provide detailed task analyses for each scenario. These scenarios may then be used to predict human error and workload, and to ultimately inform cab design at each stage in the design process. Thus, the demanding scenarios can be used to validate the cab design in conjunction with CAD modelling and a cab mock-up (at design stage) or built train (at realisation).

3.1.3.1 A diagram outlining the development process is included in *Appendix E*, this demonstrates how these activities feed into the design, review and validation of the Cab.

3.2 Anthropometry

3.2.1 Anthropometrics is the study of human body measurements in terms of size, strength and physical ability. Systems and equipment should be matched to the human user, for example, providing adequate clearance for the tallest and broadest of individuals whilst still allowing the smallest person to reach and operate all of the controls. Information about body dimensions is a result of studying and recording information from samples of the target population.

3.2.2 **A train cab should be designed taking into account the range of variability in the operator population.** The range of variability amongst a population can be illustrated using a normal distribution curve (see Figure 1). Designing to accommodate from the 5th percentile (5th %ile) female to the 95th percentile (95th %ile) male is good design practice.

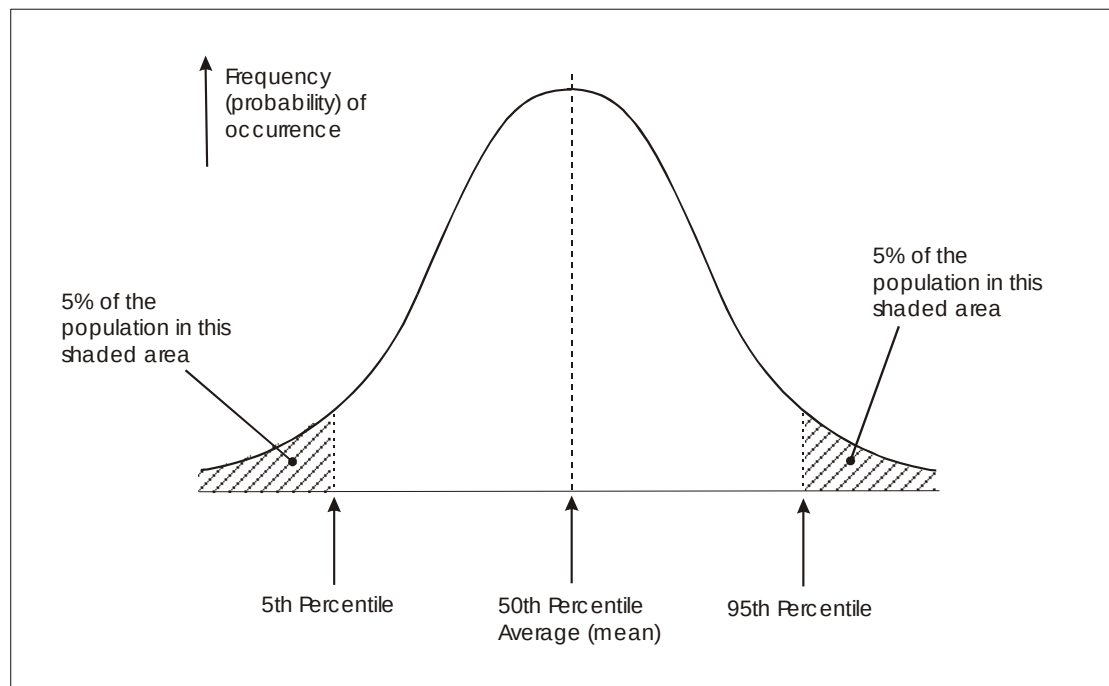


Figure 1 – Normal distribution Curve

3.2.3 The anthropometric measurements specified in Appendix A must be taken into account when designing any new system or part of the operator's cab to ensure that it matches the physical requirements of the target user group.

3.2.4 When designing a system or equipment based on measurements of static body parts:

- Ensure that the anthropometric data used is an accurate representation of the operator population;
- Ensure allowances are made for clothing worn by the operator. For example, LU issue footwear, jackets etc. The data in Appendix A does not allow for clothing;
- Ensure that anthropometric data allows for secular growth over the service life of the system or equipment. Secular growth is the increase in body size and the rate of growth of a population.



- 3.2.5 **Dynamic data must be used for developing reach parameters.** Static data only takes into account the dimensions of the body but it is also important to take into account dynamic movement of the body (i.e. dimensions measured when the body is involved in physical activity). For example, the static dimension for 'easy' grip reach is calculated from the back of the shoulder blade to the tip of the thumb with the arm raised forward horizontally. However, it is possible to stretch the shoulder forwards (without overexertion) to increase reach distances.
- 3.2.6 **Excessive use or misuse of muscles, joints, and associated soft tissues must be avoided.** The best posture for any task is one that requires it to be carried out with the least possible effort. The number of repetitive strain injuries will therefore be minimised. The middle third of any joint movement is generally considered to be the most comfortable (*Reference 4*).
- 3.2.7 **Prolonged muscle effort in a fixed position should be avoided.** Prolonged muscle effort can cause fatigue, therefore dynamic muscular activity involving contraction and relaxation is beneficial (if kept on a reasonable scale).
- 3.2.8 **The design should take into account the decrease in strength experienced by older age groups.** By age 45 the average person's strength has declined by 10%. By the time they reach age 60 this figure has declined to between 20-25%. (*Reference 4*).
- 3.2.9 **Movements that require in excess of 60% of an individual's maximum strength should be avoided.** The amount of force that an individual is able to exert has a direct relationship with posture adoption. (*Reference 4*)
- 3.2.10 **Repetitive movements that require in excess of 30% of an individual's maximum strength should be avoided.** Repetitive tasks that require excessive force can result in strain/injury (*Reference 4*).
- 3.2.11 **Continuous actions that require in excess of 15% of an individual's maximum strength should be avoided.** The individual can continuously exert up to 15% of their maximum force, however these continuous forces should be avoided wherever possible. (*Reference 4*).

3.3 Grouping of Controls and Displays

- 3.3.1 Controls and displays are rarely used in isolation so designing appropriate layouts is important. The ergonomic layout of controls and displays can increase the performance, comfort and physical well-being of the operator by reducing the unnecessary movements and actions.
- 3.3.2 **Controls and displays should be grouped according to their function.**
- 3.3.3 **Groups of controls and displays should be positioned according to their importance, sequence-of-use, frequency-of-use and any interactions they might have with other control and display groups.** Controls and displays that have an important role within the train cab should be placed in the most convenient location in terms of reach and vision. However, relationships with other controls or displays and the frequency with which a control or display is used should also be taken into consideration when arranging the layout of such components.
- 3.3.4 **Groups of controls and individual controls within each group should be easily distinguishable from each other.** Using colour, shape, spacing, borders, control type or labelling will achieve this.

3.4 Reach Envelopes

- 3.4.1 It is important that the operator is able to reach the controls that are used when the train is in motion, from the 'primary operating positions'¹. Ideally, a sit/stand workstation should be provided within the cab for the reasons identified in Section 4.3. Reach envelopes should be developed around the primary operating positions.
- 3.4.2 **All controls should be within reach of the 5thile female operator.** The position of controls within the cab should allow as many operators as possible to reach them from the operating position.
- 3.4.3 **Controls should be placed nearer the area for optimum comfort according to their importance and frequency of use.** There are areas within the reach zones that require less movement away from the normal seated position in order to reach them. These are therefore more comfortable to reach and priority controls should be placed within these areas (see Figure 2).
- 3.4.4 Normal zones are areas that can be conveniently reached with a sweep of the forearm while the upper arm hangs in a natural position; maximum zones are zones that can be reached when the upper arm has to move away from the normal (*Reference 8*).

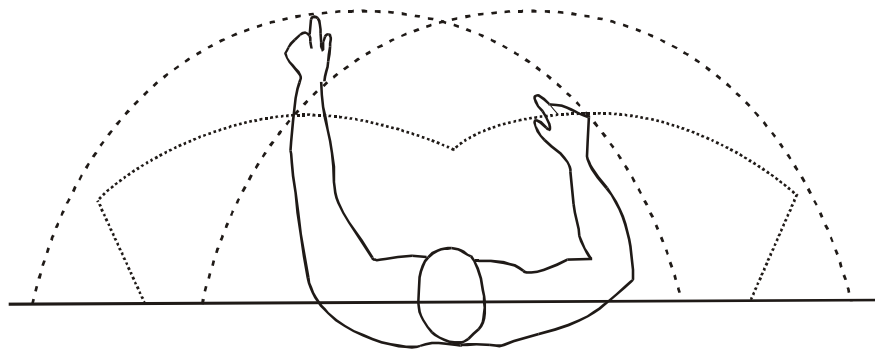


Figure 2 – Example Reach Envelopes

- 3.4.5 The following anthropometric measurements, which can be found in Appendix A, should be used to calculate the reach envelopes:
- Shoulder breadth (deltoid);
 - Elbow-fingertip length;
 - Forward reach;
 - Standing overhead reach;
 - Sitting overhead reach.

3.5 Visual Requirements

- 3.5.1 A large proportion of the operator's tasks require visual feedback from both internal and external sources. Visual pathways of operational controls and critical information sources, both within the cab and externally, are vital for safe operation of the train.

¹ Primary Operating Positions - The main positions within the cab where the operator will be situated, whilst operating the train.

- 3.5.2 **The operator's visibility of the external environment should be unrestricted as far as reasonably practicable.** Obstructions in the operator's field of vision, such as the structure of the cab, can prevent effective monitoring of the external visual field, and as such should wherever structurally feasible, be minimised.
- 3.5.3 **The operator should have an unrestricted view of all critical displays which are needed whilst the train is in motion, from the primary operating positions.**
- 3.5.4 **The operational envelope of controls within the cab should not obscure controls and displays at any point.** This should take into account both the movement of the control and the position of the operator's hand/arm when operating the control. .
- 3.5.5 **Displays possessing greater importance or a higher usage frequency should be positioned closer to the preferred field of view.** The preferred zone for display location is defined in Figure 3 (Reference 7)).

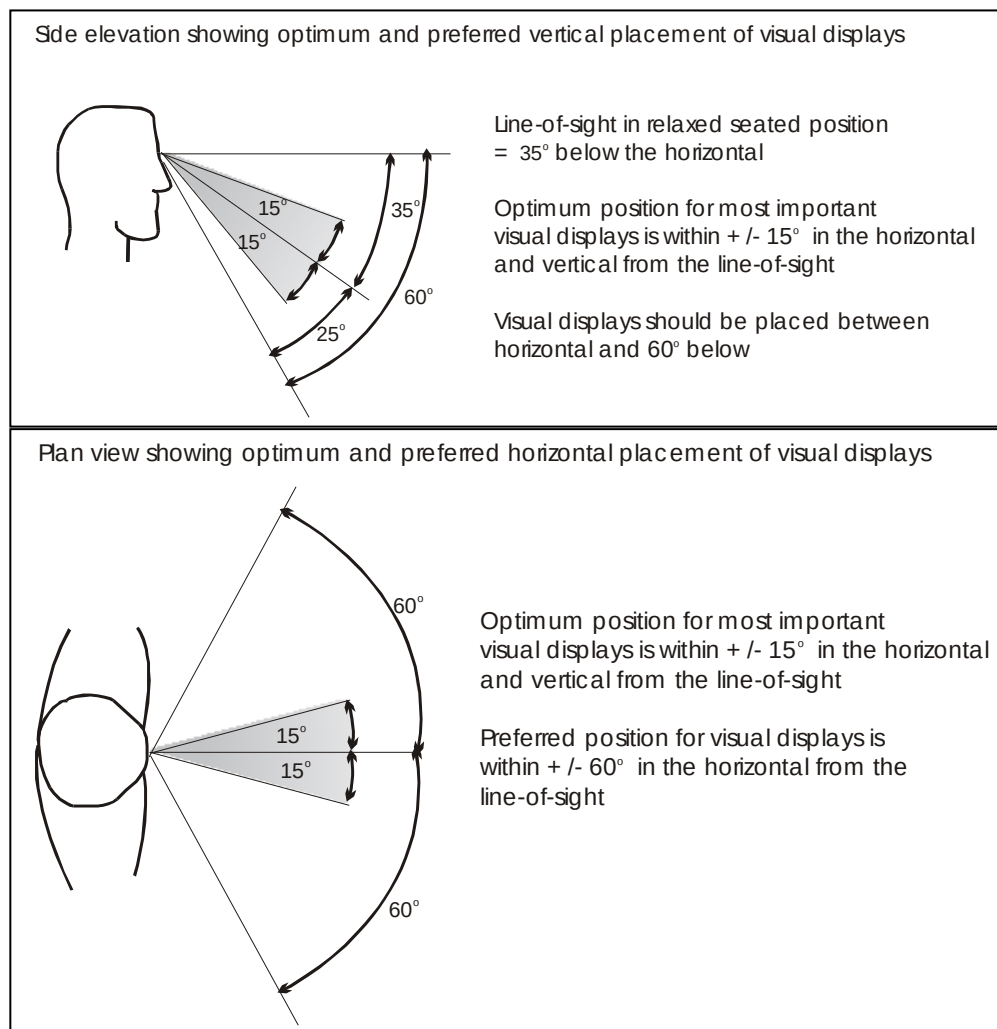


Figure 3 – Preferred fields of vision

- 3.5.6 **Care must be taken to provide appropriate positioning of critical displays without impeding the line-of-sight of the track ahead.** For example, vision of the track ahead for the shorter operators may be obstructed if the internal visual displays are positioned too high.



- 3.5.7 **Controls and displays should be free from glare.** Direct glare (e.g. from the sun) and reflected glare (i.e. light reflected by a surface) can impair visibility of controls and displays.

3.6 Use of Colour

- 3.6.1 **Colour should be used to improve the conspicuity of relevant controls and displays in the cab.** The conspicuity of an object depends on the contrast between itself and the background. The level of contrast can be altered by changing the colour (e.g. when viewed against a black, dark grey, brown or dark blue background, the most conspicuous colours are yellow, orange and red in that order). Colour can also aid the interpretation of the function.
- 3.6.2 **Colour should be used to assist interpretation of the function by following standard stereotypes (see Appendix B).** For example, a red control is used to indicate stop or off (e.g. emergency brake).
- 3.6.3 Extreme care should be taken when using green or red indicator lights within the cab environment as they may potentially be confused with the signal aspect (see also paragraph 6.2.13).

3.7 Symbols and Labelling

- 3.7.1 Features inside the cab requiring identification should be appropriately labelled to aid the identification process. .
- 3.7.2 **The symbols and text labelling around the controls and displays must be sized to be readable from the operator's position.** Generally, the greater the distance that the operator is away from the text, the larger the text should be to ensure visibility.
- 3.7.3 **The style of the text should be easy to read.** For continuous text, serif typefaces such as Times Roman should be used. For isolated words or relatively short messages sans-serif faces such as Helvetica and Ariel are more legible.
- 3.7.4 **Symbols and text should have a high contrast.** This commonly means low reflective symbols on high reflective ground (e.g. black on white) or visa versa.
- 3.7.5 **The display surface should be, as near as possible, perpendicular to the operator's line-of-sight.**
- 3.7.6 **Symbols and text should be absent from glare sources.**
- 3.7.7 **Symbols should take a simple visual form.**
- 3.7.8 **Symbols, text and terminology must be familiar to the operators.**
- 3.7.9 **Standard symbols should be used where possible.**
- 3.7.10 **Only details that improve the comprehension of a symbol should be included.**
- 3.7.11 **Meaning of symbols and text should not be ambiguous** i.e. should only mean one thing so the operator does not misinterpret information.
- 3.7.12 **A silhouette is preferable to an outline.** If an outline is required, then the interior of the symbol should differ from the background in colour and pattern.
- 3.7.13 **Left/Right symmetry is preferable to asymmetrical symbols.** Left/right symmetry increases the identification speed of the symbol.



- 3.7.14 **Symbols that are similar in height and width are preferable to long and narrow shapes.** Long narrow symbols decrease identification speed.
- 3.7.15 **Symbols should generally be presented within square enclosures.** These provide a visual separation of the symbol to the background which assures onlookers of the boundaries of the symbol.

3.8 Control Design

- 3.8.1 The usability of a control can be influenced by factors such as size, shape, operating movement and feedback given to the operator. Controls should conform to the specifications in *Appendix C*.
- 3.8.2 **The movement of controls should conform to standard operational stereotypes.** Users will expect the control movements listed below to result in activation, an increase in magnitude or an increase in intensity:
- Turning a rotary control clockwise;
 - Moving a linear control upwards or away from the operator;
 - Moving a linear control to the right.
- 3.8.3 **Controls should provide feedback to the operator.** The operator should have no doubt as to whether or not they have operated or engaged a particular control.
- 3.8.4 **Return action buttons should be designed to have a positive feel as the button engages and preferably make an audible click.** Devices that lack appropriate feedback characteristics will require enhanced feedback (e.g. in the form of an associated indicator status light).
- 3.8.5 **Controls that are operated whilst being out of the visual range should be shape coded.** If the driver is unable to use vision to identify a control then it must be identifiable by touch.

3.9 Gauge Design

- 3.9.1 Gauges are used to display information about a system to the operator. The type of display and its design features have a direct influence on its effectiveness in terms of reading speed and accuracy. Consideration must be given to:
- The type of information being displayed;
 - The accuracy with which it has to be read;
 - The time the operator will have to read the information;
 - The relevant importance of the information to the system;
 - The distance that the operator is reading the display from.

Note: A 'gauge' refers to a visual display that provides the operator with information regarding the status of a system on a train between two fixed points. A gauge may be a real (manual gauge) or a virtual representation (e.g. on a computer screen).

- 3.9.2 **Gauges should incorporate a pointer that moves against a fixed scale.** These types of gauges are better for values that are continually changing, as it requires less time to read the displayed information.
- 3.9.3 **The major numeric markers on the scale should occur at equal intervals.** Multiples of 10 are recommended with intermediate markers at 5, 15, 25 etc.

3.9.4 **There should never be more than four minor marks between intermediate marks (see Figure 4).** More than four marks can create confusion and slow down the time it takes to read off the scale.

3.9.5 **There should never be more than four intermediate marks between major marks.**

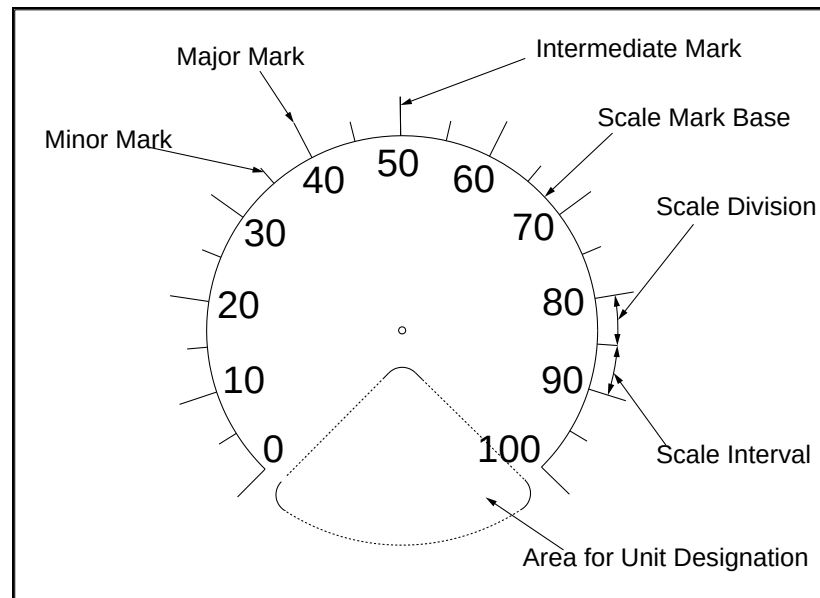


Figure 4 – Typical Circular Gauge

3.9.6 **Large numerical values should be divided by 10, 100, 1000 etc. to present information in a simpler form.** The information is then easier to comprehend and this allows for larger symbols to be placed on the gauge.

3.9.7 **The length of the scale unit should be such that the distinctions between the values can be made with optimum reliability in terms of human sensory and perceptual skills.** The separation distance between the scale units can affect the reliability of correctly reading the gauge. Scale units that are too close together or too far apart can cause errors in the operator's interpretation of the gauge.

3.9.8 **A scale marker** should be included for each unit on the scale that has a requirement to be read. Scale markers positioned on units of importance reduce the time it takes to read them.

3.9.9 **The scales must be suitable to be viewed in low levels of illumination.** Due to the fluctuation of light levels within the cab, the width of the scale lines must be sufficient and the gauge should contain suitable illumination to be read in darker conditions.

3.9.10 **Pointers should have a pointed tip with an angle of approximately 20°.** This enables the scale to be read with greater accuracy.

3.9.11 **The tip of the pointer should meet but not overlap the smallest scale markers.** If the operator has to use predictive vision to imagine a straight line from the tip of the pointer to the desired marker, then the reading accuracy decreases, as there are more margins for error.

3.9.12 **The colour of the pointer should extend from the tip to the centre of the scale.**

- 3.9.13 **The pointer should be sufficiently close to the scale to avoid reading inaccuracies.** Reading inaccuracies occur when the vertical distance between the pointer and the scale is too great. The pointer appears to be positioned on another part of the scale when not viewed from directly in front.
- 3.9.14 **The pointer should not obstruct visibility of the scale.**
- 3.9.15 **The labelling of the scale must be suitable to be viewed in all train operating conditions** (Refer to Section 3.7. Symbols and Labelling).
- 3.9.16 **The display pointer should move in accordance with the stereotype directions to indicate increasing magnitude of the measured quality defined in Table 1.** Examples of these types of scale can be found in *Appendix D*.

Type of Scale	Direction of Movement
Circular or part circular	Clockwise
Horizontal sector (top)	From left to right
Horizontal sector (bottom)	From left to right
Vertical Sector (left hand)	Upwards (i.e. clockwise)
Vertical Sector (right hand)	Upwards (i.e. anticlockwise)
Quadrant (upper left)	Upwards (i.e. clockwise)
Vertical, straight or edgewise	Upwards
Horizontal, straight or edgewise	From left to right

Table 1 – Direction of movement stereotypes

4 Physical workspace design

4.1 Overview

- 4.1.1 For the purpose of this guidance document, the physical workspace within the cab has been broken down into three main components, these are defined within Figure 5:

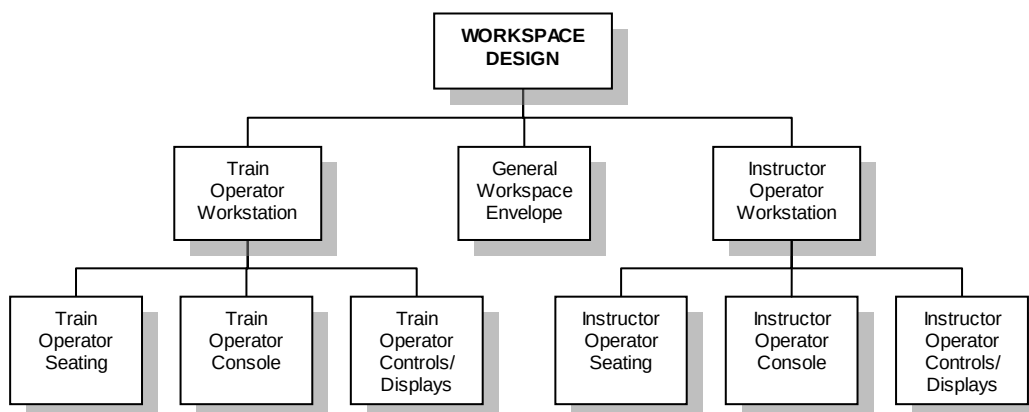




Figure 5 – Physical Workspace Breakdown

- 4.1.2 The cab is an environment which will be used by a range of individuals who vary considerably in terms of physical dimensions and personal preferences. The workspace should therefore be designed to accommodate 5th to 95th%ile of the target population (see Appendix A).

4.2 General Workspace Envelope

- 4.2.1 The layout of systems and equipment within the cab has an influence on:
- The working space of the operator (and other cab occupants) in the primary operating positions
 - Manoeuvrability around the cab
 - Cab access and egress (normal and emergency)
 - Visual requirements (internal and external)
 - Use of operational controls
- 4.2.2 **The workspace and cab layout should allow the 5th%ile female to 95th%ile male to configure the workstation/seating to suit their individual requirements**
- 4.2.3 **The workspace and cab layout should allow for easy access to and egress from the operator's seat.** Careful consideration is needed in the overall cab layout to achieve this as the operator needs to access and egress the seat regularly.
- 4.2.4 **The workspace and cab layout should not restrict manoeuvrability around the cab.** For example, to access controls such as the secondary door controls.
- 4.2.5 **The workspace and cab layout should allow for easy access and egress, under both normal and emergency procedures.** The operator needs to access and egress the cab on a regular basis. An egress route is also needed via the cab for emergency detrainment of passengers.
- 4.2.6 **The workspace and cab layout should allow the operator to view information sources both internally and externally from the primary operating positions.** The operator should not need to adopt awkward body postures to gain an acceptable view of the required information sources.
- 4.2.7 **Thoroughfares within the cab should be sized to accommodate the 95th%ile male user.** The critical dimensions to take into account are the maximum body breadth and stature. Suitable allowances for clothing, shoes and physical movement should also be applied to these dimensions to ensure a suitably designed thoroughfare.
- 4.2.8 **Thoroughfares within the cab should be free from obstructions and protrusions.** It is essential that all thoroughfares are modelled during the design stage with all known systems and equipment in position to assess the impact of these systems and equipment on thoroughfare width and height. If this is not achieved systems and equipment will impact on thoroughfare dimensions.

4.3 Train Operator Workstation Design

- 4.3.1 **Ideally, the operator workstation should be designed to allow for both seated and standing operation.** Allowing the operator to alternate their posture from sitting to standing when operating the train can have physiological advantages:

'A workplace which allows the operator to sit or stand, as he or she wishes, is highly recommended from a physiological and orthopaedic point of view. There is less to hold up when one is sitting down than when standing; on the other hand, sitting is the cause of many aches and pains which can be relieved by standing up and moving about. Standing and sitting impose stresses upon different muscles so that each change over relaxes some muscles and stresses others. Furthermore, we have good grounds for believing that each change from standing to sitting (and vice versa) is accompanied by variations in the supply of nutrients to the intervertebral discs so that the change is beneficial in this respect too.'

(Kroemer, K. H. E., & Grandjean, E., 1997. *Fitting the Task to the Human* (Fifth Edition) Reference 1))

- 4.3.2 Allowing both a seated and standing position can also improve operator vigilance.

Console Design for Standing Operation

- 4.3.4 **The operator should be provided with adequate support whilst standing.** The operator needs to be able to maintain stability and counteract movements of the body caused by the motion of the train (i.e. to prevent falling over).
- 4.3.5 It should be noted that currently, operators maintain stability by leaning back against the seat or resting on the console. This emphasises the need for providing support within the cab.
- 4.3.6 **Systems and equipment should not impede visibility of the track ahead and other external information sources from the standing position.** The 5th %ile female to the 95th %ile male, should be able to view the track and other external information sources (e.g. signals, speed limit markers), from the standing position without adopting an awkward body posture for long periods.
- 4.3.7 **The seat should not impede standing operation.** Standing operation may be prevented, or irritation to the back of the legs may be caused, if the seat-pan is too far forwards and cannot be adjusted out of the way. The seat-pan within some cabs folds up to provide standing space as can be seen in Figure 6.



Figure 6 – Seat-pan raised to allow standing operation

- 4.3.8 **Space for the operator's feet should be allowed in front of the console.** If a footrest is incorporated into the design, a 'cut out' should be provided to allow the standing operator to get close enough to the console. This concept is demonstrated in Figure 7.

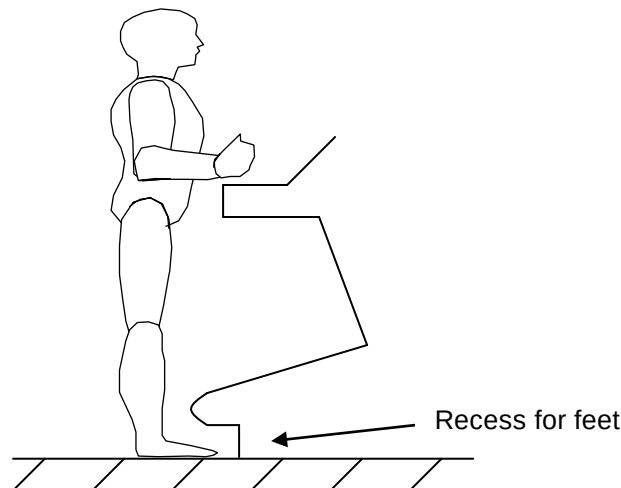


Figure 7 – Foot recess in console

Console Design for Seated Operation

- 4.3.9 **When seated, a 95thile male should be able to outstretch their legs forward without impediment from the console or cab structure.** In an office environment, the depth under the desk should not be less than 800mm at the level of the feet (*Reference 1*).
- 4.3.10 **When the operator is in a seated position, the console should not impede on the knee-space of the 95thile male.** In an office environment, the depth allowed for the knees under the desk should not be less than 600mm (*Reference 1*). The vertical clearance between the top of the seat pan and the lower surface of desk should be able to accommodate a 95thile male user in comfort. Typically, the reference material suggests that this value should be 170mm minimum (*Reference 1*), i.e. when the seat pan height is adjusted to suit the 95thile male.
- 4.3.11 **When the operator is in a seated position, the console should allow the operator to move the knees and legs laterally.** In an office environment the space for the legs and feet should not be less than 680mm wide (*Reference 1*). Sufficient space should be provided to:
- Allow postural changes of the operator's legs, which benefits health, comfort and general morale;
 - Prevents repetitive collision of the knees with the console sides during train motion;
 - Allows less restricted access and egress of the console.
- 4.3.12 **External information sources (e.g. track, signals) should be visible for a 5thile female to a 95thile male from a normal seated position.** Allowing for the operator with the lowest 'sitting eye height' to have sufficient visibility over the console will accommodate other users.



4.4 Cab Seat Design

Overview

- 4.4.1 Seating design is a critical element within the operator's workspace. The seat should aim to achieve the following:
- Allow for a healthy working posture to be adopted by all operators;
 - Allow quick and easy adjustment;
 - Allow for regular change in posture;
 - Provide adequate support when required;
 - Allow for frequent access and egress from the seat;
 - Avoid obstruction during access/egress or moving around to cab;
 - Prevent exposure to harmful vibrations.
- 4.4.2 Poor posture can cause musculoskeletal stress to the occupant, therefore the seat should ensure that a healthy working posture can be adopted and maintained for all frequently performed operating tasks. The seat is also responsible for preventing the transmission of harmful vibrations reaching the seated operator.
- 4.4.3 Seating design must take into consideration that drivers with a wide variety of body sizes will be using the seat for prolonged periods of time. A good design of seat should accommodate for the extremes of the train operator population.
- 4.4.4 A quick changeover between drivers at a station or depot is required for the running of an efficient passenger service. This has implications on the time allowed for the operator to adjust the seat. Time consuming adjustment is not acceptable due to time limitations. Also, adjustments should not require large forces or require poor postures to be adopted. This is particularly necessary due to the frequency of adjustment required.
- 4.4.5 It is important to note that the dimensions provided in the following sections are only guidance, and are taken from typical office seating. Therefore, detailed surveys, research and/or trials may be necessary to determine the most appropriate dimensions.

Seat Size

- 4.4.6 **The width of the seat pan should accommodate the physical requirements of the 5th%ile female user to the 95th%ile male user.** Typically, the seat pan width should be between 400mm and 450mm. (*Reference 1*).
- 4.4.7 **The depth of the seat pan should accommodate the physical requirements of the 5th%ile female user to the 95th%ile male user.** Typically, the seat pan depth should be between 380 and 420mm (*Reference 1*).
- 4.4.8 **The height of the backrest should accommodate the physical requirements of the 5th%ile female user to the 95th%ile male user without restricting movement.** Typically, the height of the backrest should be at least 500mm above the seat pan (*Reference 1*).
- 4.4.9 **The width of the backrest should accommodate the physical requirements of the 5th%ile female user to the 95th%ile male user, without restricting mobility of the upper body.** The backrest width in the lumbar region should be at least 305mm (*Reference 8*).

Seat Adjustments and Supporting Structure



- 4.4.10 All seat adjustments shall be designed to include adjustments, seat shape and profile to accommodate the needs of the 5thile female to 95thile males to the end of the life of the vehicle.
- 4.4.11 **The angle of the backrest should be adjustable to accommodate the physical requirements of the 5thile female user to the 95thile male user.** Typically, the preferable range of adjustability is between 90° and 120° between the seat pan and the backrest (*Reference 8*).
- 4.4.12 **The fore-aft position of the seat should be adjustable to accommodate the physical requirements of the 5thile female user to the 95thile male user.** Typically, successfully achieving this requirement will enable the operator to configure the seat correctly to operate the controls positioned on the operator's control panel
- 4.4.13 **The angle of the seat pan should be adjustable to accommodate the physical requirements of the 5thile female user to the 95thile male user.** The seat pan angle should have a minimum adjustment range of between 1° forwards and 5° backwards tilt from the horizontal (*Reference 3*).
- 4.4.14 **The position of the lumbar support should be adjustable.** The centre of the lumbar support should be adjustable between 170mm and 250mm above the seat-pan. Typically, the centre of a fixed height lumbar support should be 210mm ± 15mm. The vertical height of the lumbar support area should be at least 100mm.
- 4.4.15 **The seat should allow independent adjustment for all components such as seat pan height, backrest angle and fore-aft position.**
- 4.4.16 **The resistive force required to operate the seat adjustment mechanisms should not exceed the physical capabilities of the 5thile female.** (For further information, see (*Appendix A*)).
- 4.4.17 **Seat adjustment mechanisms should be suitably robust for the operational environment in which they are operated.** The seat adjustment mechanisms will be operated numerous times per day. Worn or damaged mechanisms may prevent the operator adjusting the seat to the required position.
- 4.4.18 **Seat adjustment mechanisms should be easy to locate.** Standard locations used for each adjustment mechanisms will allow the operator to quickly locate and adjust seat characteristics.
- 4.4.19 **Seat adjustment mechanisms should be easily identifiable.** This will be achieved through the use of appropriate symbols, colour coding and clear labelling.
- 4.4.20 **Seat adjustments should be easily operable from a seated position.** The operator should not be required to adopt unnatural body positions to operate the seat adjustment controls.
- 4.4.21 **The seat structure should reduce the transmission of the vehicles vibrations to as low as reasonably practicable (ALARP).** Vibrations produced by the vehicle can be transmitted directly to the operator via the seat, which has been reported as a cause of operator back pain. It is therefore important that the transmission of vibration to the operator is minimised through the design of the seat structure.

Seat Furnishings

- 4.4.22 **The seat covering should enable the occupant to maintain a comfortable seated position.** A textured, but none abrasive seat covering may be used to prevent the operator sliding over the seat surface during train movement.



- 4.4.23 **The seat covering should allow ventilation and water vapour exchange between the operator and the seat.** This will reduce discomfort to the seat occupant as a result of perspiration.
- 4.4.24 **Seat coverings should be suitably robust for the operational environment.** Worn or damaged seat coverings may cause discomfort to the occupant.
- 4.4.25 **The seat cushioning should reduce the transmission of the vehicles vibration to as low as reasonably practicable (ALARP).** Vibrations produced by the vehicle can be transmitted directly to the operator via the seat, which has been reported as a cause of operator back pain. The use of seat cushioning is one way of absorbing the vibrations produced.
- 4.4.26 Seat cushioning is reported to compact after use, resulting in less cushioning and therefore less comfort for the operator. One way of improving the cushioning over the long term may be to allow the seat cushions to be replaced independently of the seat as a whole.
- 4.4.27 Consideration should be given to the use of pressure relieving materials within the construction of seat cushioning. This may enhance the comfort of prolonged sitting by evenly distributing the pressure placed on the individual whilst sitting.

Armrests

- 4.4.28 **Ideally, armrests should be provided on both sides of the seat, but location and movement of the TBC should also be considered.** Armrests are a necessary requirement to support the weight of the upper body whilst seated.
- 4.4.29 **The armrests should accommodate the physical requirements of the 5th%ile female user to the 95th%ile male user.** The armrests should be at least 40mm wide, at least 200mm long and should be set back a minimum of 100mm from the front of the seat (*Reference 4*).
- 4.4.30 **The height of the armrests should be adjustable to accommodate the physical requirements of the 5th%ile female user to the 95th%ile male user.** Buttock to underside of elbow distance for the 5th%ile female is 191mm, and 288mm for the 95th%ile male user (*Appendix A*).
- 4.4.31 **Armrests should not restrict access to and egress from the seat.** One way of achieving this is to allow them to fold away when not required.
- 4.4.32 **Armrests should not restrict leg movement whilst seated.** This can be achieved by positioning the supporting structure for the armrests at the rear of the seat pan, thus allowing operator's legs to move laterally if required.

Footrests

- 4.4.33 It may be necessary to incorporate a footrest into the cab design to provide the operator with necessary support for the lower body, specifically the legs and feet. If a footrest is incorporated, the following requirements should be adhered to:
- 4.4.34 **Footrests should be large enough to accommodate the 5th %ile female to the 95th %ile male.** The footrest width should be at least 350mm wide, and have a horizontal depth of at least 450mm (reference 4). It may be considered most appropriate to use the whole area under the console for the footrest (width 680mm, horizontal depth 800mm, as described in paragraphs 4.3.9 to 4.3.11).