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FA REISEBUS

Driver's Workplace in Motor Coaches

Recommendations for ergonomic design

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The project group of the study

The project group was composed of the following participants:

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Abbreviations used in this report

BGF	Professional Association for Transport
CATIA	Computer Graphics Aided Three Dimensional Interactive Application System
DWMC	Driver’s workplace in motor coaches
Driver/motor coach driver	Designates motor coach drivers in this report
HdE	Manual of ergonomics
H point	Hip joint point is the intersection of the theoretical axes of the thigh and the torso line.
MMI	Human/machine interface
Ramsis	Computer-aided anthropological/mathematical system for passenger simulation
SAE	Society of American Engineers
SRP	Seat Reference Point
TNO	TNO Human Factors Research Institute (The Netherlands)

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0 Preface

Motor coach drivers are subjected to a heavy burden by their work at the driver's workplace. These are burdens caused by traffic conditions, the environment, the passengers and by the vehicle itself. This led the BGF to initiate a project to discover the most important aspects of these burdens in a preliminary and a main study and to derive recommendations from this for the design of the driver's workplace in motor coaches.

The preliminary study of the research project /4/ had the task of examining the ergonomic conditions in vehicles available on the market and to discover deficits and potentials for optimisation.

The main study had the task of developing the ergonomic principles for a driver's workplace concept on the basis of the determined deficits.

The objective of the study is to develop recommendations for the ergonomic design of the driver's workplace in motor coaches and to improve the work situations for drivers of motor coaches.

The focus is on work to determine the characteristic ergonomic design patterns as the basis for drivers' workplaces in motor coaches. The primary methodical concept of the main study is to deliberately avoid detailed specifications for the design of the driver's workplace components. This ensures the freedom of design for the manufacturers to develop individual solutions under application of the provided recommendations according to ergonomic criteria.

The characteristic ergonomic design patterns are derived mainly from the anthropometric shapes and sizes of the drivers to define the seated posture and the controls. They are oriented to the deficits determined in the preliminary study, which focus on unfavourable postures of the driver.

The existing volume “Recommendations“ is not an ergonomic manual with explanations of the general knowledge of work physiology. The study formulates ergonomic principles for implementation in a driver's workplace concept for motor coaches.

Apart from the written work with the drawings of the characteristic design patterns, a 3-D CAD model is available to provide support for drafts and for the correct scale representation of the results.

The implementation of the characteristic ergonomic design patterns according to this data model in a driveable motor coach had not yet been conducted at the time of publication. The results are based on trials in a dummy seat, anthropometric measurements, practical experience and the CAD system Ramsis. Installation of the DWMC in a mobile test vehicle and practical trials with the data are the next desirable steps.

Summary of the objectives of the project:

- **Improvement of the driver's workplace and thereby the work situation of drivers in motor coaches.**
- **Determination of the characteristic ergonomic design patterns as the basis for the design of drivers' workplaces in motor coaches.**
- **Preservation of freedom of design for manufacturers for the design of individual solutions according to ergonomic criteria.**

Therefore:

- **No detailed design of components such as the dashboard, seat, pedals, steering wheel and miscellaneous controls.**
- **Development of a study with an exclusively advisory character and thereby avoidance of the character of standards and specifications.**

1 Vehicle definition

In general, motor coaches are vehicles which must be suitable to transport passengers with luggage. The wide range of applications for motor coaches extends from day trips to long-distance travel, resulting in a differentiated range of manufacturer's products on the market. For reasons of profitability and costs, bus companies are often forced to operate multiple-purpose vehicles. Scheduled overland services are provided on weekdays and holiday trips at weekends with the same vehicles.

What are the differences to regular service busses and which vehicles are addressed by this study? Which criteria determine the differences to the driver's workplace in a regular service bus and thereby justify a new study relating to motor coaches?

Apart from other aspects, the different seated postures in the pertaining vehicle categories are a particularly important criterion for differentiation. The seated posture at the driver's workplace is influenced by the need of the drivers for an optimum overview of their vehicles outwards and inside. Tendentially, drivers adjust an upright seat position to improve their overview. The measure which defines the position of the upper body, the inclination of the torso, is decisively influenced by the height of the driver's workplace above the road.

The general service bus is a vehicle with a driver's seat located at a low height above the road. The floor heights for the seating in these vehicles are approximately equal for all manufacturers. The positions of the eyes are at a relatively low height above the road and thereby permit a shallow line of sight.

The floor heights of motor coaches generally differ from those of regular service busses. Due to the luggage compartments under the floor, they are substantially higher above the road and have significant dimensional differences between the various categories of motor coaches.

With a higher position of the driver's workplace above the road, the line of sight forwards from the position of the eyes is inclined more sharply downwards. In motor coaches, this leads to a steeper or "upright" seated posture to attain a comfortable posture of the head. The comfortable neck angles known from literature designate the geometrical limits of these angles.

The height above the road and the line of sight therefore have a substantial influence on the ergonomic conception of the seated posture, and not the vehicle type.

Driver's workplaces in double-decker or low-entry vehicles are placed lower above the road and should therefore have a more pronounced inclination of the torso with regard to the seated posture.

The design recommendations of this study can be adopted for these vehicles if an additional longitudinal range of adjustment for the seat is provided. The exact dimensions for this should be determined in a further study and are not addressed by this main study.

Busses used in regular overland service are usually developed from motor coaches and are used as combined busses for occasional services as motor coaches. Due to the luggage compartment, they have the higher driver's seat typical of motor coaches. In accordance with the definition described above, the recommendations should also be applied to these vehicles.

Definition

The recommendations for the seated posture model of the driver's workplace in a motor coach apply to all omnibuses with a floor height of the driver's seat of approx. 600 mm or more above the road.

Drivers' workplaces with a floor height of less than 600 mm should have a wider adjustment range for the seat in the X direction (longitudinal adjustment) and correspondingly adapted steering wheel positions.

Driver's workplace in regular busses

The main difference to the project "Driver's workplace in regular busses" /6/ is delineated by the definition described above. Other typical differences for the drivers of motor coaches to those of regular busses are:

- Long-distance travel and overnight accommodation
- Irregular working hours
- The time spent by the driver in the vehicle is often longer
- Passengers do not change as frequently
- No ticket sales
- The vehicle equipment is different, e.g. in the switching systems, communications facilities, driver's doors etc.

To avoid fundamental discussions and contradictions, the recommendations of the DWMC correspond to the specifications of the driver's workplace in regular busses /6/ for equal equipment features and equal ergonomic issues.

2 Reference system

The reference system is the system of co-ordinates commonly used in vehicle construction in X, Y and Z axes. This is equivalent to the system described in DIN ISO 4130 /15/.

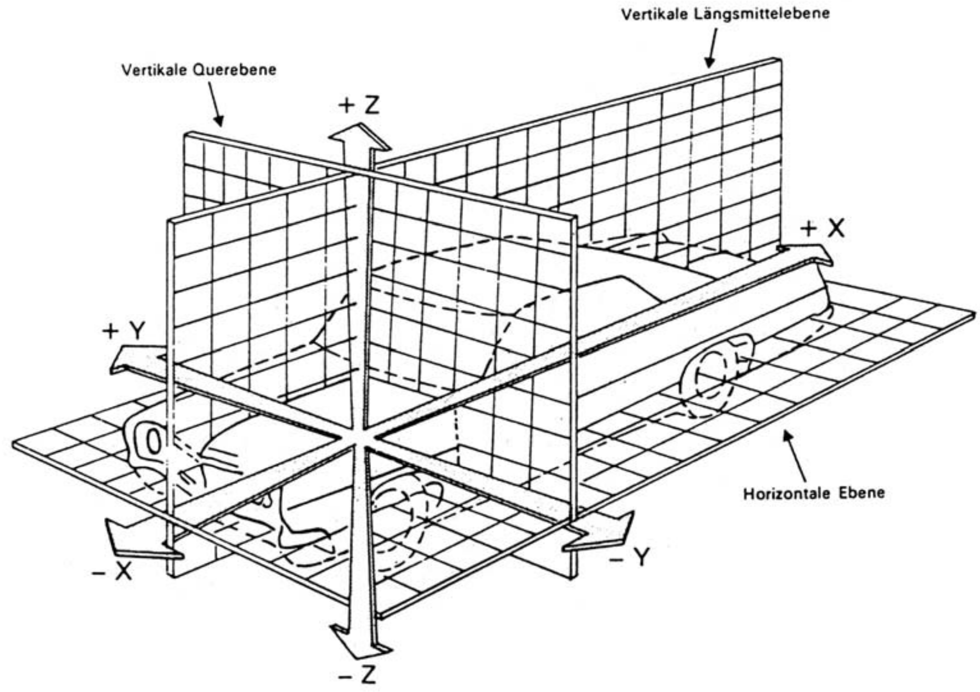
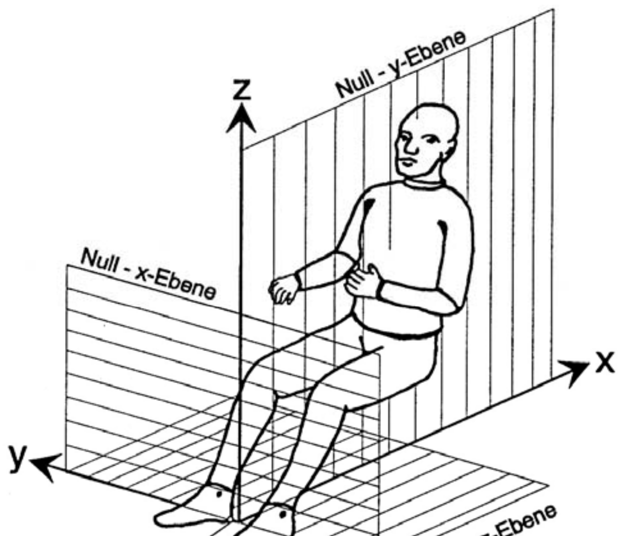


Fig. 1: Co-ordinate system to ISO 4130



The heel point relates to type P95 only

Fig. 2: Co-ordinate system for driver's workplace in motor coaches /6/

The co-ordinate system for the driver's workplace in motor coaches relates as in the specifications for regular busses to the heel point as the zero point for the X and Z coordinates. However, the 0X co-ordinate applies only to the heel point of one type of the specified population (P95). As a result of the different anthropometric dimensions of the population and the positions of the ball points on the pedal, the heel points of the other types are not found at the 0X co-ordinate.

The Z co-ordinate has dimension 0 for all types.

The Y co-ordinate is described by the human median plane in the direction of travel. This is located parallel to the central axis of the vehicle.

3 Design recommendations

In Chapter "Design recommendations", the results are presented mainly in the form of drawings with brief information. These are the results of the ergonomic investigations and the assessment of scientific knowledge.

The implementation of the design recommendations in a driver's workplace concept by vehicle manufacturers guarantees ergonomic standards for the driver.

3.1 Anthropometry

Population

The population of motor coach drivers was determined by anthropometric measurements of motor coach drivers in Germany /25/. Also, the acceleration of young people found in a study by the Dutch TNO institute was included in the study /33/.

Definition of the motor coach driver population for the DWMC project:

Body height "H":

	P5/ Bus	**1648 mm**
	P50/ Bus	**1751 mm**
	P95/ Bus	**1879 mm**
Supplement	**P99**	**1983 mm**

Age 20 years/region NL/TNO study/male 2015
Dimensions without shoes, normal build.

Body weight/build

	P5/ Bus	**66,0 kg/ corpulent**
	P50/ Bus	**87,0 kg/ corpulent**
	P95/ Bus	**117,5 kg/ corpulent**

The complete anthropometric dimensions of the population are contained and presented in the research report by the research group for industrial anthropology at the University of Kiel /25/.

In the CAD model Ramsis, this anthropometric data is represented as the corresponding Ramsis types. Slight differences occur between the measured anthropometric data and the CAD model during conversion in the computer. These differences are within the tolerance range and can be neglected.

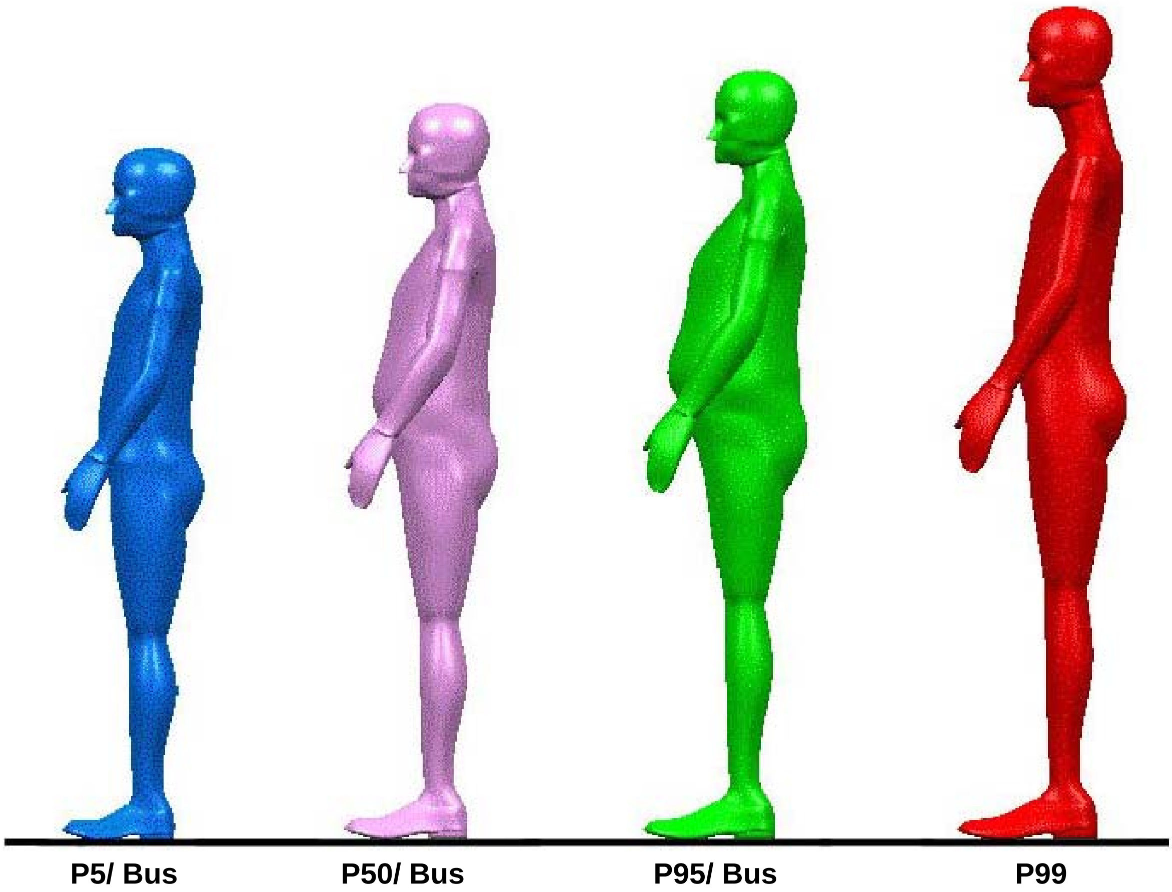


Fig. 3: Bus driver population, upright

3.2 Seated posture model

The seated posture model describes the basic posture of the generated population. It is the starting point for all dimensional allocations and is available as a Ramsis file. The figures are arranged from the 0 position in the X, Y and Z directions.

X 0 = Floor and heel rest line / P95/ Bus
Y 0 = Median plane of the driver
Z 0 = Floor and heel rest line of all Ramsis types

The basic position and the allocation of the persons P5/ Bus to P99 are conducted according to the accelerator pedal position in the normal driving position. The reference point of the persons to the pedal surface is the heel or ball point. The pedal travel is ~ 1/3 of the overall pedal travel. As a consequence of the different anthropometric dimensions of the chosen population, the heel points of types P5/ Bus and P99 are not at the 0 co-ordinate of X.

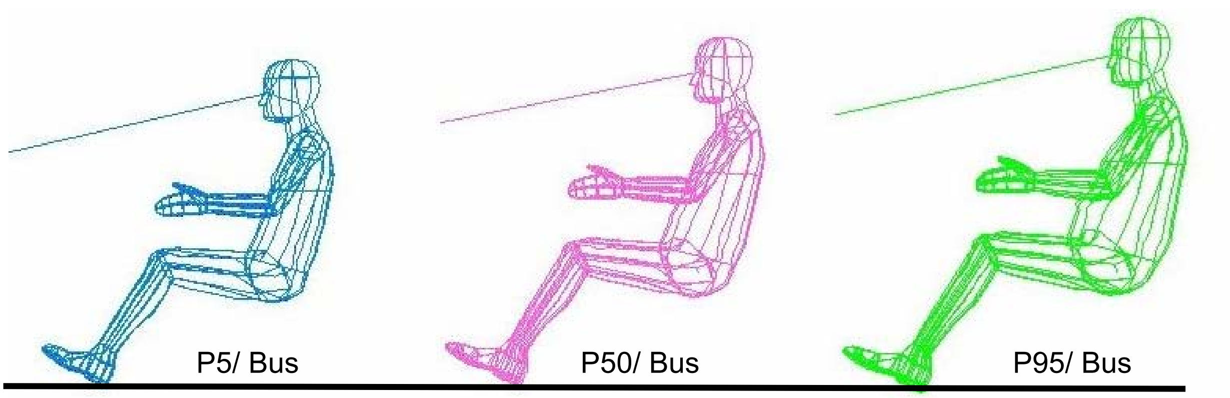


Fig. 4: Seated posture of the bus population

The seated position of a driver is connected with the height above the road. The higher the position above the road, the steeper the line of sight directed downwards from the eye point. This leads to a steeper or more upright seated posture to achieve small angles of inclination in the neck.

The relationships between the floor height above the road and the inclination of the line of sight determine the ergonomic conception for the seated posture, and not the vehicle type.

The generated seated posture model includes verified orthopaedic knowledge to represent comfortable seat positions.

Seat position

Ramsis adjustments

For CAD work using Ramsis, the following specifications are required for adjustment of the seat position. This takes account of the influence of the line of sight on the posture setting of the CAD tool.

- The line of sight is directed at a vehicle/car ahead.
- Distance from leading edge of bus to car at 80km/h = 40m.
- The viewed point is the car brake light.

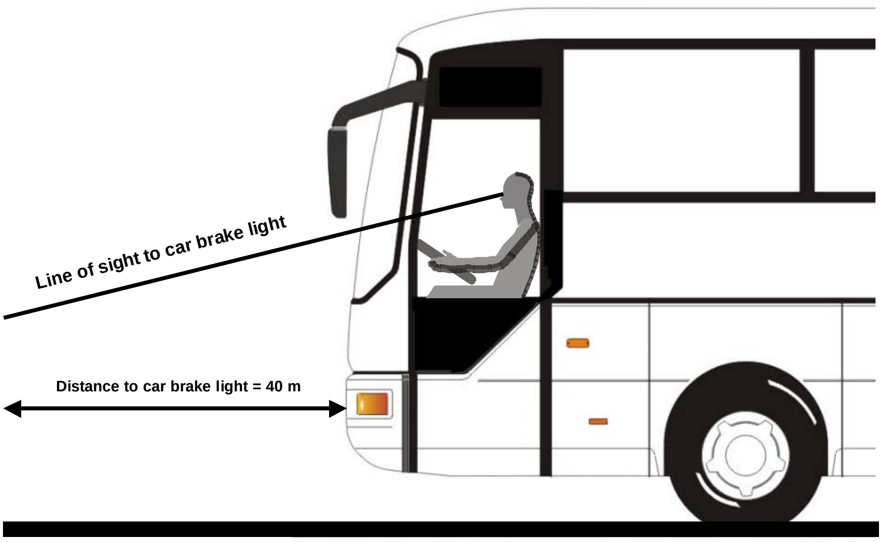


Fig. 5: Basic Ramsis position viewing a car ahead

3.3 Driver's workplace

3.3.1 Access

The minimum free space to reach the driver's workplace is indicated. The regulations of ECE R 36 ("Uniform conditions for the approval of motor omnibuses regarding their design features") are applicable. The requirements of the accident prevention regulations "Vehicles" (BGV D29/, formerly VBG 12) of the professional association for the design of steps and handles are recommended.

The definition of the free space is based on the anthropometric dimensions of motor coach drivers with particularly marked corpulence and body girth dimensions.

Access to the driver's workplace is often obstructed by the gear lever in vehicles with mechanical gear shifting. The recommendation is to employ electro-pneumatic, electric or automatic gear systems. The recommended dimensions of the free space should be maintained until the driver's seat is reached.

For safety when leaving the vehicle at night, lighting for the step treads and the road surface should be provided at the front door. This lighting should be independent of the ignition and should not extinguish before 10 seconds after the vehicle has been locked from the outside. Trapping and shearing points as described in DIN EN 349 should be avoided.

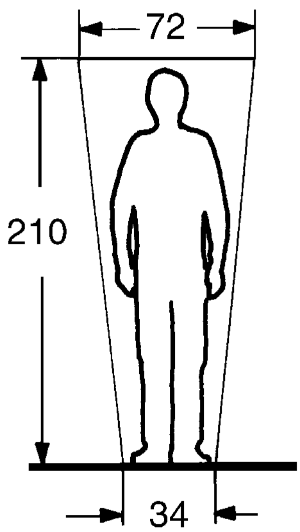


Fig. 6:
Profile according to the anthropometric data of the measured motor coach drivers, dimensions in cm.

3.3.2 Main dimensions

Length/ height

The basis is the seated posture model of the defined population. The maximum dimensions result from the seated position of type P 99.

The space behind the driver's back is not geometrically defined. Space must be reserved here according to the seat type. The seat back setting with a minimum inclination of 15° from the vertical determines this dimension.

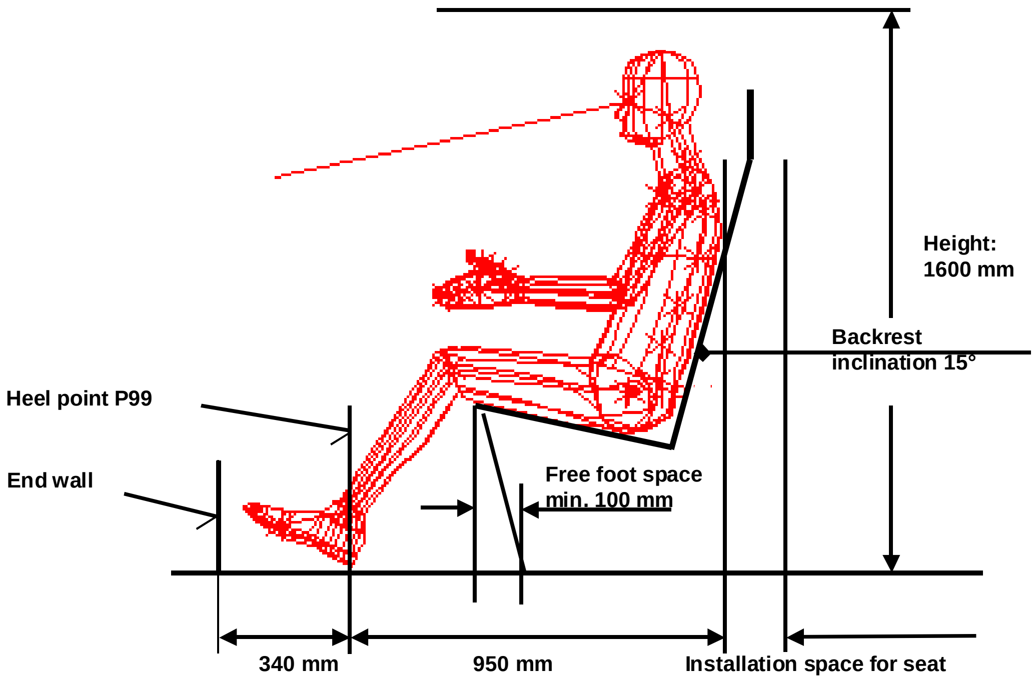
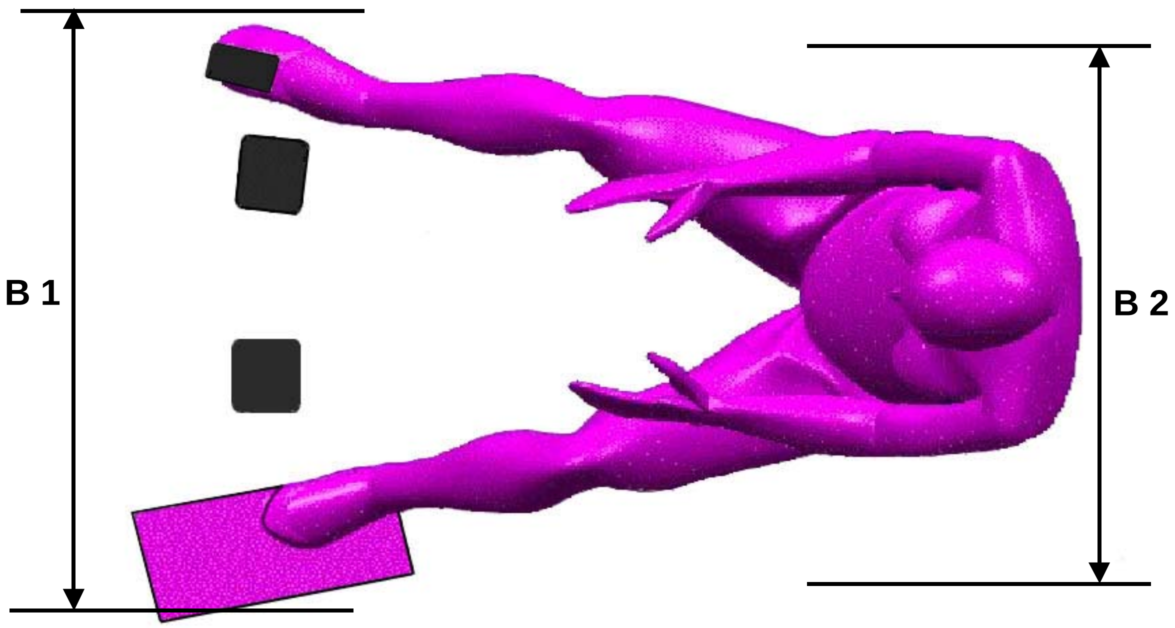


Fig. 7: Main dimensions of the driver's workplace, length and height.

Width

The width of the driver's workplace is determined by the free space and elbow width for type P99.

Sufficient foot space must be available for type P99 for a relaxed seated posture. A sufficient rest space for the left foot should be provided.



B1:	Foot space of up to 300 mm height above the floor line	= 730 mm
B2:	Elbow space above the seat to head height	= 800 mm

Fig. 8: Main dimensions of the driver's workplace, width

Detailed dimensions of the pedals and footrest can be seen from the CAD model.

3.4 Visibility

Direct visibility outwards and inside has a particular significance. The overview of the surroundings of the vehicle and direct sight of the important controls determine the seated posture together with the position of the steering wheel.

Visibility from the vehicle is therefore an important design criterion to represent the seated posture. Optimum visibility conditions together with a comfortable seat position are the ergonomic objectives.

Visibility, regulations and recommendations

A series of regulations and recommendations exist for visibility, which must be taken into account by vehicle manufacturers. A selection is included below:

Direct visibility

- StVZO (German vehicle registration ordinance) § 35b *Visible semicircle*
- Dutch recommendations *4,0 m Viewpoint in front of vehicles*
- Traffic signal visibility to RILSA 292 /31/
- Door windows, door 1, direct visibility of school children
- List of requirements for motor omnibuses and minibuses to convey school children to § 34 a StVZO

Indirect visibility

- Rearview mirrors 71/127/EEC and § 56 StVZO

Display of information

- Recommendation of 2000/53/EC

3.4.1 Ergonomic parameters

The **focusing times** and the **frequency of focusing** on the information devices and the controls determine the priorities of the fields of view. To determine the priorities, the fields of view are divided into three zones according to the focussing times.

The ergonomic principles for this originate from the study by Dreyfuss /16/, Bauer /42/ and the BAuA /43/. The basis of all considerations is the definition of the task of the driver to steer the vehicle safely through traffic. The visibility outwards has primary significance. All circumstances in which the view is diverted from the road to the controls and information devices must be kept as short as possible. The design and arrangement, particularly of information devices, must satisfy this demand.

		Wahrnehmungszeit	Körperbewegung	Abweichung v. norm. Sehachse	
				vertikal	horiz.
①	OPTIMALES GESICHTSFELD	≈ 0,2 sec.	normale Fixationsbewegung des Auges	± 15°	± 15°
②	MAXIMALES GESICHTSFELD	< 0,5 sec.	Augenbewegung	±22,5°	±22,5°
③	BLICKFELD		max. Augenbewegung, bei fixem Auge bis hierher Farbinformation	+25° -45°	±30°
			Sicht unscharf bei fixem Auge	+40° -45°	± 45°
④	UMBLICKFELD	< 2 sec.	Kopfwendung.	+35° -65°	±50°
			Bewegung erkennbar bei fixem Auge	max.: +70° -65°	± 75°
⑤	SEHFELD	> 2 sec.	Augen-, Kopf- u. Körperdrehung		

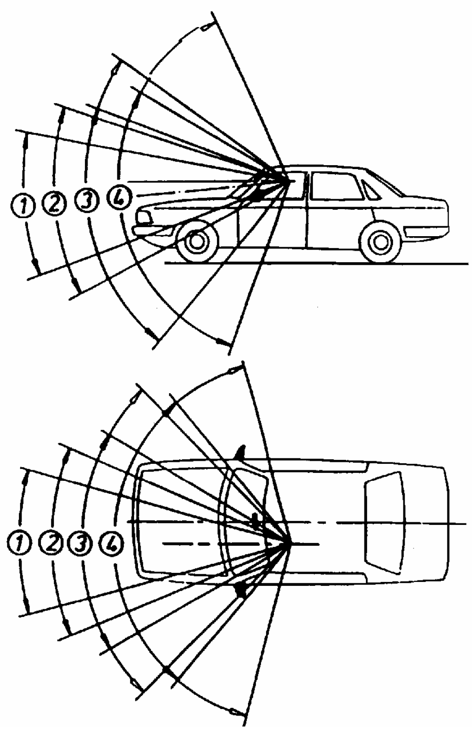


Fig. 9: Focussing times according to Bauer /42/.

Determination of the priorities for the DWMC
Fields of view

Priority I
A – limits of the optimum field of view

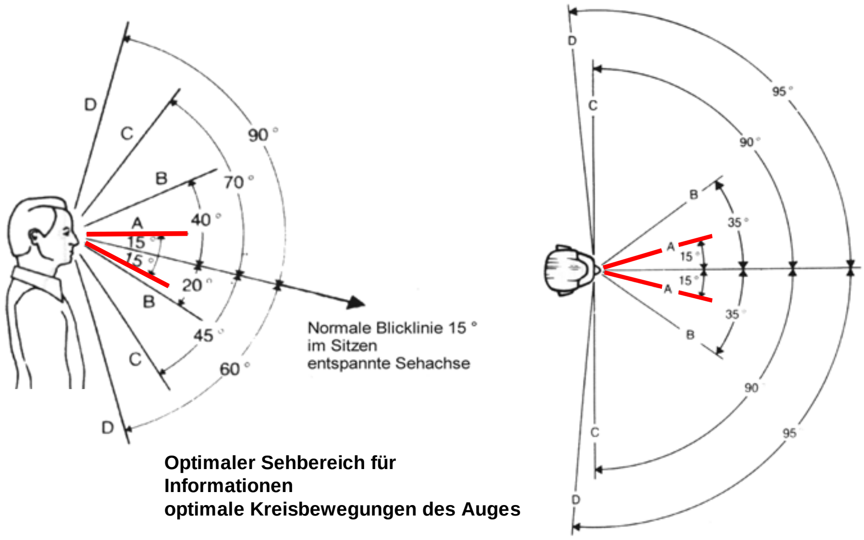


Fig. 10: Diagram of priority I /16/43/

Priority II
B – limits of the maximum field of view

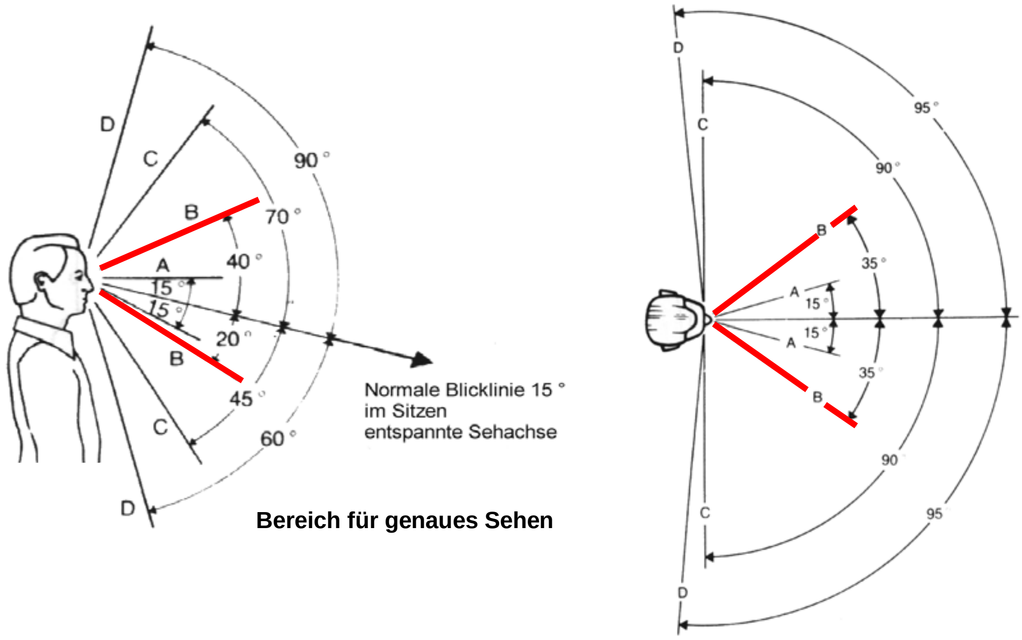


Fig. 11: Diagram of priority II /16/43/

Priority III
C – limits of the maximum field of sight

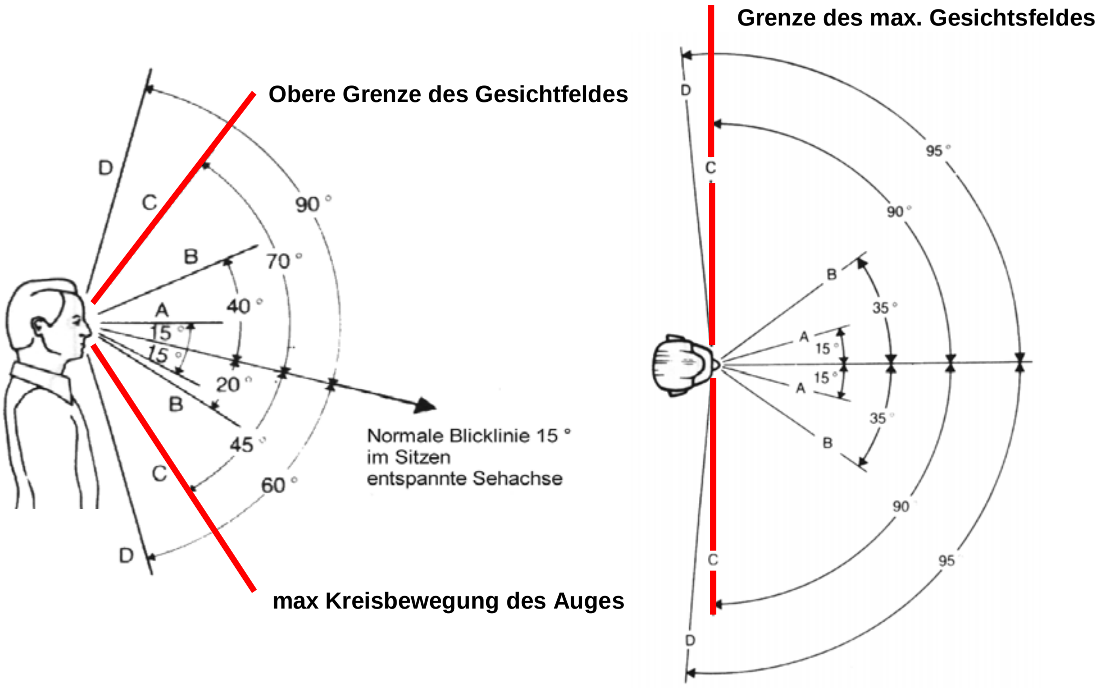


Fig. 12: Diagram of priority III /16/43/

3.4.2 Visibility of the instruments

Starting from the normal line of sight directed outwards to observe the traffic, the instruments should be arranged such that they can be viewed in the shortest possible time. Their positions are determined by the priority of the field of sight, which is chosen according to the requirement for short focusing times.

To avoid parallax errors, the indicator surfaces should be perpendicular to the line of sight. However, to avoid reflections towards the eyes, from the covers and reflective surfaces, the reflective surfaces should be inclined by approx. +/-10° from the ideal position towards the line of sight /7/.

The obstruction of the view on the instruments by the steering wheel rim and hub must be determined according to the eye points of the defined population. The instruments must not be covered by the shadows of the steering wheel.

Positions of the eye points

The field of the eye points relates to the monocular eye points of the Ramsis figures.

The co-ordinates were determined with the Ramsis CAD model. The Ramsis posture model is concerned mainly with car seating postures and generates a forward-inclined head position, which is only slightly corrected for an upright posture by the computer program.

The viewing positions, particularly for the legibility of the instruments, must therefore be verified in a physical model.

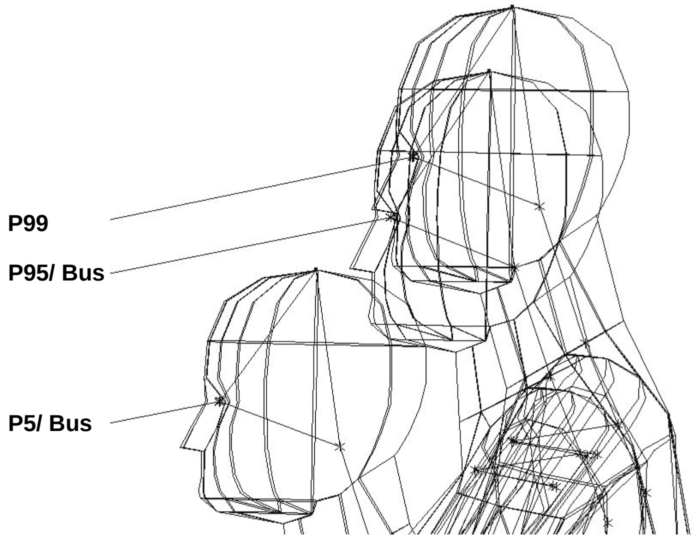


Fig. 13: Eye points of the Ramsis types

Co-ordinates of the eye points

	X	Y	Z
P5/ Bus	**538**	**- 9.5**	**1012**
P95/ Bus	**686.5**	**2.5**	**1172.5**
P99	**706**	**- 15.5**	**1225**

Design for the position to the line of sight

Inclination of the instrument surface

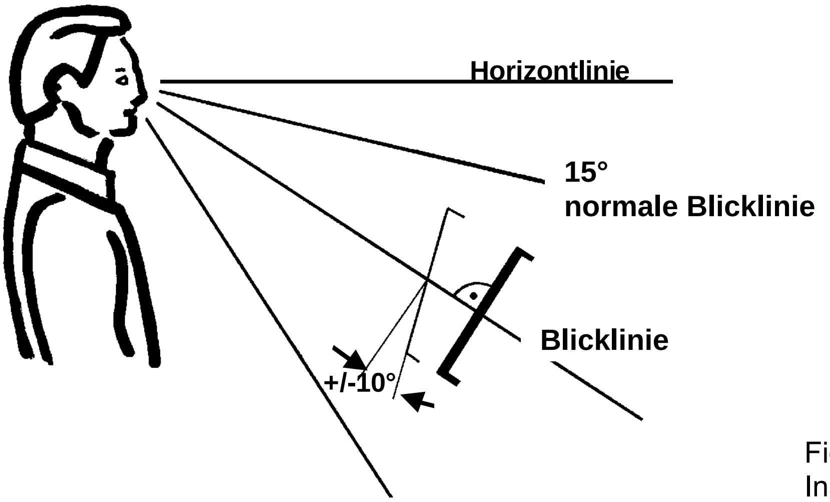


Fig. 14:
Instrument surface

- Instrument surface arranged perpendicular to the line of sight.
- Reflective surfaces arranged +/- 10° to the line of sight to avoid reflections in reflective surfaces such as diffusing lenses/glass covers and displays.

Distance to the instrument surface

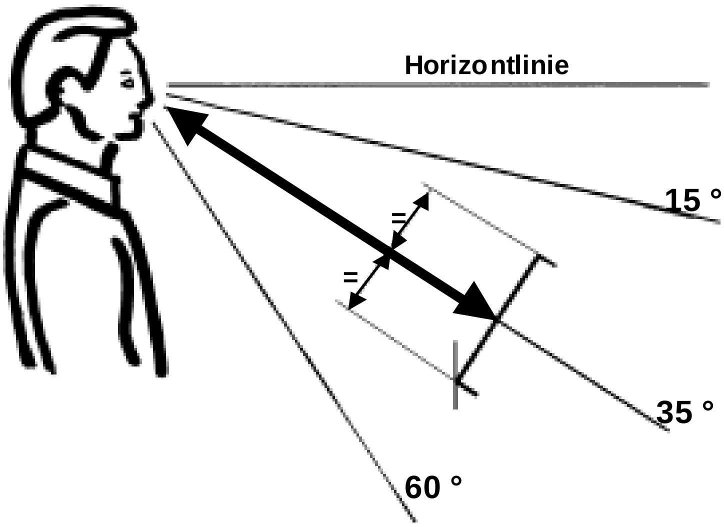


Fig. 15: Instrument surface

- Distance of instrument panel to eye point min. 700 mm
- Middle of instrument panel at least to 35° line
- Fully visible to 60° line

Visibility of the instruments

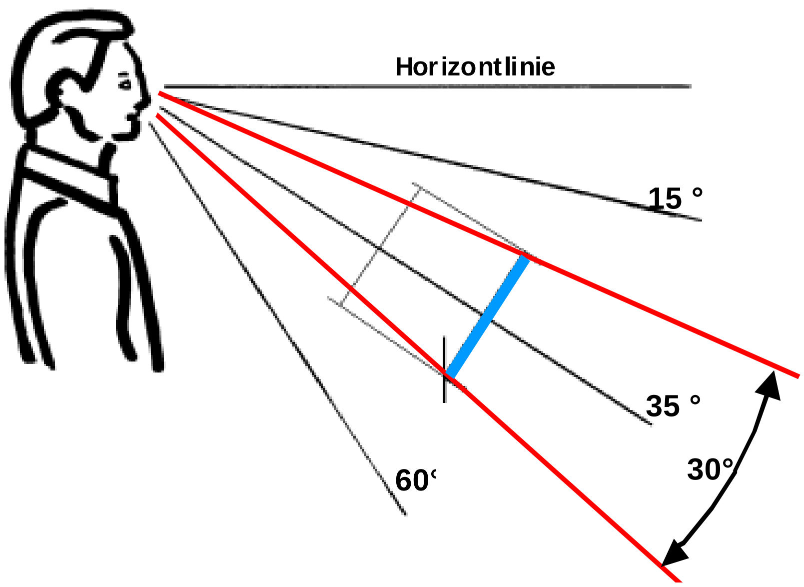


Fig. 16: Instruments

The following must be fully visible within a 30° cone:

- Tachometer
- Speedometer
- Indicator lamps and warning devices
- Central display

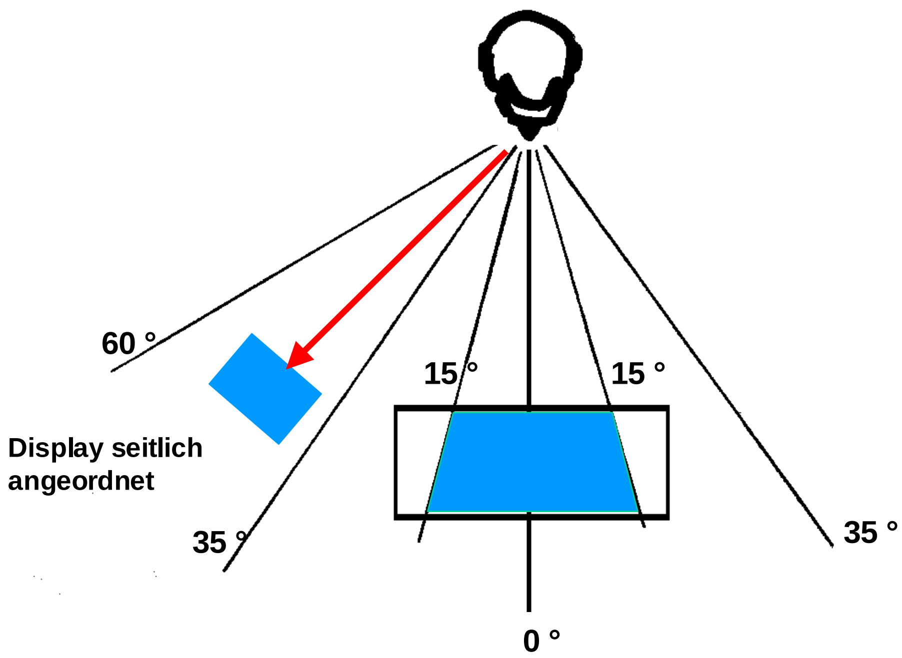


Fig. 17: Instruments

Visible up to the 15° line:

- Tachometer
- Speedometer
- Indicator lamps and warning devices

- Central display

Visible up to the 35° line:

- Complete instrumentation

Visible up to the 60° line:

- Peripheral displays
  e.g. navigation or communications equipment

Displays located at the sides should be placed at right angles to the line of sight with a tolerance of ± 15°.

3.4.3 Visibility of displays

For the visibility of displays, central and peripheral displays are discerned.

Central displays are information devices integrated in the dashboard which provide information on the status of the vehicle and aid in the safe steering of the vehicle. The principles defined for the instruments apply to these.

Peripheral displays provide information which has no direct effect on driving. For example, this is information on the radio, TV, navigation systems, on-board computer etc. These displays may be placed in an extended field of vision. According to the principle of short focusing times, these displays should be placed as closely as possible to the central display. This also applies to their vertical position. The inclination of the surfaces should face the line of sight of the driver.

Not only the short focusing time from the view straight ahead to the display determines the ideal positions of peripheral displays. The form and complexity of the displayed content must also be included in the considerations.

Displays placed close to the normal line of sight must only have a minimum of content and graphic displays. Panorama pictures and moving maps are negative examples which can cause long periods of distraction due to the visual gripping reflex. The visual gripping reflex is the unconscious reaction to peripheral stimuli which "forces" the driver to focus on this display.

Technological progress now permits the consolidation of central and peripheral displays in the central field of view of the dashboard. With the means of displaying information by priority of road safety, an ideal form of information bundling at one place is created with short focusing times from the normal line of sight to the display. The design recommendations to avoid moving and complex representation of information are particularly valid in this respect.

If peripheral displays are unavoidable, they should be placed as a compromise between little distraction and short focusing times in the extended field of view up to 35° from the centre. Less important indicators can be placed up to the 60° line. TV and video displays, computer games and similar displays should always be outside the driver's field of view.

In general, when the content of information is presented in graphic form, it should be "reduced to the essence".

3.4.4 Information presentation

Principles of presentation

Screens should be flicker-free with a minimum repetition rate of 70 Hertz and their surfaces should be non-reflective /4/.

When driving, the driver focuses his eyes mainly at a long range. The eye must adjust quickly to focus briefly on the instruments. For this reason, the character size of the displays should exceed the recommended value of the visible angle for office screens of 18 to 26 minutes of arc. An optimum value for the visible angle is above 55 minutes of arc.

The lettering should be displayed brightly on a dark background/7/.

Sufficiently large depiction of symbols, taking account of long-range vision in ageing people should be employed.

The principles of MMI design laid down by the European Commission (2000/53/EC) are summarised in a catalogue. This catalogue summarises the most important safety aspects relating to on-board information and communications systems.

Principles of design according to 2000/53/EC:

The objectives:

- How can information and communications systems be designed and positioned so that their benefit is complementary to driving a vehicle?

- How can the information be presented so that the driver's attention is not distracted from the traffic on the road?

- How can interaction with the system be conceived so that the driver retains control of the vehicle under all circumstances, feels relaxed, can trust the system and react safely to unexpected events at all times?

The scope of validity:

- The catalogue of principles applies to all information and communications systems intended for use by the driver when driving. It is assumed that the most important task of the driver when driving is to safely steer the vehicle through complex, dynamic traffic.

- The principles were formulated with a view to the design and installation of individual systems. This does not take account of electrical features, material properties, system performance or legal aspects.

Principles for the overall design:

- The system should be designed so that it supports the driver and is not a cause of a potentially dangerous behaviour by the driver or other vehicle drivers.
- The system should be designed so that the attention given by the driver to the system displays or controls is consummate with the traffic situation.
- The system should be designed so that it does not distract the driver or provide visual entertainment.

Principles of installation:

- No part of the system must obstruct the driver's view of the road.
- Visual indicators should be installed so that they are within the normal line of sight of the driver.
- Visual indicators should be designed and installed so that glare and reflection effects are avoided.

Presentation of the information:

- The driver must be able to understand visual information at a brief glance without effects on driving the vehicle.
- Information which is important to the driver must be presented accurately and in due time.
- The system must not present information which could result in potentially dangerous behaviour by the driver or the drivers of other vehicles.

Interaction with displays and controls:

- The system must not require long sequences of interaction which cannot be interrupted.

- The system controls must be designed so that they can be operated without impairing driving.

- The driver must be able to determine the speed of interaction with the system.

- The system must not force the driver to react by making an entry within a specified period.

- The reactions of the system (e.g. feedback, confirmation) to entries by the driver must occur without delay and in an easily understandable manner.

- It must be possible to switch systems with moving visual information which is irrelevant to safe driving into a mode in which this information is not perceived by the driver.

Principles of system behaviour:

- Visual information which is irrelevant to driving a vehicle and which can distract the driver significantly (e.g. TV, video and automatically running pictures or text) must be switched off or displayed in a form in which it cannot be viewed by the driver when driving.

- System functions which are not to be used by the driver when driving must not be available for interactive operation during driving or must issue a clear warning signal if used unintentionally.

- If the system fails partially or completely, the vehicle must remain controllable or must at least be capable of stopping safely.

Principles of information input into the system:

- The operating instructions must clearly specify which functions of the system are intended for use by the driver when driving and which functions (e.g. special functions, menus etc.) are not intended for use when driving.

- The description of the product must clearly specify whether particular skills are required to use the system or if the product is unsuitable for certain users.

(End quote)

3.4.5 Visibility of the wing mirrors

For reasons of the design, wing mirrors are attached to the A-columns or roof struts at the outer points of the bodywork. This leads to relatively long focussing times. A side view across the vehicle with short distraction times and a minimum turning of the head is desirable.

This is possible by designing a camera system with screens close to the dashboard. However, statutory specifications and practical trials for this technical application are lacking. The ergonomically ideal range is inside a field of view of +/-30°, providing a view without significant movements of the head and with short focussing times.

For the reasons described above, side angles of view of up to +/-180° are tolerated. Obstructions in the view of the mirrors by struts etc. must be avoided under all circumstances. Angles of view of + 25° upwards and -35° downwards are defined. These angles are consummate with the requirement for short focusing times.

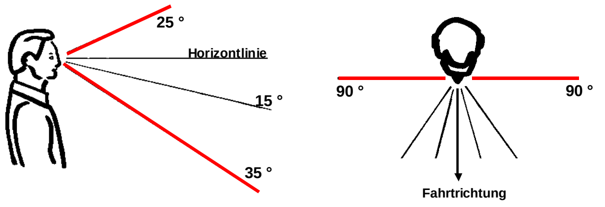


Fig 18: Visibility of the wing mirrors and the inside mirrors

3.4.6 Visibility of the inside mirrors

The arrangement if the inside mirrors should be within the field of view as defined for the visibility of the wing mirrors.

3.4.7 Visibility of children

In busses and trams, the so-called “crossing accident” is often observed. When leaving the vehicle through the front door, passengers attempt to cross the road in front of the vehicle before it starts. Due to the often inadequate direct view, small people are not seen or seen too late by the driver. When the vehicle starts, the people can then be run down, particularly at the often cited impact area at the front right and in the middle of the front of the vehicle /10/. Children are particularly endangered due to their small bodily height.

The view of a six-year old child of the 50th percentile of school beginners is recommended. The view begins at the A-column on the right to the centre of the vehicle. The view obstructed by the steering wheel and the instruments is excluded.

The recommendation applies particularly to vehicles which are not used as school busses and are therefore not equipped with the school bus mirrors required by regulations.

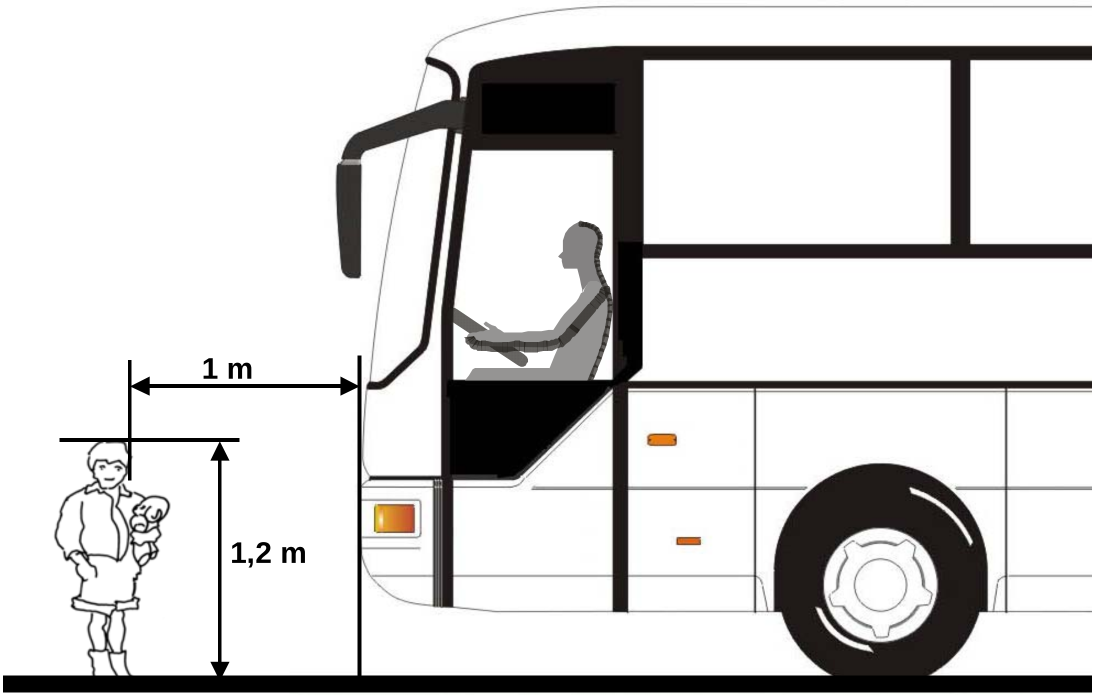


Fig. 19: Visibility of children

3.4.8 Visibility of traffic signals

The drawing shows the positions of traffic signals according to the guidelines for traffic signal systems RILSA /31/.

When the vehicle is stationary, the traffic signals must be directly visible without restrictions or changes in the seated position. This applies to both depicted positions on the road.

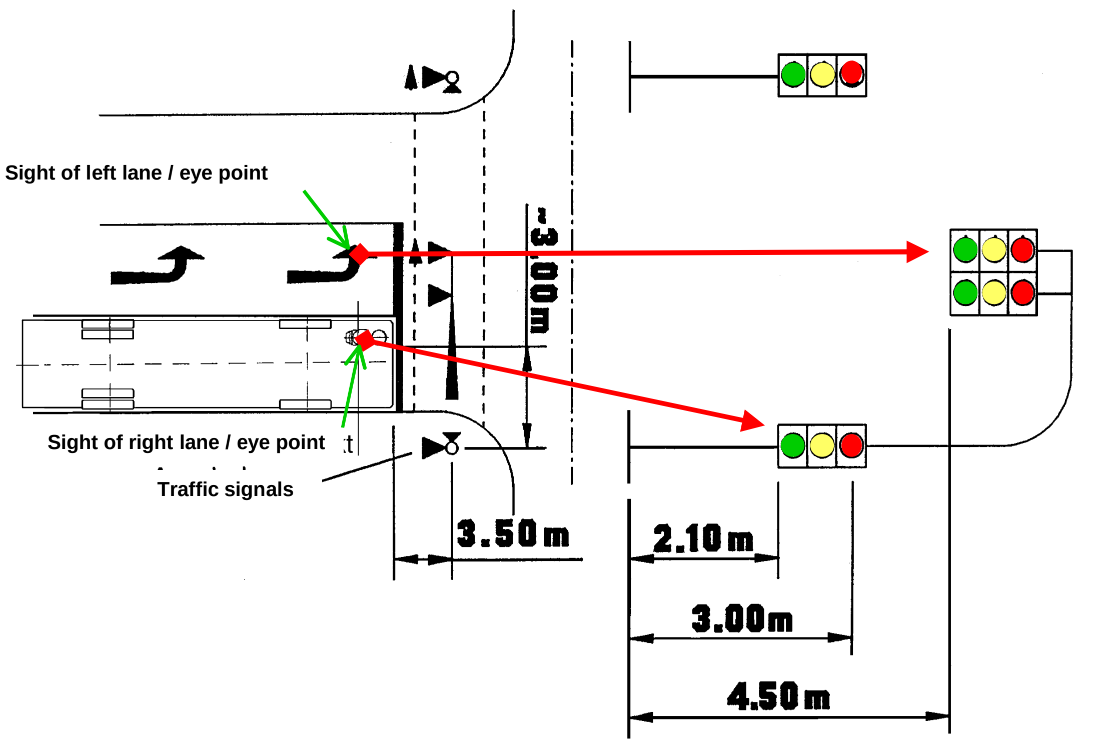


Fig. 20: Traffic light visibility

3.5 Controls

The controls are divided into:

central controls
and
miscellaneous controls

Central controls

These are controls with direct influence on safety when driving the vehicle and which are in constant contact with the driver.

The central controls are:

- **Steering wheel**
- **Steering column switches**
- **Pedals**

These are described separately in the design recommendations and their dimensions are defined.

Miscellaneous controls

These are controls which are not in constant contact for actions by the motor coach driver. These are mainly keypads, switches, levers, handbrakes and similar actuators.

The controls of the seat are summarised in Chapter Seat design.

3.5.1 Central controls

Steering wheel, comfortable field

The comfortable field of the steering wheel specifies the co-ordinates for the recommended range of the centre of the steering wheel. Any position of the steering wheel with its centre within this field permits a comfortable hand and arm position for the driver.

The specified inclinations of the steering wheel are values determined by practical trials and from ergonomic literature /24/36/. These are 30-45° from the horizontal.

In addition, the theoretically ideal positions for the selected population are specified with regard to comfort.

The influence of the steering wheel position by the professionally-related anthropometry becomes clear in the dimensions for abdomen clearance.

The centre of the steering wheel should be related to the median plane of the driver. Max. deviation from the centre of the body to the steering wheel +/-15 mm.

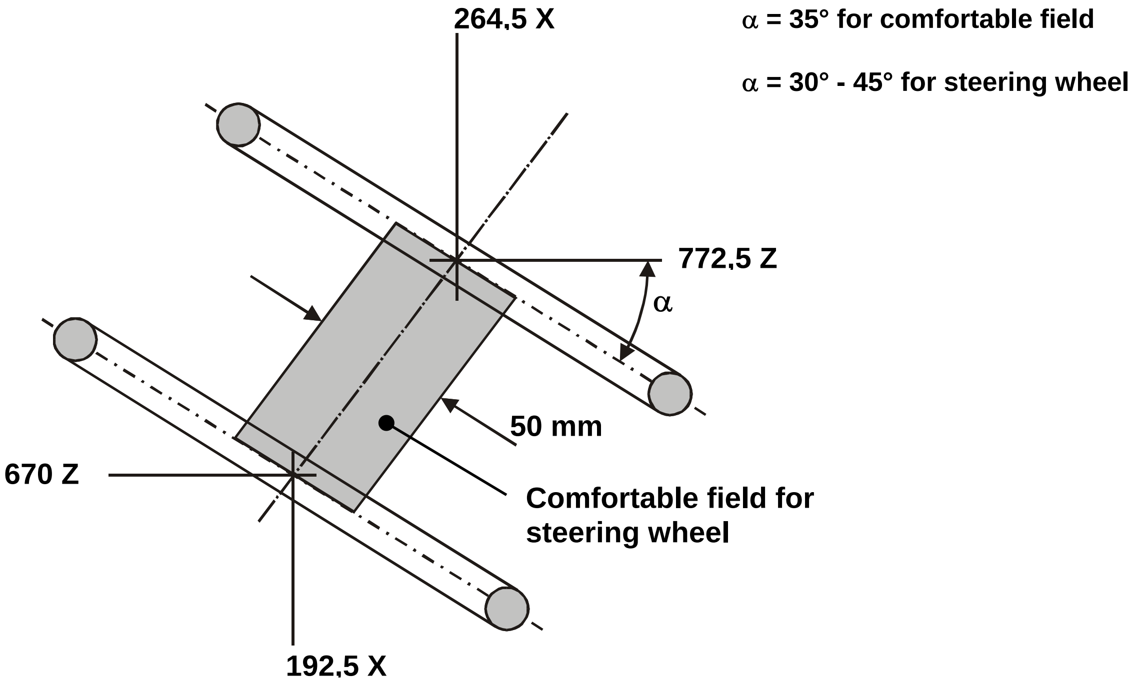


Fig. 21: Comfortable field for steering wheel

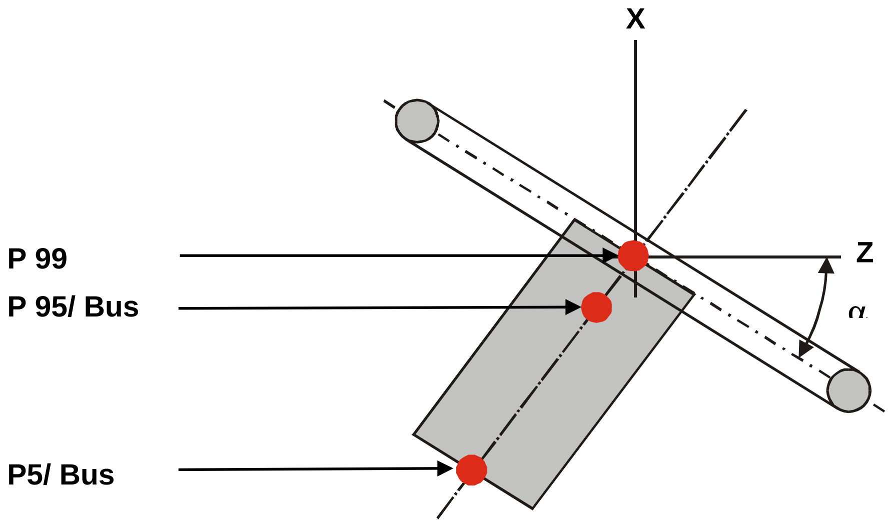


Fig. 22: Steering wheel, ideal positions

	X	Y	Z	α
P 5/ Bus	**192.5**	**0**	**670**	**35°**
P 95/ Bus	**261.5**	**0**	**768.5**	**35°**
P 99	**264.5**	**0**	**772.5**	**35°**

The values specified as ideal positions relate to the comfortable positions determined with Ramsis. These are static values and cannot take account of the individual preferences of drivers.

Recommendation

The points for types P5/ Bus to P99 designated as the ideal positions must lie within the range of adjustment in the manufacturer's comfortable field of the steering wheel. The steering wheel should permit an angular adjustment of 30° to 45° from the horizontal.

Steering wheel design

The diameter of the steering wheel is specified by the maximum permissible force required by regulations. If the power steering fails, the defined limits for the force applied to the steering wheel must not be exceeded. In the past, this has led to the steering wheel diameters of 500 to 550 mm common in the construction of utility vehicles. Technical improvements in design and execution now permit reductions in the outside diameters. The optimum diameters result from relaxed hand and arm positions. The project Driver's Workplace in Regular Buses defines the diameter as 450 mm /7/. For the DWMC, 450 to 480 mm are recommended within certain tolerances. The average value of 465 mm was employed for the CAD examinations.

The handgrip diameter is specified according to Burandt /11/ with a diameter of 32 mm to 40 mm. 32 mm is recommended as a compromise between a comfortable handgrip design and less obstruction of vision by shadows falling on the instruments.

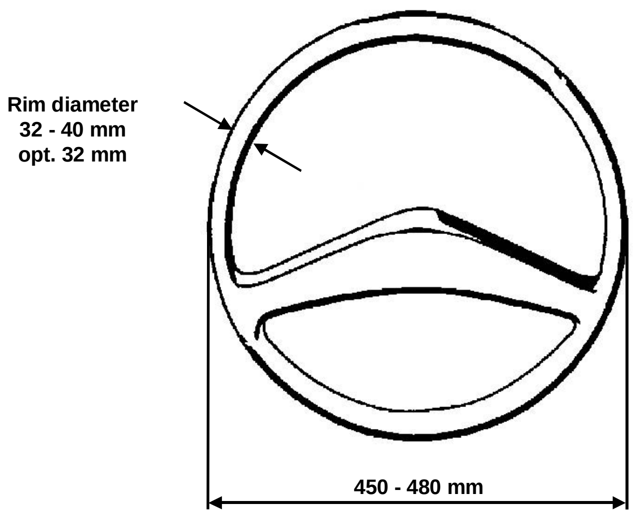


Fig. 23: Steering wheel dimensions

Steering column switches

The anthropometric conditions for types P5 and P95 as well as ISO 4040 are taken as the basis for the arrangement of the steering column switches.

The switches should not project beyond the rim of the steering wheel. Tolerance ± 10 mm.

The distance from the rim of the steering wheel should provide a minimum free space for the knuckles to avoid unintentional operation, but should also be such that the levers can be reached with the fingers when in contact with the steering wheel. It is recommended to place them within the 35 mm envelope curve.

The levers for the retarder and cruise control often located on the right hand side are arranged one above the other due to the available space. This results in restrictions in the vicinity of the thighs, particularly when pedals are operated. It would be desirable to reduce this to one steering column switch each on the left and right.

To avoid incorrect operation, a safety clearance of at least 10 mm must be maintained between switches placed one above the other and these should have a lateral offset as seen from above the steering wheel.

Actuation as seen from above the steering wheel should be restricted towards the instrument surfaces to the angular range of 90° recommended in ISO 4040. This usually pertains to operation of the retarder. The instruments must not be concealed by control elements.

The angles are specified in compliance with ISO 4040. If technically unavoidable, the retarder functions should be restricted from 40° to 30° in the front position. However, this must not cause obstruction of the displays.

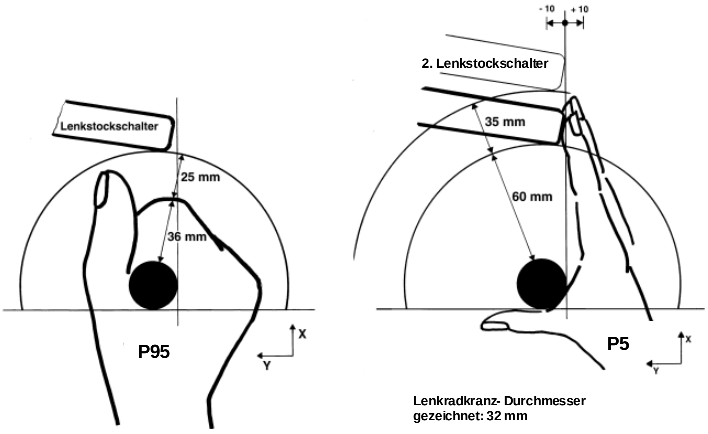


Fig. 24: Steering column switch anthropometry

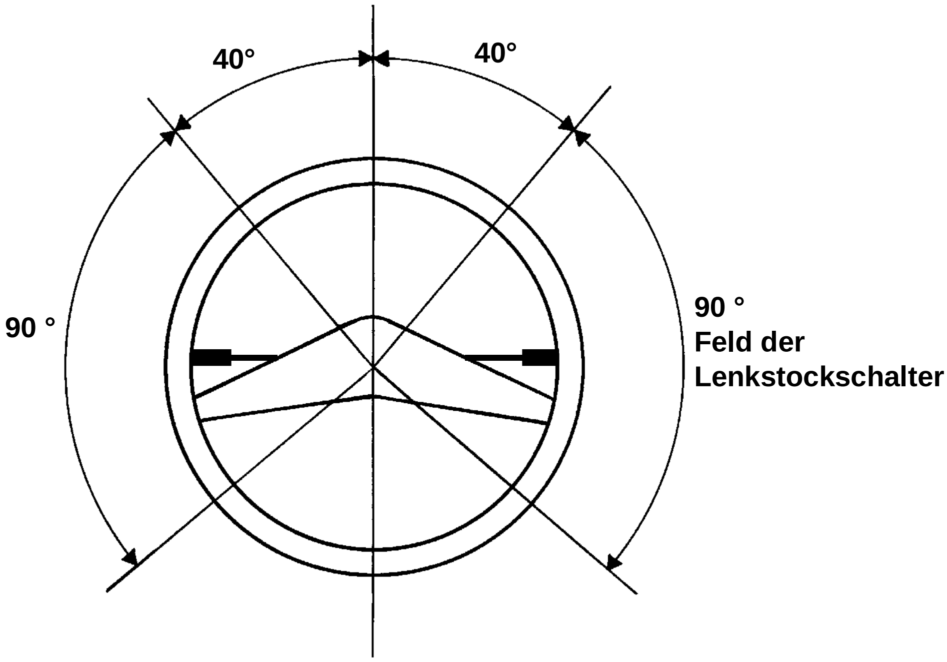


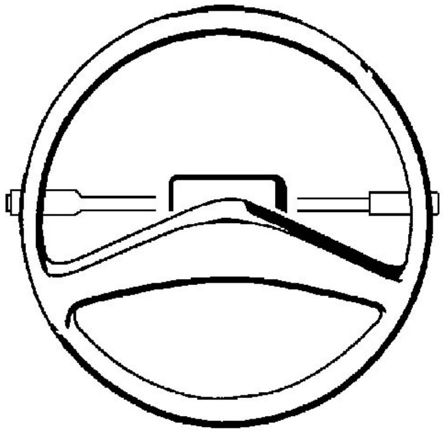
Fig. 25: Fields of the steering column switch

Steering column switch functions

Left hand steering column switch

Combined switch

- Lights
- Indicators
- Wiper functions
- Horn



Right hand steering column switch

Combined switch

- Retarder
- Cruise control

This recommendation is a compromise developed from the assignment concepts available on the market. An assignment similar to car concepts is optional:

Light functions: **placed on the left** **Wiper functions: placed on the right**

Horn function: **in the centre of the steering wheel or in the steering wheel spokes**

Steering wheel controls

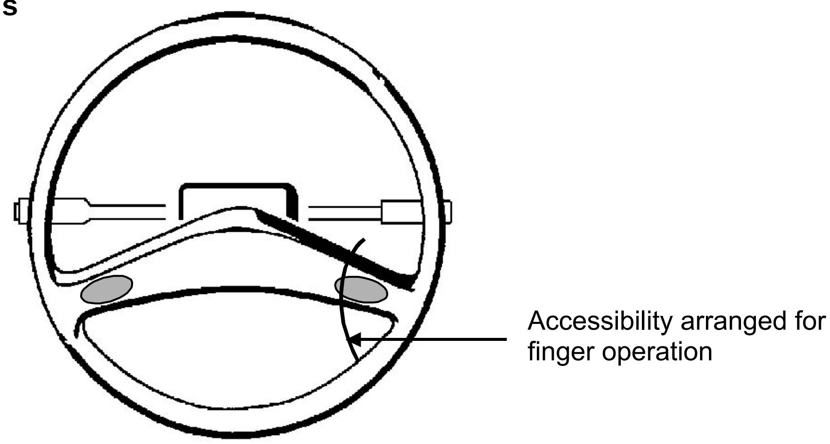


Fig. 26: Controls in the steering wheel spokes

Controls in the steering wheel spokes such as for the radio or telephone must be arranged for operation with the fingers. Operation of these controls should be possible whilst holding the steering wheel. Operation of the horn in the middle is an exception.

Pedals

Automatic gearboxes are increasingly used for motor coaches. This variant does not require a clutch pedal. However, the recommendations take account of the arrangement of the clutch pedal for designs with mechanical gearboxes. In the CAD model, a larger footrest for the left foot is recommended if the clutch pedal is omitted.

Different anthropometric dimensions of the population produce different heel point positions and thereby fulcrums with different X co-ordinates.

A defined foot support surface with a uniform contact point of the ball point on the pedal is important. Furthermore, collisions of the shoe heel with the pedal must be taken into account in the design of the pedal. With upright pedals, the foot is raised due to this collision in deeply depressed pedal positions and the foot and leg system is forced to execute increased static retaining work.

Positions of the heel and ball points

For the production of the concept, the heel point of type P95/ Bus is taken as a reference of the 0 position of the X and Z co-ordinates. Y= 0 is the median plane of the driver.

The reference points for adjustment of the foot positions are the ball points at the accelerator pedal in normal driving position. The Ramsis types are aligned to a theoretical pedal surface which represents an accelerator pedal position in the normal driving position.

Due to the different foot positions and anthropometric dimensions of the defined population, the heel and ball points move.

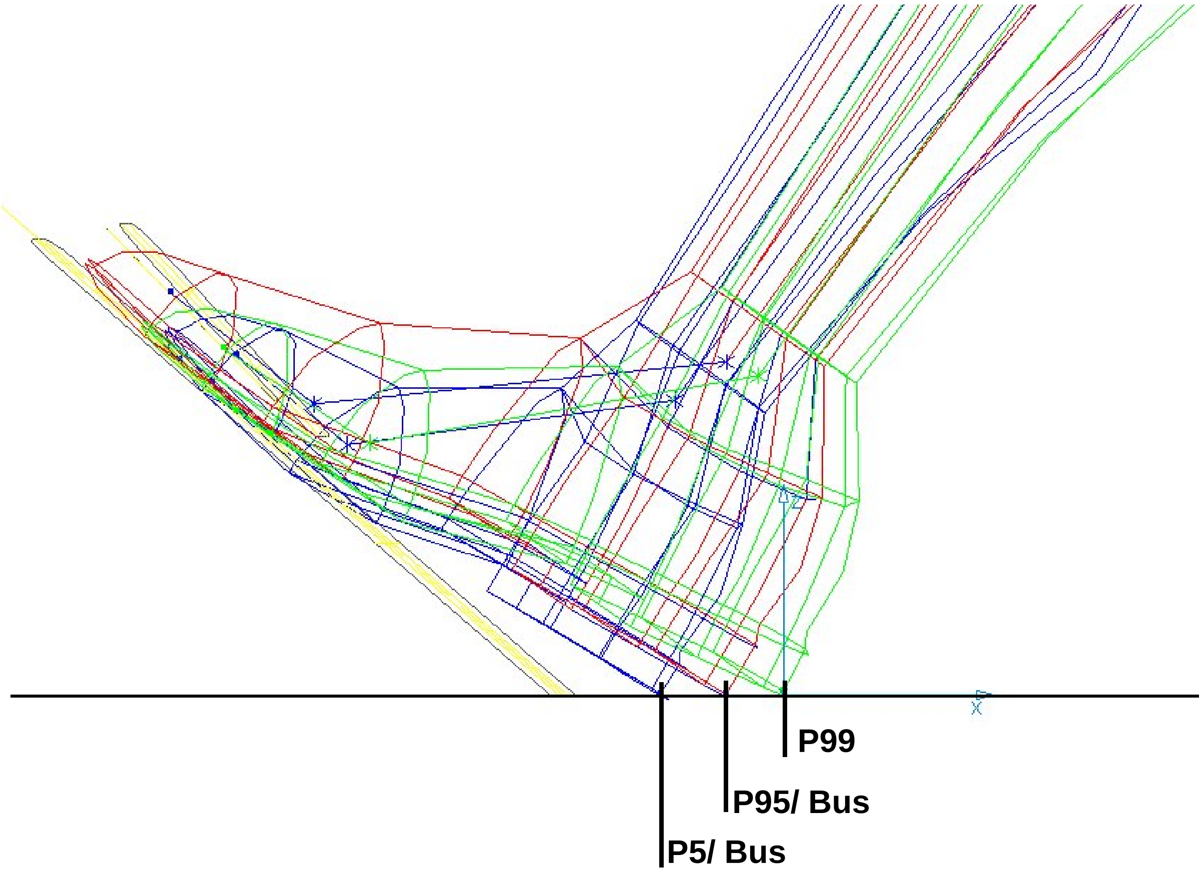


Fig. 27: Heel points of the Ramsis types

Co-ordinates of the heel points

	X		Y		Z	
	left	right	left	right	left	right
P5/ Bus	**- 29.5**	**- 51.5**	**- 176.5**	**196.5**	**0**	**0**
P95/ Bus	**30**	**0**	**- 180**	**197**	**0**	**0**
P99	**14**	**- 24**	**- 203**	**192**	**0**	**0**

Table: Co-ordinates of the heel points

Pedal design

Starting from the accelerator foot position, it should be unnecessary to raise the foot for a rapid and easy change from the accelerator to the brake pedal. The height of the brake pedal should therefore be equal to the height of the accelerator pedal under normal conditions.

As a compromise for all types of people, a pedal should be designed with a fulcrum at an average distance to all heel points and with a curved surface in the X axis, which permits the pedal to be easily reached by the ball points of all percentiles.

The movements of the pedal should be adjusted to the narrow comfortable angular ranges of the ankle joint. The optimum values for the movement are 90 -110° /1/. The starting value for the ankle joint angle should not be less than 80° /27/. For the project, the optimum value of 90° was defined for a medium depression position of the right foot for the accelerator position. The accelerator is at approximately 1/3 depressed position of the entire range of movement.

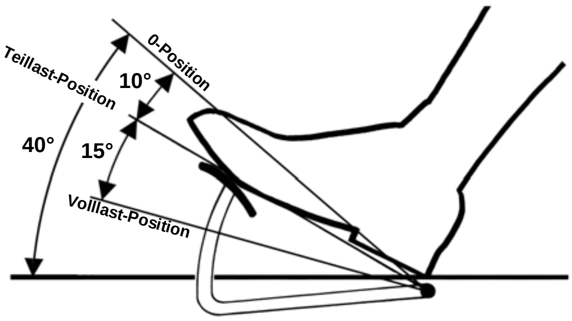


Fig. 28: Pedal shape with fulcrum close to the heel
Foot position at torsion angle of 15º

The partially depressed position of the pedal shown in the drawing represents the position of the seated posture model in the CAD plan.

A free space must be ensured between the pedals for safe movement of the foot between the pedals when wearing shoes and to avoid incorrect operations. The free space should be at least 50 mm and is optimally 100 mm /6/.

The natural spread of the foot-leg system in the seated position requires a rotation of the accelerator pedal in the Y axis by approx. 12°.

The so-called spoon pedal is recommended, with a design which allows the advantages of a fulcrum close to the heel, a shape which prevents collision with the shoe heel and a uniform contact point for the ball point.

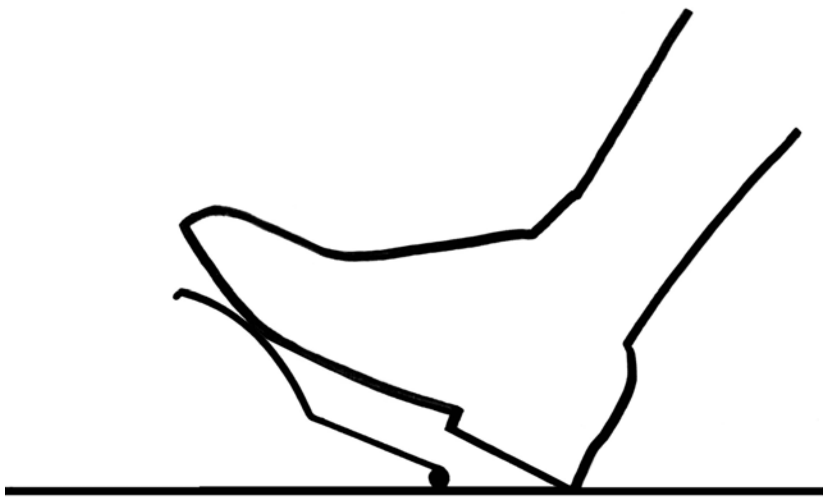


Fig. 29: Recommended design "spoon pedal"

Leg-operated pedals such as the clutch permit higher forces to be transmitted. The direction of movement of the pedal should be chosen such that the direction of force is in line with the backrest. By this means, the higher required force is aided by support from the backrest. This makes it easier to hold the clutch for a longer period.

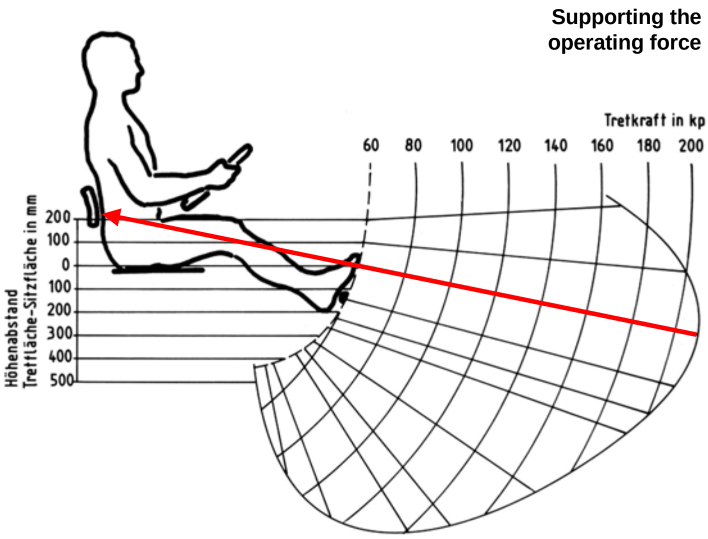


Fig. 30: Vectors /11/

Pedal forces

The defined forces are oriented to the VDV specifications for the regular bus/ 6/.

Accelerator pedal:

Operating force F = 35 – 40 N

Return force F = 20 N

Brake pedal:

Braking	Force	Angle of operation	Type of operation
First response	40 ± 10 N	4° ± 1°	foot-operated
20%	120 ± 30 N	8° ± 2°	foot-operated
50%	180 ± 50 N	13° ± 3°	foot-operated
100%	≤ 420 N	≤ 25°	leg-operated

A lower maximum force is preferred

Clutch pedal:

Operating force F = ≤ 420 N

3.5.2 Miscellaneous controls

The structure for the arrangement of the miscellaneous controls is defined according to:

- **Visibility and accessibility**
- **Formation of logical units**
- **Position**

The definitions of the accessibility and the position in the arrangement of the controls are the result of an extensive survey of bus drivers.

Accessibility

Priorities are defined for the accessibility of controls, which are described and depicted in the Ramsis CAD model as geometrical envelope curves. The envelope curves describe movements of the hands and arms with different degrees of comfort and thereby the corresponding access times.

The definitions

Priority I

Envelope curve defined by the hand and arm movements with all degrees of freedom of the shoulder joint.

Priority II

Envelope curve defined by the hand and arm movements with comfortable shifts of the upper body with slight rotation.

Priority III

Changes of posture from the seated position are permissible for this. However, the body must remain in contact with the seat.

Priority III should only be fitted with controls which are used mainly in non-critical situations such as standstill of the vehicle.

The envelope curves are anthropometrically measured, three-dimensional curves. They were determined with people representative of the defined population in a dummy seat.

The envelope curves contained in the Ramsis CAD model are not used in the DWMC project.

In general, no controls may be placed outside priority III accessibility.

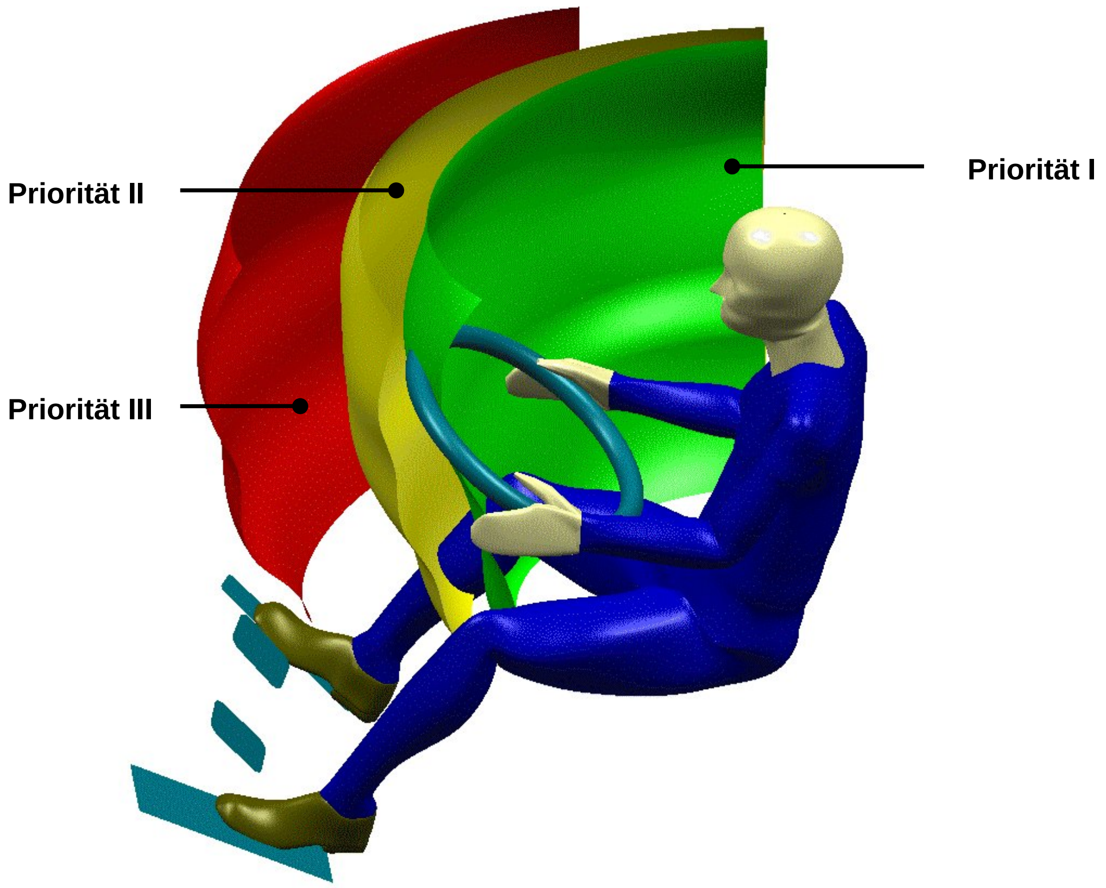


Fig. 31: Envelope curves of priority I to III for P5/ Bus

In the CAD model, types P5/Bus and P95/Bus are assigned to the anthropometrically measured accessibility. Type P99 contains the intersecting fields of the anthropometric accessibilities of all types.

Visibility

According to the frequency of operation and the safety relevance, controls should be placed in the field of view of the corresponding priority. The four-way indicator switch is particularly noteworthy, which is infrequently operated and may be placed in the extended field of access, but must be visible in the direct field of view of priority I without obstructions.

In general, the visibility of the miscellaneous controls within the field of eye movement according to priority II is sufficient. It should be possible to view the controls without turning the head.

The controls for gear shifting and seat adjustment are an exception. Their particular positions do not permit direct sight. The aspects of tactile encoding should be taken into account for these. The lacking direct sight is compensated by sensory information.

Priorities I to III are described in detail in Chapter 3.4 Visibility.

Arrangement

This defines the spatial positions of the miscellaneous controls in a rough structure, such as front left, front centre, front right etc. The specification of the spatial position provides an improved orientation inside the vehicle, particularly for drivers who frequently change vehicles.

Exact dimensional allocation for the individual functions is deliberately omitted to preserve the freedom of design for manufacturers.

The graphic limits for fields E and B arose to provide a visual overview for the questionnaire. For example, the handbrake could also be placed between fields B and E.

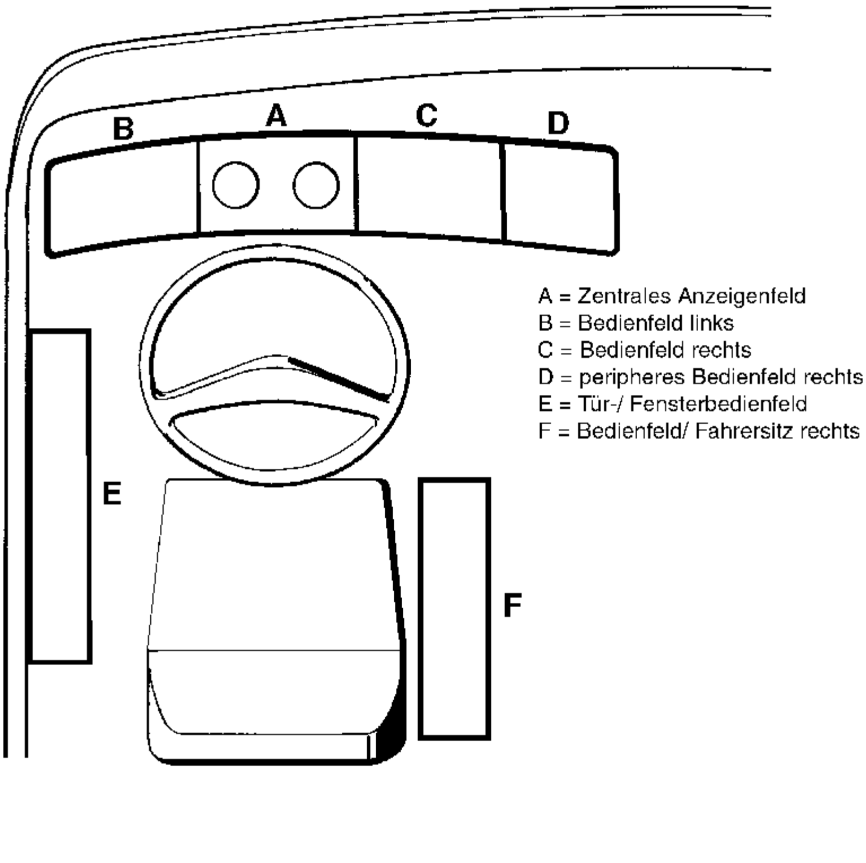


Fig. 32: Control fields at the driver's workplace

Arrangement of the miscellaneous controls by accessibility and by the control field arrangement for the miscellaneous controls

Control	Priority/accessibility			Control field arrangement					
	I	II	III	A	B	C	D	E	F
Driving/safety									
Gear lever, automatic	X								X
Wing mirror adjustment		X						X	
Electric window control, driver's door		X						X	
Handbrake	X							X	
Gear lever, mechanical	X								X
Electric sunshade		X			X				
Ignition/ignition lock		X				X			
Door operation	X					X			
4-way indicators		X			X				
Light functions									
Interior lighting		X			X				
Instrument illumination		X			X				
Fog lamp		X			X				
Rear fog lamp		X			X				
Parking and head lights, main switch	X				X				
Heating - ventilation – air conditioning									
Wing mirror and side window heating	X				X				
Driver's seat air conditioning		X				X			
Passenger's air conditioning		X				X			
Seat heating			X					X	
Communications									
Radio, CD, cassette		X					X		
TV, on – off		X					X		
Telephone, keypad		X					X		
Video system		X					X		
Navigation system		X					X		

Arrangement of the miscellaneous controls

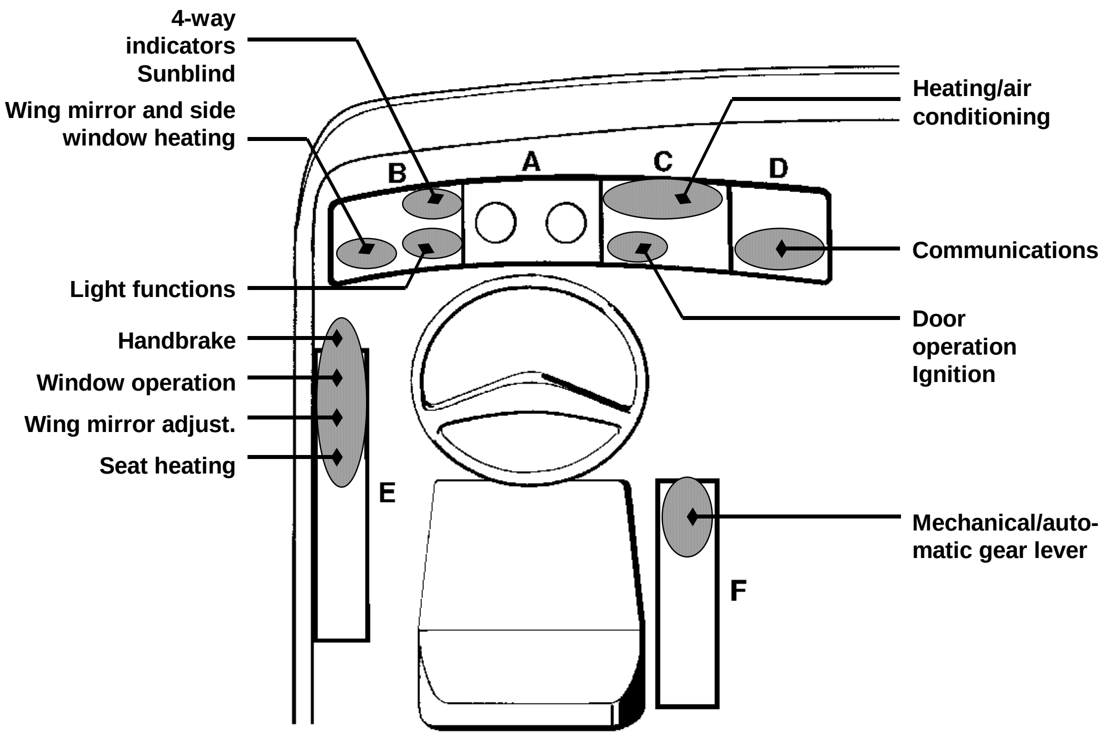


Fig. 33: Graphic summary of the recommendations for the arrangement of the miscellaneous controls according to their position and place in each control field

3.5.3 Design principles for controls

No detailed specifications are made on the formal design of the controls in order to preserve the freedom of design for manufacturers. However, the minimum ergonomic requirements below should be maintained.

Prevention of incorrect operation

- The controls should be structured in a clear and comprehensible manner.
- Fewer incorrect operations are anticipated if logical units and groups are formed according to the recommendations.
- Clearly separated groups with interstices simplify finding the desired positions.
- The reduction of controls to the essential degree simplifies comprehensibility and reduces mental effort.
- The multifunctional controls in use in other vehicle categories should be employed.
- Slightly convex switches offer more safety against incorrect operation.
- The key width for finger operation should be approx. 17 - 25 mm /11/.
- The distance between the centres of switches should be 16 -30 mm /11/.
- Non-slip surfaces should be used.

The principle that the overall arrangement of all elements must be more than the sum of the components always applies /18/. The interactions between the systems and the design of the driver's space with the aspects of product semantics are the parameters for the overall assessment of a system.

Crushing and shearing points, safety clearances

Crushing and shearing points as described in DIN EN 294/ 349/ 811 must be avoided.

Compatibility

The congruence of displays and the resulting control operations is known as compatibility. It applies equally to indicators and controls /36/. DIN EN 60447 Human/machine interface (HMI), Principles of operation, provides information on suitable applications.

Function	Direction of movement
on	turn clockwise upwards to the right upwards forwards pull
off	turn anticlockwise to the left downwards backwards push
right	turn clockwise to the right
left	turn anticlockwise to the left

Source: Schmidtke & Rühmann, 1981/24/

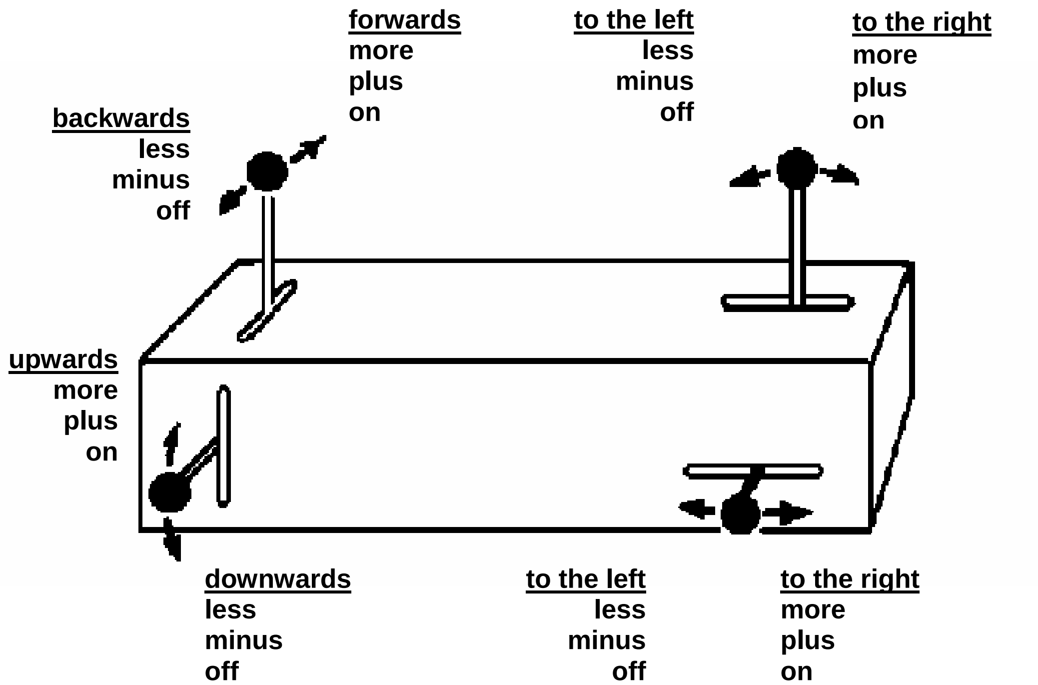


Fig. 34: Compatibility of operations and effects /44/

There are different input keypads for numeric entry in computers and telephones. To avoid incorrect entries, it must be ensured that only one of the two systems is used for all input keypads at the DWMC.

Computer and calculator	Telephone
7 - 8 - 9 system	**1 - 2 - 3 system**

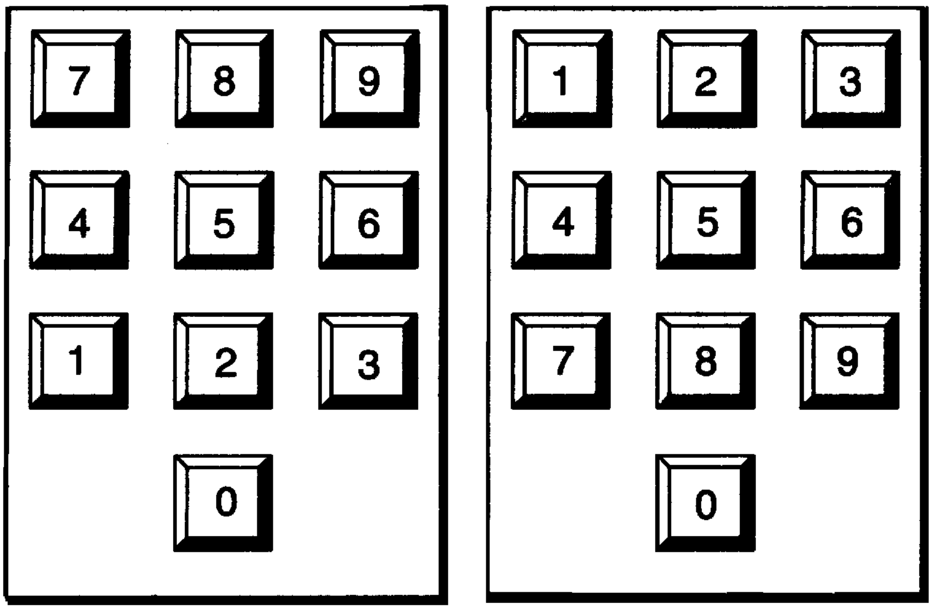


Fig. 35: Examples of numeric input keypads /24/

Tactile encoding

It is important to note tactile feedback after controls have been operated. To ensure the conducted action, the user requires feedback whether or not the control has actually been operated. Tactile encoding must be taken into account for these controls.

Another aspect may be the tactile encoding of controls. This applies to controls which are not within the visible range of the driver. The external shape and position on the seat should permit the significance of the control to be identified by feeling the movement of the handle. The driver should be able to perceive the resulting action without direct sight of the control.

Actuating travel and forces

The minimum requirements are described in DIN EN 894-3 and DIN 33411, Human physical strength.

The requirements with regard to the actuating forces must be adapted to the task, the frequency of operation, the duration of operation and the anthropometric conditions.

Examples of actuators	Actuating travel		Actuating force
Finger contact, e.g. pushbutton		**2 – 10 mm**	**1 – 8 N**
Hand contact, e.g. pushbutton		**10 – 40 mm**	**4 – 16 and up to 60 N for emergency switches**
3-finger grip, e.g. twist switch		**>360° (with intermittent release)**	**0.02 – 0.3 Nm with 15 – 25 mm diameter**
Hand grip, e.g. gear lever		**20 - 300 mm**	**5 – 100 N**
Hand grip, e.g. hand lever		**100 – 400 mm**	**10 – 200 N**
Full foot contact, e.g. pedal		**20 – 150 mm**	**30 – 100 N**

Fig. 36: Examples of actuating travel and forces /to 45/

3.6 Shelves

No detailed design guidelines have been developed for the positions of shelves. Their sizes are described, but not their exact geometrical position at the driver's workplace. Accessibility is defined according to the priorities. This preserves the freedom of design for manufacturers.

Recommendations:

- A space should be provided at the driver's workplace to store a driver's bag in the size of a briefcase as well as a place for a torch.
  Accessibility has no priority.

- One or more shelves should be available for objects required during driving. For example, this applies to a log book, maps and passenger lists. The required size is at least that of an A4 folder.
  Accessibility with priority III.

- A clothes hook should be provided at a suitable place.
  Accessibility has no priority.

- A writing panel to fill in tachograph cards must be included.
  Accessibility has no priority.

- A small compartment must be capable of receiving the following objects: spectacle case, ballpoint pen, cigarette box and coins.
  Accessibility with priority II.

- Cup holder
  Accessibility with priority II.

3.7 Seat design

Modern seat concepts have now reached a high standard of ergonomic quality. The most important and new requirements determined in the course of this project are indicated.

3.7.1 Dimensions

The anthropometric investigation of motor coach drivers has revealed clear information on seat upholstery contours requiring modifications.

Female drivers under P50 are no longer found or only in few cases. The calf support for the defined population can therefore be correspondingly modified. An extension of the seat length to support the thighs from P50 female can be implemented. The clear increase in corpulence at the abdomen and hips must be taken into account by an adjustment of the width of the middle seat section.

Lumbar support

Due to the long periods of exposure of drivers, an individually adjustable lumbar support should be an essential component of the equipment. A so-called lumbar support must be integrated in the backrest to achieve the orthopaedically desirable position of the lumbar vertebrae. The great anthropometric differences in the position of the lumbar vertebrae and individual preferences with regard to the pressure on the back require adjustable systems.

Seat adjustment ranges

The seat adjustment ranges can be adapted more precisely to the ergonomic requirements for the bus driver population specified in this project. The shift of body size towards taller people makes optimised adjustment ranges possible for the mainly represented group of people.

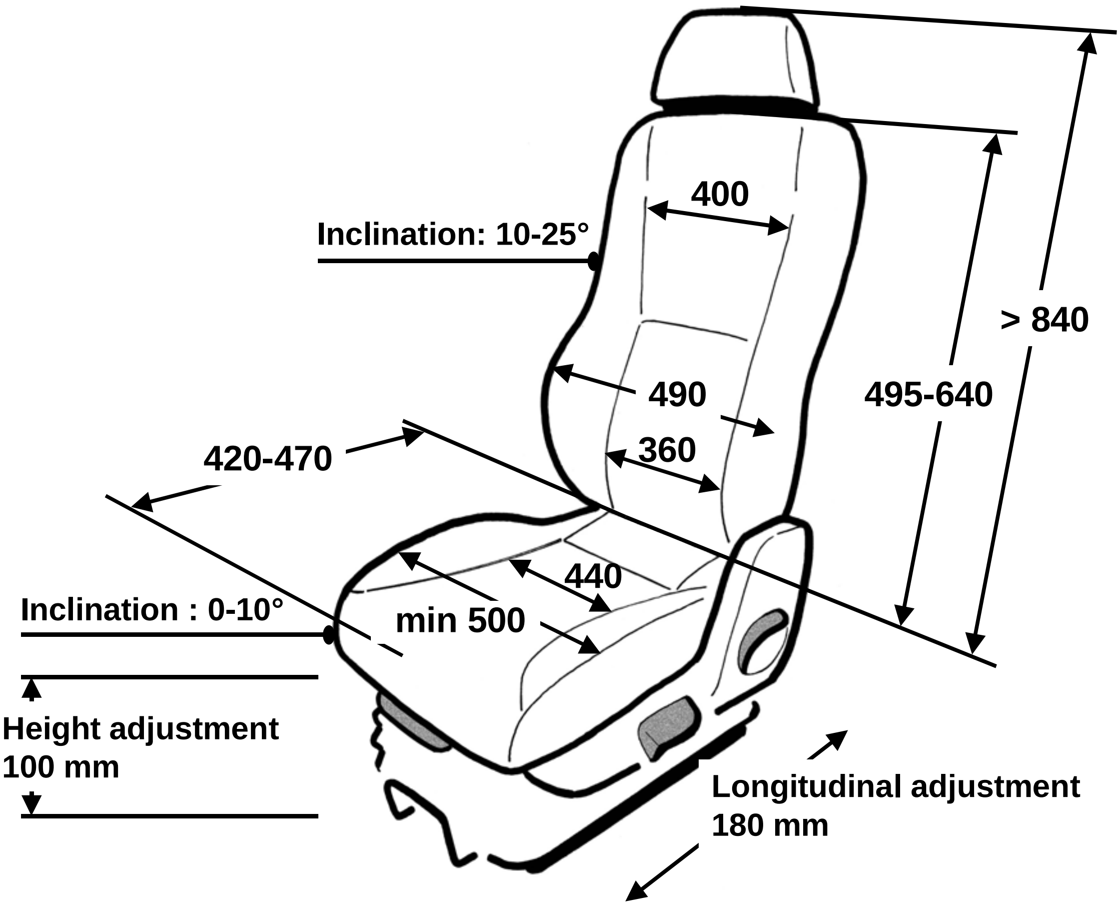


Fig. 37: Seat main dimensions and adjustment range

However, below P50 female, people are not completely excluded from a means of operating the vehicle. The new design is focused on the comfort of the majority of the group of people. Smaller people must only accept compromises with regard to comfort in favour of the majority of drivers. The demands of larger drivers for an extension of the adjustment ranges confirm this.

3.7.2 H-point positions and seat adjustment

The H-points of the anthropometric figures in the Ramsis CAD system were used to produce the concept. The relationships with the H-points defined in the EC directives were determined by design methods. In the project, a clear difference was made between the hip points resulting from the anthropometric dimensions of the Ramsis types and the points determined with seat templates according to EC or SAE directives.

The table below describes the correlation of the H-points from the Ramsis CAD model and according to the EC directives. The seat adjustment field is shown in the drawing with regard to the seat manufactured by Isringhausen: ISRI 6820/ 347. As a result of practical experience, the position of the seat adjustment field is entered higher than the determined EC H-point positions. This fulfils the wishes of bus drivers to adjust the seat a little higher or lower.

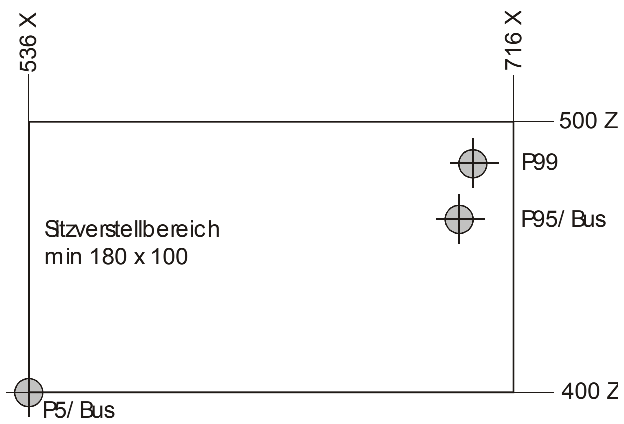


Fig. 38: H-point adjustment field for the seat

Co-ordinates of the H-points

	X		Y		Z	
	Ramsis	Seat/EG	Ramsis	Seat/EG	Ramsis	Seat/EG
P5/ Bus	548.5	536	-7	0	364.5	400
P95/ Bus	678	696	0	0	406.5	462
P99	713	701	-18	0	453.5	488

3.7.3 Effects of vibrations

Spring damping systems are now standard equipment for seats in motor coaches and are seen as a sign of quality in good driver's seats. When correctly adjusted to the body weight of the driver, relative movements of the driver to the controls of the vehicle occur during driving, such as to the steering wheel and accelerator pedal. When the clutch is operated, the greater required force results in a force vector in the Z axis (vertical), which can cause undesirable movements of the seat in this direction.

These undesirable movements of the body are often reduced by motor coach drivers by switching off the springs and dampers or by making a higher weight adjustment. The desired effect of the damping system is then virtually ineffective.

This is the subject of investigations by the union of professional associations /8/ on the effects of vibrations on driver's workplaces in omnibuses. These confirmed the high standard of the sprung bodies of motor coaches.

The measurements made on both the chassis and the seats of motor coaches revealed values which exclude health hazards for drivers caused by vibration of the entire body for normal driving periods with regard to the assessed strength of the vibrations.

If the discussion is extended to include the effects of relative movements described above, particularly for vibrations with a high deflection, seating systems for particularly well-sprung motor coaches are not essential. This is conditional on compliance with the general values demanded in VDI 2057 and the worksheet issued by the Federal Ministry for Labour and Social Order (BMA) for medical examination of vocational disorders (BK) 2110, minimum requirements of the total exposure to vibrations.

The natural resonance at the seat top with or without a spring damping system should not exceed 1- 1.3 Hz. The assessed spring deflection according to BK 2110 should not exceed a K r value of K r 16.2.

3.7.4 Thermal comfort

The influencing factors with regard to thermal well-being in the vehicle are described by three components:

- The person
- The vehicle seat
- The interior climate

With its microclimate, the seat is an important component. Comfort is influenced by design and material components.

Design parameters

Containment of the body by particularly prominent seat contours should be avoided. The body contact points must be set to the physiologically necessary degree. Dynamic processes during the seated phase of the driver must be taken into account. A design of the upholstered surfaces with profiled contours can contribute to the dissipation of water vapour caused by sweat (pipe design).

Material parameters

Suitable covering and upholstery materials should be chosen for an optimum dissipation of water vapour. The recommendations in the research report for regular buses /7/ specify the minimum values at the contact points between the person and the seat for the following parameters:

- Water vapour permeability $\geq 4 \quad \frac{g}{m^2 \text{ h mbar}}$
- Relative humidity max. 85 %
- Temperature at contact points max. 36°

3.7.5 Controls

Seat memory

As described in Chapter "Seated posture model", the seated posture is influenced by the position of sight to the road or to vehicles driving ahead. The posture is often varied when driving in towns, overland or on motorways. Drivers frequently readjust their seats during a period of work to avoid a static seated posture. If drivers are changed, it should be possible to reset the initially adjusted position easily and correctly using a memory function of the seat.

Seat memory supports the demands in the preliminary study of the project for *dynamic seats.*

Memory should be available for the following adjustment functions:

- **Longitudinal adjustment**
- **Height adjustment**
- **Backrest inclination**
- **Seat top depth**
- **Seat top inclination**

Mechanical controls

Controls for seat adjustment should be safely accessible without direct sight according to the model of tactile encoding. The shape and positions of the controls should be an indication of the expected actions of the seat. Seat concepts with unclear "piano keyboards" require too much attention for these individual components and lead to situations in which the seat is not sufficiently adjusted. The positions of the most important controls should therefore be the same for all seats and have prominent designs:

Electric controls

The knowledge described in section "Mechanical controls" also applies to electric controls, whose design should fulfil the requirements of compatibility and tactile aspects.

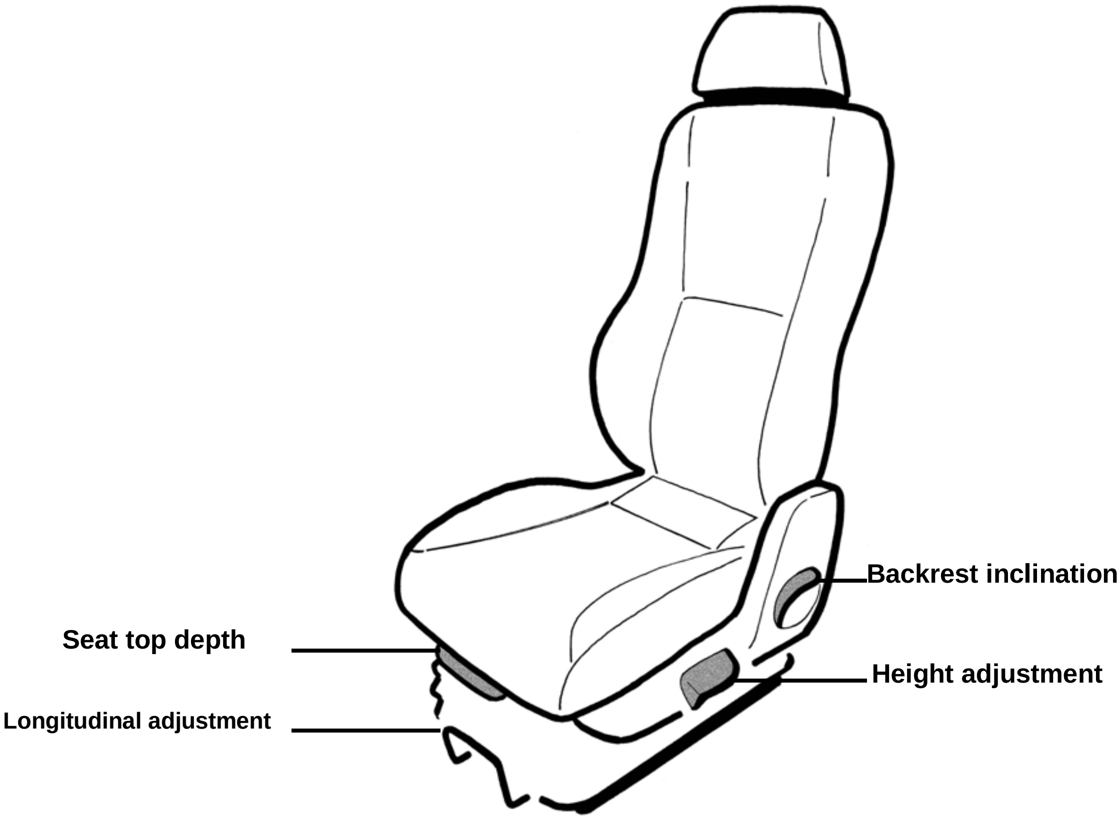


Fig. 39: Seat design, arrangement of the controls

The position of the controls for the lumbar support depends on the technical execution and is not contained in this list for these reasons. However, they should be positioned in the vicinity of the lumbar position.

4 CAD data

The drawings and seated posture models depicted in this report are available as CAD data from the client, the "Berufsgenossenschaft für Fahrzeughaltungen" (Professional Association for Transport).

Data formats

The computer-aided investigations were made with CATIA V 4.2.2 and Ramsis 3.7. The results of the investigations are available as data records, as a Catia model and in a neutral VDAFS data format.

A data record contains the following information for types P5 Bus, P95 Bus and P99:

- The optimum posture models
- The accessibility fields
- The steering wheel
- The seat contour positions
- The fields of view
- The area for unobstructed instrument arrangement
- The traffic signals
- A child crossing the road

Notes on the representation of accessibility fields

In the CAD model, the measured anthropometric accessibility is assigned to types P5/Bus and P95/Bus. Type P99 contains the intersecting fields for the anthropometric accessibility of all types.

The data record is organised in a layered structure. Logically associated elements are assigned to the same layer. A list of layers and an explanation of the project environment is enclosed. With these, the user can activate the desired elements immediately. Filters are also defined to make suitable groups of layers visible.

The following filters are defined:

- The posture models of types P5/ Bus, P95/ Bus and P99
- The posture models with the associated steering wheel position, the seat contour and the fields of view
- The posture models with the associated steering wheel position, the seat contour, the fields of view, area of the instrument positions and the surroundings of the vehicle.

Sources for data media:

Professional Association for Transport BGF
- Federal Republic of Germany -
Technischer Aufsichtsdienst
Ottenser Hauptstraße 54
22 765 Hamburg
Germany

Further information is provided by the authors:

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Bild 1:

Vertical transverse plane
Vertical longitudinal centre plane
Horizontal plane

Bild 2:
Zero y plane
Zero x plane
Zero z plane
Heel point
Heel point line

Bild 5:
Line of sight to car brake light
Distance to car brake light = 40 m

Bild 7:
Heel point P99
End wall
Free foot space min. 100 mm
Installation space for seat
Height 1600 mm
Backrest inclination 15º

Bild 9:

	Perception time	Body movement	Deviation from normal axis of sight	
			Vertical	Horizontal
Optimum field of view		Normal fixation movement of the eye		
Maximum field of view		Eye movement		
Field of gaze		Max. eye movement, colour information up to here with fixed gaze Sight unfocussed with fixed gaze		
Extended field of gaze		Head turning Movement		

		visible with fixed gaze		
Field of sight		Turning of eyes, head and body		

Bild 10:
A – Limits of the optimum field of gaze

Normal line of sight 15º when seated, relaxed axis of sight

Optimum range of sight for information
Optimum rotation of the eye

Bild 11:

B – Limits of the maximum field of gaze

Normal line of sight 15º when seated, relaxed axis of sight

Range for accurate sight

Bild 12:

C – Limits of the maximum field of sight

Upper limit of the field of sight

Normal line of sight 15º when seated, relaxed axis of sight

Maximum rotation of the eye

Limit of the maximum field of sight

Bild 14:

Horizontal line
Normal line of sight
Line of sight

Bild 15:

Horizontal line

Bild 16:

Horizontal line

Bild 17:

Display placed at the side

Bild 18:

Horizontal line

Direction of travel

Bild 19:

Visibility of children

Bild 20:

Sight of left lane / eye point
Sight of right lane / eye point
Traffic signals

Bild 23:

Rim diameter

Bild 24:

Steering column switch

Steering wheel rim diameter drawn: 32 mm

Bild 25:

Field of the steering column switch

Bild 26:
Accessibility arranged for finger operation

Bild 28:

0 position

Partially depressed position
Fully depressed position

Bild 30:

Supporting the operating force

Foot force in kp

Vertical distance pedal surface to seat top in mm

Bild 31:

Priority I
Priority II
Priority III

Bild 32:
A = Central display field
B = Left control field
C = Right control field
D = Right peripheral control field
E = Door and window operation field
F = Driver's seat control field, right

Bild 33:

4-way indicators
Sunblind
Wing mirror and side window heating
Light functions
Handbrake
Window operation
Wing mirror adjustment
Seat heating

Heating/air conditioning
Communications
Door operation
Ignition
Mechanical/automatic gear lever

Bild 35:

7 – 8 – 9 system

1 – 2 – 3 system

Bild 37:

Inclination
Inclination
Height adjustment
Longitudinal adjustment

Bild 38:

Seat adjustment range min. 180 x 100

Bild 39:

Seat top depth
Longitudinal adjustment

Backrest inclination
Height adjustment