Drivers' field of view from large vehicles

Phase 4 – Final Report

Prepared for:

The Department of the Environment, Transport and the Regions

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Executive Summary

The UK Government's Department of the Environment, Transport and the Regions identified what appeared to be a relatively high number of road traffic accidents involving large vehicles - buses, coaches and HGVs - and other more vulnerable road users - pedestrians, cyclists and motorcyclists. One contributory factor in this high accident rate may be an inability of large vehicle drivers to see safety critical areas around their vehicles. ICE Ergonomics was subsequently tasked with researching the scope, causation and possible solutions to the problem of insufficient or ineffective drivers' vision from large road vehicles.

The findings of discussion groups, comprising key personnel from organisations representing the haulage and passenger transport industries, road safety and vulnerable road user groups, revealed that a significant problem does exist that is worthy of the DETR's concern. Accident data, based on STATS 19 reports, failed to fully identify the extent to which ineffective driver's fields of view from large vehicles might be a contributory factor because no directly relevant data fields exist. However, some insight as to the extent of the problem was revealed by a study conducted by the Transport Research Laboratory (Robinson, 1994) which analysed 1585 fatal accidents involving at least one HGV in the years 1988 to 1990. A significant conclusion of this report was that improving the forward vision afforded to HGV drivers would have saved approximately 26 of the 217 pedestrian fatalities within the sample. This would yield an estimated 16 lives saved each year.

As a means of identifying the physical causes for insufficient or ineffective drivers' fields of view, a representative sample of the UK's large vehicle fleet were modelled, using a computer-aided human-modelling system. This technique ensured that any assessment of the visual environment could include a majority of the driver population from 5th %ile female to 95th %ile male. Computer modelling also provided the means to quickly assess potential field of view improvement strategies and to generate graphic representations of the results.

Objective judgements of the fields of view achievable from each large vehicle were made against a benchmark field of view requirement. This benchmark requirement had its rationale based upon such factors as the swept path profiles of large vehicles whilst manoeuvring, road and road junction design standards and vehicle construction characteristics.

The most cost-effective means for improvements to the drivers' field of view often entailed a combination of additional, modified and/or repositioned convex mirrors. To ensure that the smaller radii of curvature mirrors, determined as a result of the computer analysis, would not be detrimental to other aspects of the driving task, a number of user tests were performed under controlled experimental conditions. These tests investigated the effects of a convex mirror's radius of curvature on a driver's ability to make accurate judgements about the distance, lateral positioning and approach speed of objects viewed through them. Test results suggested that the legislated minimum radii of curvature for Class II rear-view mirrors could be reduced without significantly affecting drivers' judgements about the changing road scene around their vehicle.

Prior to producing a final set of recommendations, for improvements to the drivers' field of view from large vehicles, a number of validation road trials were conducted. These trials identified a number of issues relating to the practicalities of implementing the improvement specifications to in-service vehicles. Feedback from drivers was generally favourable and the safety advantages of improving their field of view recognised.

A set of recommendations is proposed that will facilitate a significant proportion of the driver population in achieving full visual coverage of the benchmark requirement. In making these recommendations, consideration has been given to the physical and operational limitations imposed on large vehicles and, therefore, on the cost effectiveness of implementation and usability of the specification.

Articulated HGV recommendations:

- Reduce the Class II, rear-view mirror's minimum convex radius of curvature to 1200mm.
- Fit an additional Class IV, wide-angle mirror to the off-side of the vehicle, mounted below the Class II, rear-view mirror (the wide-angle mirror currently fitted to the near-side should also be mounted below the Class II, rear-view mirror).
- Fit a forward-viewing mirror with a 200mm (minimum) radius of curvature, to the near-side, such that it provides a view to the immediate front of the vehicle.
- Mount all near-side mirrors forward of the A-pillar so that they can be viewed through an area of the windscreen swept by the windscreen wipers.
- Provide the means to remotely adjust the near-side mirrors from the driver's seated position.
- Fit a reversing aid CCTV system.
- Design instrument binnacles to reduce their intrusion in to the driver's line of sight to the lower edge of the windscreen.

Rigid HGV recommendations:

- Reduce the Class II, rear-view mirror's minimum convex radius of curvature to 1200mm.
- Fit Class IV, wide-angle mirrors below the near-side and off-side rear-view mirrors.
- Fit a Class V, close-proximity mirror to the near-side.
- Fit a forward-viewing mirror, with a 200mm (minimum) radius of curvature, to the near-side such that it provides a view to the immediate front of the vehicle.
- Mount all near-side mirrors forward of the A-pillar so that they can be viewed through an area of the windscreen swept by the windscreen wipers.
- Provide the means to remotely adjust near-side mirrors from the driver's seated position.
- Fit a reversing aid CCTV system.
- Design instrument binnacles to reduce their intrusion in to the driver's line of sight to the lower edge of the windscreen.

Coach recommendations

- Reduce the Class II, rear-view mirror's minimum convex radius of curvature to 1200mm.
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- Fit a forward-viewing wide-angle mirror, with a 200mm (minimum) radius of curvature, to the near-side such that it provides a view to the immediate front of the vehicle.
- Mount all near-side mirrors forward of the A-pillar so that they can be viewed through an area of the windscreen swept by the windscreen wipers.
- Provide the means to adjust all mirrors from the driver's seated position.
- Fit a reversing aid CCTV system.
- Design instrument binnacles to reduce their intrusion in to the driver's line of sight to the lower edge of the windscreen.
- Design internal furniture to the near-side of the driver, such as the entry/exit door, steps and co-driver's seating, to reduce direct vision obscuration of the windscreen and immediate near-side.

Bus recommendations

- Reduce the Class II, rear-view mirror's minimum convex radius of curvature to 1200mm.
- Fit a two-camera CCTV system with one camera to monitor directly behind the vehicle and one to monitor the near-side of the vehicle. The monitor to be mounted in the cab so that the driver's line of sight to it is close to that of the off-side mirrors.
- If the structure of the bodywork permits, fit Class IV wide-angle mirrors below the near-side and off-side rear-view mirror such that the minimum mounted height is 2m.
- Fit a forward-viewing wide-angle mirror, with a 200mm (minimum) radius of curvature, to the interior near-side A-pillar such that it provides a view to the immediate front of the vehicle.
- Provide the means to remotely adjust near-side mirrors from the driver's seated position.

- Design instrument binnacles to reduce their intrusion in to the driver's line of sight to the lower edge of the windscreen.
- Design internal bus furniture, such as driver's security screening and automatic ticketing technology, to reduce direct vision obscuration of the windscreen, passenger entry/exit door and first near-side window area.

Finally, the EC Directives pertaining to direct and indirect vision requirements from road vehicles were assessed against the benchmark field of view requirement.

Currently, the Directive regulating minimum, direct fields of view are only applicable to vehicles in Category M_1 (cars). Application of the same regulatory process to larger vehicles, where the height of the drivers' eyes above the road is greater, makes them inappropriate. EC Directives concerning indirect vision requirements, while applicable to larger vehicles in Categories M_2, M_3, N_2 and N_3, do not adequately legislate for the visual coverage of some safety critical areas around these vehicles.

Revisions to the process for legislating direct and indirect fields of view from large vehicles have been proposed. Drivers' visual coverage of the benchmark requirement is defined using target objects that must be seen via direct or indirect means. These targets having dimensions based upon anthropometric data from the lower end of the predicted population of vulnerable road users.

Contents

1.0 Introduction

This report forms the concluding part of a four phase project researching the extent, causation and possible solutions to the problem of insufficient or ineffective drivers' vision from large road vehicles. Details of the research methodologies used in earlier stages of this work are referred to in previous interim reports for phases 1, 2 and 3.

1.1. Reasons for this research

Accident data suggest that drivers of large road vehicles, such as HGVs, buses and coaches, may have difficulty seeing pedestrians, cyclists and other vulnerable road users during certain manoeuvres.

1.2. Nature of the problem

Current large vehicle designs require that their drivers sit relatively high above the road's surface and are relatively far from the windscreen and near-side windows. This seating position, combined with relatively high dashboards, inadequate or ineffective mirrors and poor cab designs, can lead to significant 'blind zones' around the vehicle.

1.3. Research methodologies

The extent to which undesirable interaction between large vehicles and vulnerable road users occur was investigated through analysis of accident data (Phase 2, Section 2) and from previous research studies (Robinson, 1994). In order to establish the nature of the problem, surveys and consultations were conducted involving organisations and individuals from the large vehicle and vulnerable road user representation groups (Phase 2, Section 3).

The drivers' field of view from a representative sample of the UK's current large vehicle fleet was investigated using computer aided, human-modelling techniques (Phase 3, Sections 3 & 4). Each vehicle was assessed against a benchmark field of view requirement that was derived from analysis of the driving task, road dimensions and swept path envelopes during vehicle manoeuvres (Phase 3, Section 2).

Whenever the computer modelling analysis of a vehicle identified significant shortfalls against the benchmark field of view requirement, a number of improvement strategies were developed and investigated (Phase 3, Sections 5 & Appendix 1). This process led to a preliminary set of field of view improvements that, predominantly, utilised additional, repositioned or modified mirrors and a CCTV-based reversing aid (Phase 3 Sections 5.8.5 - 5.8.8).

To ensure that the computer modelled improvement strategies would not be detrimental to other aspects of the driving task, a number of tests and road trials were conducted. The controlled tests investigated the effect of reducing a convex mirror's radius of curvature on a driver's ability to make judgements about the distance, lateral positioning and closing speed of objects viewed through them (Phase 3, Section 7).

Additional tests also investigated the effectiveness and reliability of systems designed to aid reversing safety. Amongst these were proximity detection devices using infrared, ultra-sonic and radar technology as well as CCTV systems of differing price and quality (Phase 3, Section 7.5).

Validation road trials were then carried out on operational, large vehicles that had been modified with the relevant field of view improvements. Subjective ratings were obtained from appropriately qualified drivers and any problems relating to the practicalities of implementing the improvement specification on operational large vehicles were identified (Phase 4, Section 2).

A cost/benefit analysis was conducted which attempted to compare the cost to the national fleet of implementing an improvement specification against the potential savings to be made from accident reduction (Phase 3, Section 8 & Phase 4, Section 6).

The report that follows details the road validation stages of this research and also proposes a format for any new Directives that would be required to define and legislate the improved drivers' field of view specification for large vehicles.

2.0 Validation road trials

The aim of the road trials was to validate, in the real world, the field of view improvement specifications which had been developed as a result of computer-aided modelling and tests under artificial, experimental conditions. They investigate the practicalities of implementing and using the improvement specifications under the potentially restrictive conditions imposed by a vehicle's construction, its operational duties and the attentional limitations of the driver.

Any road safety benefits derived by increasing the field of view should not be negated by inadequate image quality. The ability of drivers to make accurate judgements about the behaviour of traffic, once it has been detected, is an essential element of the validity of any field of view improvement strategy.

2.1. Methodology

Road validation trials were carried out using four large vehicles modified to incorporate the field of view improvement specification. Three of the vehicles were involved in longer term trials which required the drivers to go about their normal, operational duties for a period of approximately two to three weeks. The validation trials for the bus are reported separately at the end of this section because of their radical deviation from the original proposed specification.

The fourth validation trial involved a modified, articulated HGV being driven by ten volunteer drivers around a test-route of approximately 45km and incorporating a variety of different road classifications. The drivers had, on average, 23 years HGV driving experience and most drove approximately 1200 miles a week.

Evaluation feedback from drivers involved in the long-term trials was via a self-completion questionnaire and from the test-route drivers by interviews both during and after the test drive. Questions were presented or delivered in a style that would not introduce bias but, where necessary, drivers were prompted to consider particular aspects of their driving task in relation to the improvement specification.

2.2. Test Vehicles

The articulated vehicle used in the longer-term road trial was a Scania, Series III P113 tractor unit fitted with Wilson double-deck semi-trailer.

Figure 1. Modified Scania P113 - near-side mirrors

The rigid HGV used in the long - term trial was a Leyland/Daf FA45 fitted with a box-body.

Figure 2. Modified Leyland/Daf FA45 - near-side mirrors

The articulated HGV used for the test-route validation trials was a Volvo FL10 with 38t tractor unit and curtain-side semi-trailer.

Figure 3. Modified Volvo FL10 - Off-side ¾ view

2.3. Results

2.3.1. Articulated HGV – Long-term validation trial

The articulated HGV validation trials involved two drivers operating predominantly on a route consisting of motorways and main roads whilst delivering high volume, low weight products to major city destinations in Scotland and Northern England. During the trial period, the vehicle covered approximately 5000 miles. Both drivers were generally in favour of the field of view improvements but expressed reservations for differing reasons.

One driver, who predominately operated the vehicle at night, stated that when using his mirrors in conditions of dark and rain he had difficulty judging accurately the distance to following vehicles using only their headlamps for reference. Although the extent to which night-time lighting conditions made the task of distance estimation more difficult was not specifically investigated, it is considered that the improvement specification had not significantly degraded the visual clues used in making those judgements.

Meanwhile, the day time driver initially found the mirrors to provide an improved field of vision and reported positively on their benefits. However as the trial progressed the driver became suddenly dissatisfied and expressed a desire to have the original mirrors refitted. It is suspected, though not definitively expressed, that this change of heart was more to do with the unusual appearance of the prototype, forward-mounted mirrors and the subsequent, unwanted attention that they attracted than with any field of view issues.

2.3.2. Rigid HGV – Long-term validation trial

The operational routine of the rigid HGV consisted mainly of multi-drop deliveries in and around Southeast England, including parts of London's more congested outskirts. The two drivers involved in the validation trials were positive about the improved field of view the additional and modified mirrors provided. However, both were justifiably concerned about the height above the ground of the forward protruding mirror arm. Whilst the Leyland Daf FA45 falls under the remit of this research, its dimensions are such that when the prototype forward-mount mirror arm was fitted its lower edge was below that of the average pedestrian head height. It was not possible, with the proposed additional wide-angle mirror fitted, to achieve a condition where all parts of the external mirrors were positioned higher than 2m above the ground.

However, it is envisaged that the future design of a mirror arm, permitting HGV mirrors to be mounted forward of the near-side A-pillar, would resemble those currently fitted to a number of coaches (Figure 4). Despite the coach driver's low seated position, a full array of mirrors can be accommodated at a safe height. The coach's mirrors are mounted above pedestrian head height and are viewed through a windscreen with sufficient glazed area to permit drivers an upward line of sight to them. The glazed areas of smaller HGV cabs may have to be designed with similar characteristics to permit forward located mirrors to be mounted at a safe height.

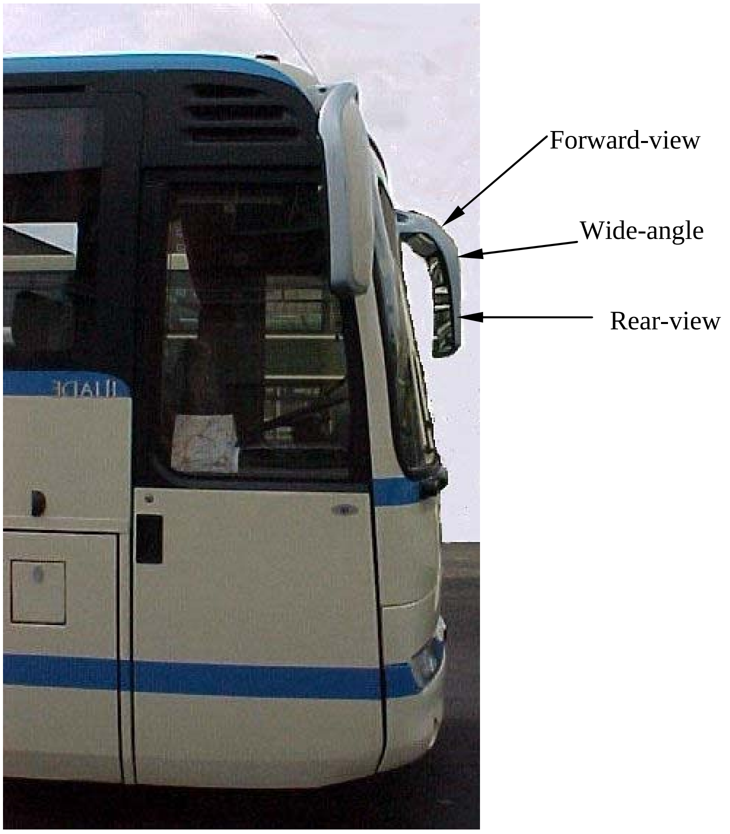

Figure 4. Coach with forward-mounted near-side mirrors.

2.3.3. HGV articulated – Test-route trials

The main findings of the drivers' evaluation feedback, obtained during the test-route validation trials, are categorised under the specific area of the field of view improvement specification to which they relate. The number in brackets, following each of the feedback statements is the number of drivers - out of 10 - who specifically made comment about an individual improvement specification. Each statement, while not necessarily the driver's exact words, conveys as accurately as possible what was considered the driver's meaning and intent at the time of the interview. A plus sign (+) or minus sign (-) before each statement indicates an endorsement or a criticism respectively.

Near-side mirrors mounted forward of the A-pillar

+ Less head rotation is needed to monitor both sets of mirrors. (4)
+ Although the combined area of obscuration caused by the A-pillar and near-side mirrors is the same there is now a gap between them which is beneficial. (4)
+ Forward mounting the mirrors seems to prevent them collecting so much rain and wheel spray so they stay drier and cleaner. (2)
- The mirror arm extending forward of the vehicle reduces the available space to manoeuvre. Many depots and road junctions are not designed with articulated HGV's in mind and all available space is required. (6)

1200mm radius of curvature rear-view mirrors

+ There is no obvious difficulty or appreciable difference in judging the distance to objects viewed through the 1200mm radius of curvature mirrors. (8)
- There is a slight difference in distance perception between near-side and off-side mirrors. (2)

Wide-angle mirrors

+ The wide-angle mirrors on both the near-side and off-side are best mounted below the rear-view mirrors. (6)
+ All of the semi-trailer's swing on both the near-side and off-side could be seen on sharp turns. (3)

Forward-viewing mirror

+ Forward-view mirror is useful when manoeuvring in tight yards close to walls and in towns where pedestrians cross the road close to the front of the vehicle. (3)
- Forward-view mirror in its current position cannot be seen through an area of the windscreen swept by the wipers. (1)

Close-proximity mirror

- The image quality is poor because the radius of curvature is too small. (6)

Near-side mirrors adjustable from the driver's seated position.

+ Good for contract drivers who are continually driving different vehicles. (2)
+ Could temporarily adjust mirrors to cope with extreme road junctions. (1)

CCTV

+ Reversing was safer and could be achieved more accurately and confidently using the CCTV system. (10)
- The CCTV monitor needs shielding from the sun and/or mounting at the top of the A-pillar. (2)

General

+ The combination of modified rear-view mirrors and wide-angle mirrors allow overtaking cars to be viewed for the entire length of the vehicle and in all adjacent lanes. (3)
+ Overall, the field of view in the modified vehicle is an improvement over standard mirror configurations. (10)

2.4. Bus – long-term validation trial

A double-deck bus, operated by a local city operator, was to be modified with the field of view improvement specification proposed as a result of the computer-modelling and testing procedure. However, due to constraints imposed by the vehicle's construction and its operational duties, the improvement specification required significant alteration from that initially proposed.

The constraints were revealed during discussions with the operators and are described below:

- Mounting mirrors forward of the A-pillar would not be possible as their buses go through an automatic vehicle wash on a daily basis. Any items protruding significantly from the vehicle would cause damage to either the mirrors and/or washer brushes.

- The size and the number of mirrors proposed could not be accommodated with current bus designs. Multiple, large mirrors could not be positioned such that they could all be seen by the driver and yet still be mounted high enough to avoid the heads of pedestrians or passengers waiting by the kerb side.

- The rate at which the rear-view mirrors of buses are struck and damaged is such that electrically adjustable mirrors would not be cost effective.

As it was recognised that buses have a specific problem, due to their operational environment and high interaction with vulnerable road users, a compromise field of view improvement strategy was investigated.

2.4.1. Test Vehicle

The bus used in the validation trial had a double-deck body on a Dennis Trident, low floor chassis (Figure 5).

Figure 5. Modified D/D bus (Dennis Trident)

2.4.2. Methodology

The new field of view improvement specification incorporated a CCTV system with two cameras. One camera viewed the near-side of the bus while a second viewed the area to the immediate rear when reversing.

A recent collaboration project between a mirror manufacturer and a CCTV supplier has led to the development of a rear-view mirror fitted with two-way mirrored glass and a CCTV camera mounted in the housing behind the glass. This combined mirror/camera unit was fitted as part of the alternative improvement specification. The mirror used in this combined unit was larger than the standard bus item as it had originally been intended for HGV use.

The CCTV monitor was mounted in the drivers' cab such that the off-side mirror and monitor could be viewed within close lines of sight. This arrangement permitted the near-side of the vehicle, including the passenger entry/exit door and pavement area, to be monitored whilst attending to the off-side mirror when moving away from the kerb. Additionally, the manufacturer of the bus had fitted a second CCTV system to allow the driver to monitor the bus's upper deck (Figure 6).

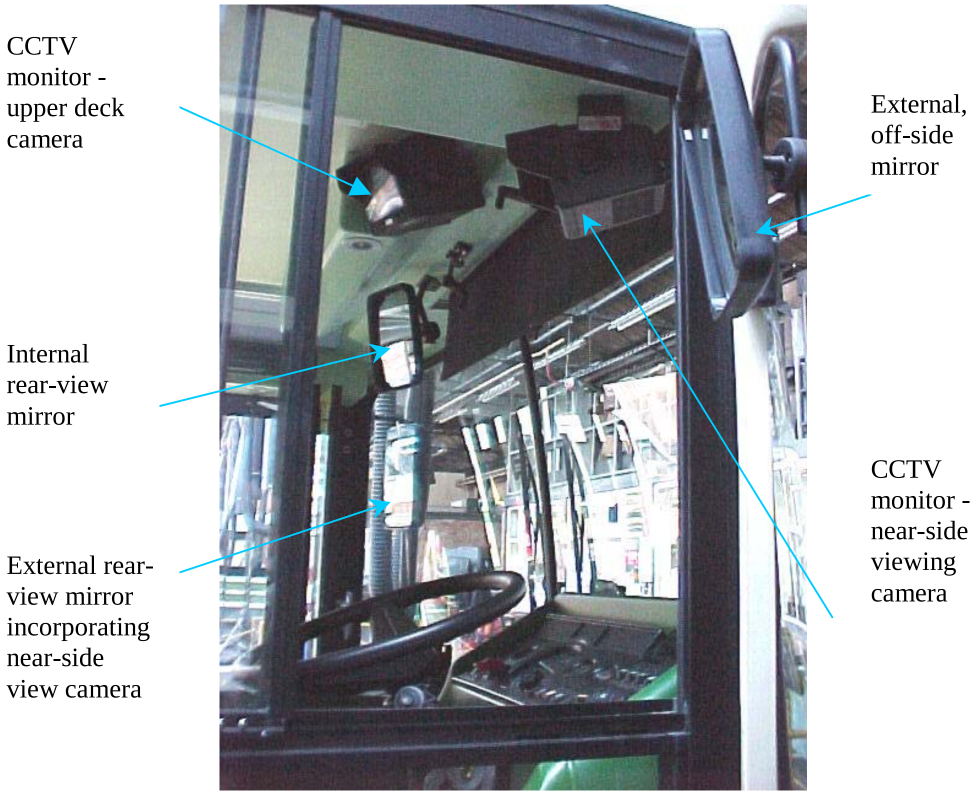

Figure 6. Bus drivers' cab with alternative CCTV option fitted.

2.4.3. Results – driver feedback evaluation

Approximately 10 drivers operated the bus modified with the field of view improvement specification, of which six responded with evaluation feedback. Driver responses had to be collected via a self-completed questionnaire, which ultimately reduced the quality of the data that could be collected. This remote method of data collection was due to reluctance on the part of the bus operating company to expose drivers to personal interviews either during or after shifts.

Generally, responses to the questionnaire indicated reluctance on the part of drivers to see a CCTV monitor as another form of mirror placed in a more convenient position. None of the drivers said they would consider using the camera's view to the near-side of the bus without also checking the near-side mirror. When asked why not, responses indicated that force of habit was too strong or that they had interpreted the question such that they were being asked to drive the vehicle by CCTV monitor view alone. This, not surprisingly, was considered dangerous.

Five of the six drivers considered that there were too many mirrors and monitors in the bus and that they would not like to see similar systems in other buses. However, they all rated favourably the CCTV system as a reversing aid.

2.4.4. Conclusions

The concern of some drivers that they were now overwhelmed by mirrors and CCTV monitors had been compounded by the manufacturer of the bus. They had supplied the test vehicle with an additional mirror and CCTV system to monitor the interior, lower and upper decks respectively. The number of monitors could be reduced by combining the two CCTV systems so that near-side, rear and upper deck camera views were shared by the same monitor. Camera views could then be presented automatically under certain vehicle states (i.e. reverse gear being selected), or manually as required by the driver.

Some of the written responses to the questionnaire indicated that drivers had misinterpreted some questions. They responded as if they were being asked to consider using the near-side camera's view as the sole means of navigating the vehicle to the curb when coming to a halt. It was only ever intended that the near-side CCTV monitor be used in a manner similar to that of a rear-view mirror, i.e. with regular glances, and then predominantly whilst pulling away from stationary.

Because no meeting could be arranged with the drivers, to brief them more thoroughly on each part of the field of view improvement system, it was felt that the validity of this trial had been compromised. Under the restrictions imposed by current bus designs, it was however felt that the alternative specification did provide drivers with improved visual coverage. Only small detail changes and perhaps a longer driver familiarisation period would be required to see a more general acceptance.

3.0 Modifications to the initial improvement specifications

The initial field of view improvement specifications, proposed as a result of the computer modelling process, considered only the means to provide maximum quantity of visual coverage against the benchmark requirement. What was not considered at this stage was the final image quality or the practicality of applying the specification under real world conditions. The following section outlines the modifications required to the initial specification because of these factors.

3.1. Mounting mirrors forward of the near-side A-pillar

Mirrors should only be mounted forward of the near-side A-pillar if, when positioned so that the driver can view them all, no part of the mirror or its mounting arm is below a height of two meters.

Future large vehicle designs should consider the relationship between the range of drivers' eye heights, the upper extremity of the windscreen's glazed area and a forward-mounted mirror arrangement permitting full view of the mirrors and 2m ground clearance.

3.2. Class V, close-proximity mirror specification change

The radius of curvature for the Class V, close-proximity mirror, initially proposed at 200mm, is too small to provide an image of sufficient clarity. Whilst the close-proximity mirror is predominantly used to detect the presence of an object, rather than to identify its nature, the image provided was still too small to achieve satisfactory detection.

A radius of 200mm was initially proposed because when computer modelled it covered an area of the benchmark field of view requirement that was not adequately covered by other means. However, road validation trials demonstrated that appropriate visual coverage could be achieved with a standard class V mirror (nominal radius of 400mm) used in conjunction with a forward-mounted rear-view mirror of 1200mm radius and a wide-angle mirror mounted below it.

3.3. Final field of view improvement specifications

Articulated HGVs

- Reduce the Class II, rear-view mirror's minimum convex radius of curvature to 1200mm.
- Fit an additional Class IV, wide-angle mirror to the off-side of the vehicle, mounted below the Class II, rear-view mirror (the wide-angle mirror currently fitted to the near-side should also be mounted below the Class II, rear-view mirror).
- Fit a forward-viewing mirror with a 200mm (minimum) radius of curvature, to the near-side, such that it provides a view to the immediate front of the vehicle.
- Mount all near-side mirrors forward of the A-pillar so that they can be viewed through an area of the windscreen swept by the windscreen wipers.
- Provide the means to remotely adjust the near-side mirrors from the driver's seated position.
- Fit a reversing aid CCTV system.
- Design instrument binnacles to reduce their intrusion in to the driver's line of sight to the lower edge of the windscreen.

Rigid HGVs

- Reduce the Class II, rear-view mirror's minimum convex radius of curvature to 1200mm.
- Fit Class IV, wide-angle mirrors below the near-side and off-side rear-view mirrors.
- Fit a Class V, close-proximity mirror (450mm radius of curvature) to the near-side.
- Fit a forward-viewing mirror, with a 200mm (minimum) radius of curvature, to the near-side such that it provides a view to the immediate front of the vehicle.
- Mount all near-side mirrors forward of the A-pillar so that they can be viewed through an area of the windscreen swept by the windscreen wipers.

- Provide the means to remotely adjust near-side mirrors from the driver's seated position.
- Fit a reversing aid CCTV system.
- Design instrument binnacles to reduce their intrusion in to the driver's line of sight to the lower edge of the windscreen.

Coach

- Reduce the Class II, rear-view mirror's minimum convex radius of curvature to 1200mm.
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- Fit a forward-viewing wide-angle mirror, with a 200mm (minimum) radius of curvature, to the near-side such that it provides a view to the immediate front of the vehicle.
- Mount all near-side mirrors forward of the A-pillar so that they can be viewed through an area of the windscreen swept by the windscreen wipers.
- Provide the means to adjust all mirrors from the driver's seated position.
- Fit a reversing aid CCTV system.
- Design instrument binnacles to reduce their intrusion in to the driver's line of sight to the lower edge of the windscreen.
- Design internal furniture to the near-side of the driver, such as the entry/exit door, steps and co-driver's seating, to reduce direct vision obscuration of the windscreen and immediate near-side.

3.4. Buses' field of view improvement specification

With current designs and operational requirements of buses, much of the initially proposed field of view improvement specification was inappropriate to implement. However, a compromise specification, which incorporates an additional CCTV camera, viewing the near-side of the vehicle, resolved the main areas of concern. The revised specification for buses is:

- Reduce the radius of curvature of the Class II rear-view mirror to 1200mm.
- Fit a forward-viewing wide-angle mirror, with a 400mm radius of curvature, to the interior near-side A-pillar such that it provides a view to the immediate front of the vehicle.
- Provide the means to remotely adjust near-side mirrors from the driver's seated position.
- Fit a two-camera CCTV system. One camera to monitor directly behind the vehicle and one to monitor the near-side of the vehicle including the passenger entry/exit doors. The monitor is to be mounted in the cab so that the driver's line of sight to it is close to that of the off-side mirrors.
- Design instrument binnacles to reduce their intrusion in to the driver's line of sight to the lower edge of the windscreen.
- Design internal bus furniture, such as driver's screening and automatic ticketing technology, to reduce direct vision obscuration of the windscreen, passenger entry/exit door and first near-side window area.

4.0 Technical detail of the field of view improvement specification

4.1. Additional mirrors

The minimum number of each class of mirror to be fitted to each category of large vehicle, currently specified by EC Directives, is not sufficient to provide adequate visual coverage of the benchmark field of view requirement. Therefore, additional mirrors have been specified to permit full coverage. A diagrammatic representation of the approximate ground area covered by each of the proposed mirrors is shown in Figure 7, followed by a technical specification for each mirror.

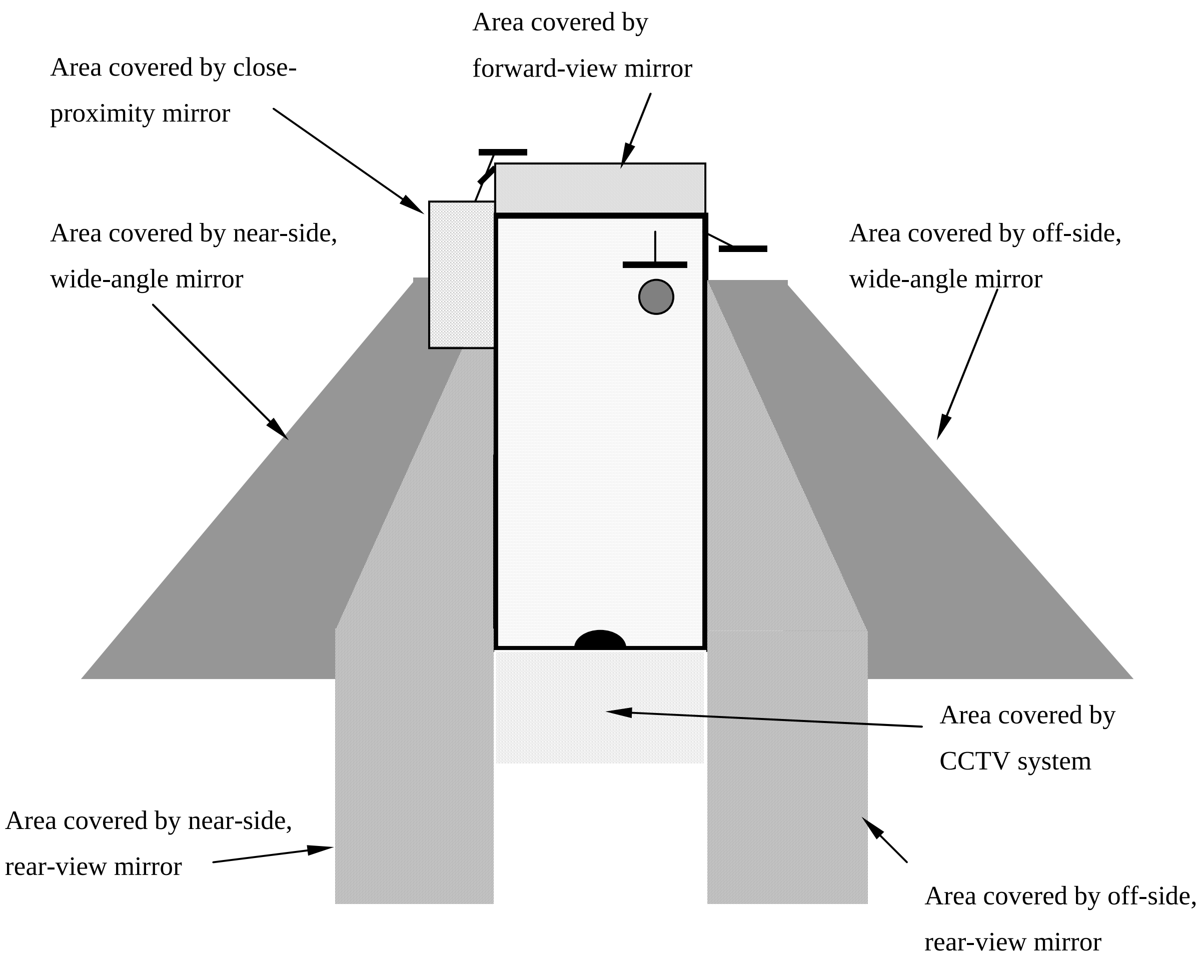

Figure 7. Approximate ground area covered by mirrors and CCTV.

4.1.1. Near-side, wide angle (class IV) mirror

A near-side, wide angle mirror of rectangular dimensions approximately 150mm x 250mm and with a convex radius of curvature of 400-450mm should be fitted to all large vehicles (*Currently, a wide angle mirror is only a requirement on the near-side of category N_3 articulated tractors*). Exemption from this requirement may be necessary where current large vehicle designs will not permit mirrors to be mounted so that none of their parts is less than 2m above the ground.

4.1.2. Off-side wide angle (class IV) mirror

An off-side, wide angle mirror of rectangular dimensions approximately 150mm x 250mm and with a convex radius of curvature of 400-450mm should be fitted to all large vehicles (*Currently there is no requirement for any off-side wide angle mirror*).

Off-side and near-side wide angle mirrors should be mounted below the rear view mirrors to maximise coverage of the floor area to the front of the vehicle. Wide angle mirrors fitted to both the near-side and off-side will be of benefit to drivers operating large vehicles internationally.

4.1.3. Forward viewing mirror

A forward viewing, wide angle mirror with a convex radius of curvature of 200mm (minimum) should be fitted to all large vehicles (*Currently no provision is made for coverage of the area immediately to the front of large vehicles*). This mirror may be mounted internally on the near-side A-pillar or externally, forward of the A-pillar. An internal mounting position may be required where a minimum mounted height of 2m can not be achieved

4.1.4. Close-proximity (class V) mirror

A near-side, kerb viewing mirror with a convex radius of curvature of 400mm to 450mm should be fitted to the near-side cant rail of all large vehicles (*Currently, a close-proximity mirror is only a requirement on the near-side of category* N_3 *articulated tractors*). Exemption from this may be granted where near-side doors are used for regular passenger entry and exit or where adequate direct vision to the kerb is possible, i.e. buses and coaches. The close proximity mirror may in fact become redundant with the improved coverage of the kerb/floor area provided by the wide angle mirror mounted forward of the A-pillar and below the rear-view mirror.

4.2. Modified Class II rear-view mirrors

Near-side and off-side class II rear-view mirrors of rectangular dimensions approximately 400mm x 200mm and a convex radius of curvature of 1200mm should be fitted to all large vehicles (*The current minimum convex radius of curvature for Class II rear-view mirrors is 1800mm*).

4.2.1. Remotely adjustable mirrors

Ideally, all mirrors should be adjustable from the driver's normal seated position and posture. However, in the interests of cost/benefit efficiency, a minimum requirement would be that near-side mirrors are adjustable by remote means, providing that off-side mirrors can be adjusted manually by the driver from a seated position. The small radii of curvature of the forward-view and close-proximity mirrors means that adequate views can be achieved from most driver's eye positions without the necessity to adjust these mirrors.

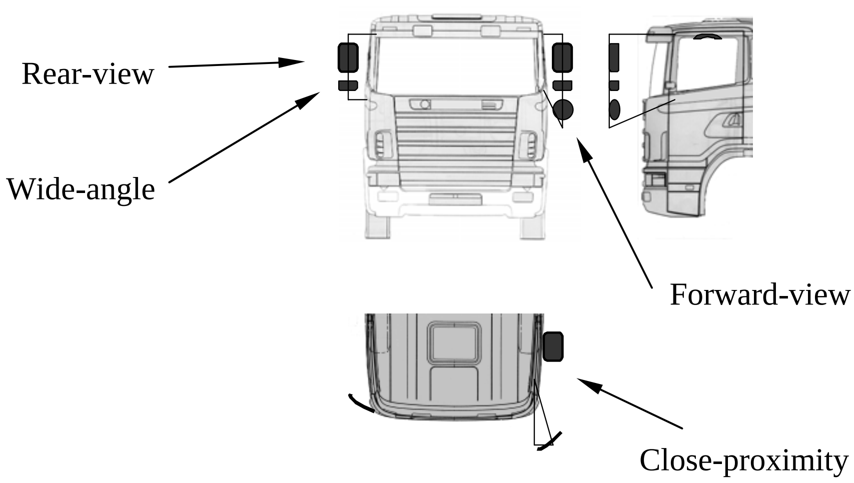

Figure 8. Proposed positioning of additional and modified rear-view mirrors

4.3. Near-side mirrors mounted forward of the A-pillar

External near-side mirrors should be mounted forward of the A-pillar such that they are viewed by the driver through an area of the windscreen swept by the windscreen wipers.

4.4. Vehicle reversing safety aids

CCTV systems can provide drivers with a view to areas around their vehicles not easily achieved by any other means.

4.4.1. CCTV as a reversing aid

All large vehicles should be fitted with a CCTV reversing aid system such that the monitor provides the driver with a view of the area immediately behind their vehicle. The view afforded the driver should extend for at least 10m behind the vehicle and view the entire width of the vehicle for location reference purposes. Vehicle construction that will not permit cameras to be mounted in such a way as to achieve this view may have cameras mounted in lower positions that achieve as much of the recommended viewing area as is possible.

4.4.2. CCTV as a near-side vision aid

On many large vehicles operating in urban areas, but especially on buses, the operational nature of the vehicle necessitates that there is high interaction with vulnerable road users on the near-side (boarding and alighting passengers, pedestrians, cyclists). CCTV can provide improved vision to the near-side area, whilst careful positioning of the monitor will permit drivers to continue observations to the off-side whilst pulling away from kerbs or lane changing etc.

4.4.3. Proximity warning devices

None of the proximity devices tested by ICE Ergonomics performed with a satisfactory degree of reliability, accuracy and speed of response. During our trials (see Phase 3, Section 7.5 for details) a 1m tall child target was too often not detected in areas behind the vehicle deemed to be important. Additionally, auditory warnings were either confusing, failed to activate or were slow to respond to changing conditions. For these reasons, we would not recommend proximity detection devices as the sole means of providing drivers with information about the area immediately behind their vehicle.

5.0 Proposed Directive defining large vehicle fields of view

The following section proposes ways in which a new or modified Directive might legislate for a minimum requirement for the drivers' field of view from large vehicles. The proposed Directive takes the benchmark field of view requirement as the standard upon which to base any controlling legislation.

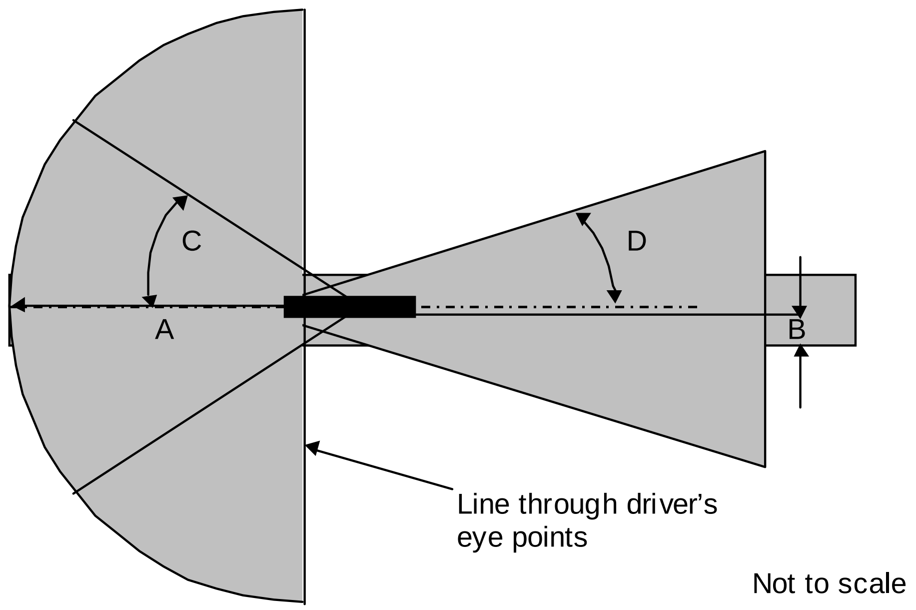

Figure 9. ICE Ergonomics field of view requirement

The benchmark field of view requirement (Figure 9) is based on:

- an average estimated stopping distance for large road vehicles travelling at 56mph (A= 90m);
- the recommended lane width for a district distributor road (B=3.65m);
- the angle 'C', emanating from a point at half the vehicle's length and extending forward through a point defined by the vehicle's front near-side or off-side corner after a full-lock right or left forward turn which leaves the vehicle's

vertical longitudinal plane, or the tractor unit's vertical longitudinal plane in the case of an articulated vehicle, perpendicular to its starting position;

- the angle 'D', emanating from a point at the vehicle's front near-side or off-side corner and extending backwards through a point defined by the vehicle's rear near-side or off-side corner, or the rear near-side or off-side corner of the tractor unit in the case of an articulated vehicle, after a full lock right or left reverse turn which leaves the vehicle's vertical longitudinal plane perpendicular to its starting position or the point of full articulation in the case of an articulated vehicle.

The main condition for the proposed Directive is that all the areas defined by the benchmark field of view requirement can be seen either by direct or indirect means but that maximum coverage by direct means is desirable.

5.1. Existing direct field of view regulations

Direct fields of view are currently defined relative to vehicle and driver reference points and a three-dimensional reference grid. The main reference points are:

- R point or seating reference point - the reference point specified by the vehicle manufacturer which has co-ordinates determined in relation to the vehicle structure and corresponds to the theoretical position of the point of torso/thighs rotation (H point) for the lowest and most rearward normal driving position.

- Design seat-back angle - the angle prescribed by the vehicle manufacturer which determines the seat-back angle for the lowest most rearward normal driving position and is formed at the R point by the vertical and the torso reference line.

- V points - the points whose position in the driver compartment is determined as a function of vertical longitudinal planes passing through the centres of the driver's seat and in relation to the R point and the design angle of the seat-back.

Currently, Directive 77/649/EEC, relating to vehicles in category M_1 only, defines the minimum drivers' direct vision requirement in the following terms:

'Other than the obstructions created by the "A" pillars, the fixed or movable vent or side window division bars, outside radio aerials, rear-view mirrors and windscreen wipers, there should be no obstruction in the driver's 180° forward direct field of vision below a horizontal plane passing through V_1, and above three planes through V_2, one being perpendicular to the plane X-Z and declining forward 4° below the horizontal, and the other two being perpendicular to the plane Y-Z and declining 4° below the horizontal'.

Also:

'The transparent area of the windscreen must include at least the windscreen datum points; these are:

- *a horizontal datum point forward of V_1 and 17° to the right*
- *an upper vertical datum point forward of V_1 and 7° above the horizontal*
- *a lower vertical datum point forward of V_2 and 5° below the horizontal'.*

The application of this Directive to large vehicles in categories M_2, M_3, N_2 and N_3 is not appropriate for a number of reasons. Defining a minimum forward direct vision requirement by using a fixed angle of decline from a horizontal plane, running through the V point, takes no account of the V point's height above the ground. The V point is positioned relative to the R point, which in turn corresponds to the H point for the lowest rearward position of the driver's seat adjustment range.

Subsequently, a typical car may have a driver's V point 1.2m above the road's surface, while an HGV driver may have a V point at 2.5m above the road's surface (Figure 10). The driver of a car which conforms with minimum requirement to the current direct vision Directive, i.e. direct vision is obstructed up to but not beyond a plane through V_2 and declining 4° from the horizontal, would first see the road's surface in front of their vehicle at about 17m, whereas, the driver of a similarly specified HGV would first see the road at 35.5m.

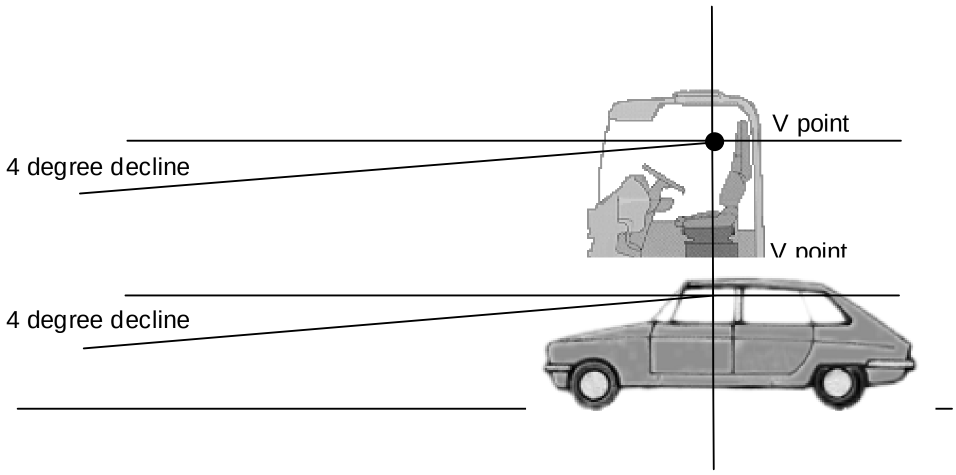

Figure 10. Drivers' forward direct vision.

Similarly, with a 4° decline from the horizontal for planes left and right of the vehicle, the effective height of the V point above the ground again determines the stringency of the direct vision specification (Figure 11).

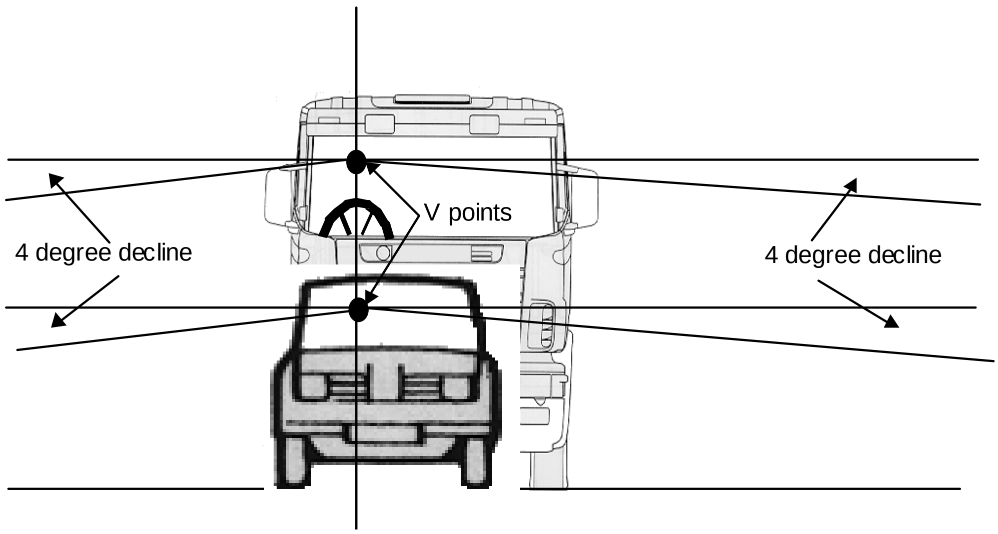

Figure 11. Drivers' near-side and off-side direct vision

5.2. Proposed method of defining a minimum direct field of view requirement

An ideal direct vision requirement for large road vehicles would be that no feature of the vehicle's design should prevent driver's visual coverage, by direct means, of the 180° forward field of view. However, any new legislative requirement must be realistic and achievable without major alterations to the basic nature of current large vehicle designs. Therefore, obstructions created by "A" pillar, the fixed or movable vent or side window division bars, outside radio aerials, rear-view mirrors and windscreen wipers are permitted. The angle of obstruction for each "A" pillar shall not exceed 6° and no vehicle shall have more than two "A" pillars.

Rather than defining direct vision requirements by declining planes emanating from V points, above which no obscuration will be permitted, a minimum direct field of view requirement might take the following format: (see also Figures 12 and 13 below)

- all of a sphere with a diameter equivalent to that of the head of a 50^{th} %ile adult (19 to 65 years) female - *0.18m*,
- the top of which is at a height above the ground equivalent to the 50^{th} %ile adult (19 to 65 years) female's stature - *1.61m*,
- must be seen from an eye level corresponding to the height of V_2 ,
- at 5 equally spaced points - *0.73m apart*,
- which extend across the front of a vehicle which is positioned centrally in a lane with a width equal to that recommended for a district distributor road - *3.65m*,
- and running parallel with the vehicle's front at a distance of 2.5m from the most forward point of the vehicle.

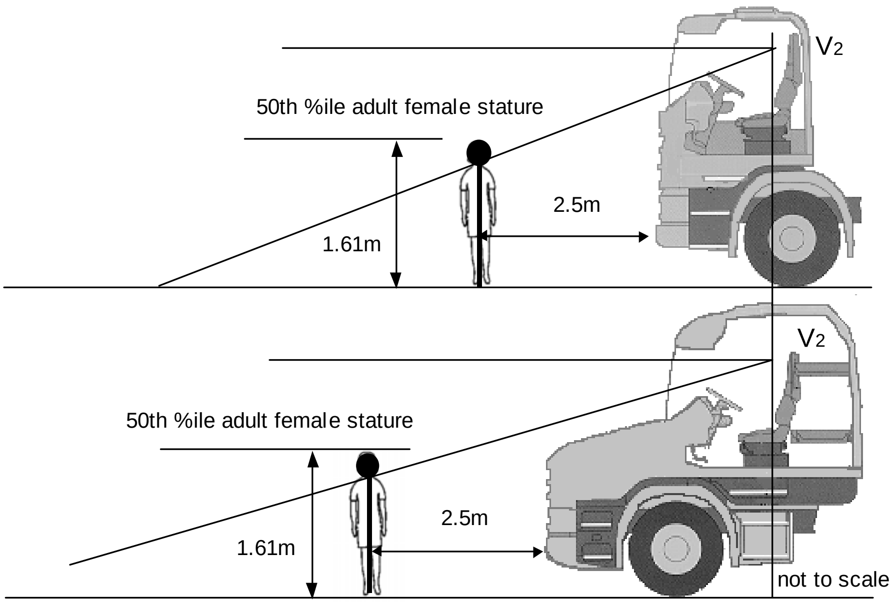

Figure 12. Proposed minimum requirement for forward direct vision

Direct vision to the near-side and off-side would be similarly specified by viewing the same target sphere at a distance of 2m from the longitudinal sides of the vehicle and at three points equally spaced between a transverse line passing through the V point and a parallel line passing through the forward most point of the windscreen (Figure 13). Vehicle designs that permit direct visual coverage extending rear of the forward 180° are to be encouraged. Extended direct visual coverage should be taken into consideration when assessing the indirect field of view coverage.

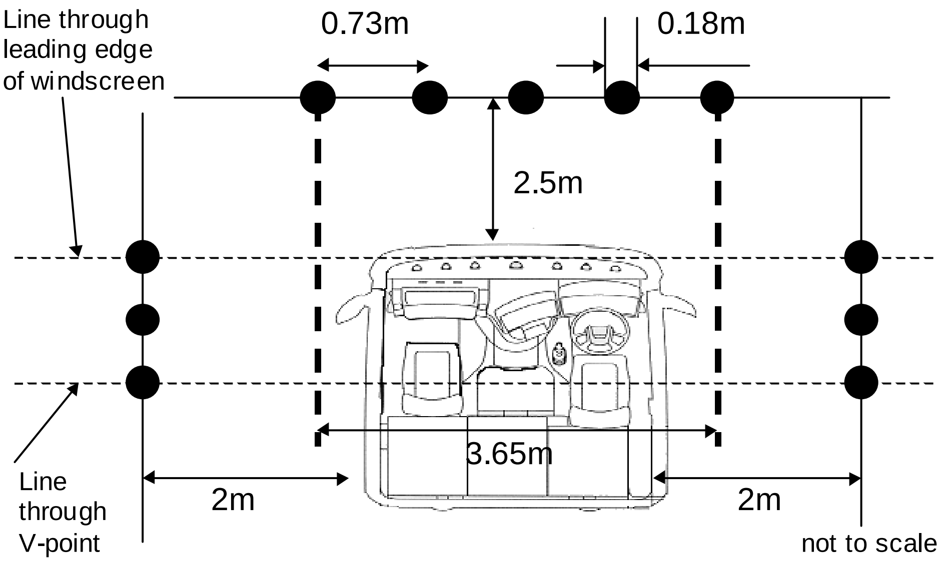

Figure 13. Proposed minimum requirement for forward and side direct vision

Defining a direct field of view requirement in this way now takes into account the human and environmental conditions under which a vehicle will operate as opposed an arbitrary angle of inclination above which obscuration is not permitted.

5.3. Proposed method of defining a minimum <u>indirect</u> field of view requirement

Any area at ground level specified by the benchmark field of view requirement and not included in the forward 180° zone, but excluding the area immediately behind the vehicle, should be visible to the driver by indirect means (usually by using convex rear-view mirrors).

Additionally, any area in the forward 180° zone not covered by minimum direct vision requirements should also be visible to the driver by indirect means (usually by using convex rear-view mirrors).

The area directly behind the vehicle should be visible to the driver by means of a reversing aid viewing technology (e.g. a CCTV system).

5.3.1. Convex mirrors - specification and positioning requirements

The minimum radii of curvature for convex vehicle mirrors should be as specified in Table 1.

Table 1. Proposed minimum radii of curvature for convex vehicle mirrors

Mirror	Minimum convex radius of curvature
Class II - rear-view	1200 mm
Class III - rear-view	1200 mm
Class IV - wide-angle	400 mm
Class V - kerb view and forward view	400 mm
Forward View	250mm

To achieve full coverage of the benchmark field of view requirement, other than the area directly behind the vehicle, it is recommended that the required minimum number and category of mirrors be as described in Table 2.

Table 2. Proposed minimum number of mirrors required

Vehicle category	Interior or Exterior	Exterior rear-view mirrors		
		Main rear-view mirrors	Wide-angle	Close-proximity
	Forward View	Class II	Class IV	Class V
M2	1	2	2	1
M3	1	2	2	1
N2	1	2	2	1
N3 Rigid	1	2	2	1
N3 Articulated	1	2	2	1

Where only 1 mirror is specified this will be fitted to the near-side of the vehicle,

The recommended arrangement of exterior mirrors, as viewed from a driver's perspective, are shown at Figure 14. It should be noted that all near-side mirrors, with the exception of the Class V close-proximity mirror, are mounted forward of the 'A' pillar such that they are viewed by the driver through an area of the windscreen that is swept by the windscreen wipers.

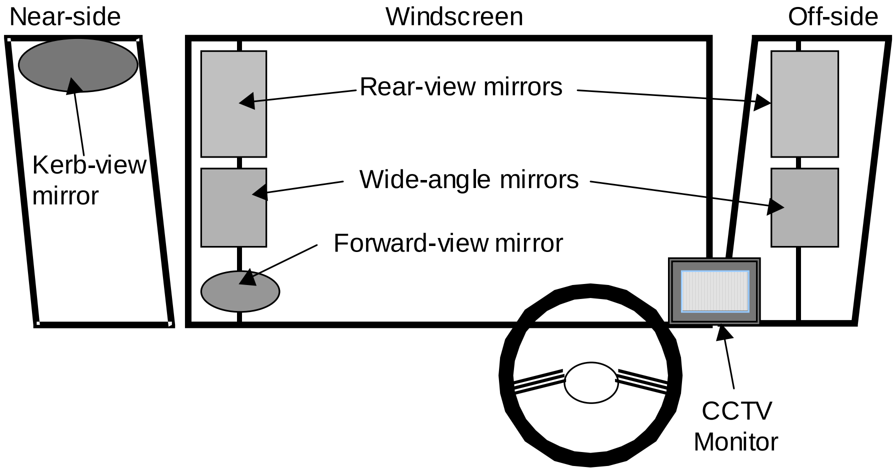

Figure 14. Proposed positioning and arrangement of mirrors

Ideally, all exterior rear-view mirrors should be adjustable from the driver's normal driving position and posture.

5.3.2. Minimum indirect field of view requirement in the forward 180°

A minimum requirement for indirect driver vision in the forward 180° zone, providing that the minimum direct vision requirement has been fulfilled, should be as follows: (see Figures 15 and 16)

- all of the profile of a cylinder with a diameter equivalent to the 50^{th} %ile shoulder breadth of a 3-4 year old child - *0.26m*,
- with a height equivalent to the 50^{th} %ile stature of a 3-4 year old child - *1.0m*,
- should be visible (indirectly) when positioned:
- at any point across the entire width of the vehicle,
- along a line parallel to the front of the vehicle at a distance equivalent to the 50^{th} %ile shoulder breadth of a 3-4 year old child - approx. *0.30m*,
- and at any point along a line parallel to the near-side and to the off-side longitudinal planes of the vehicle,
- between two vertical lateral planes, one running through the V point and the other through the forward most point of the windscreen.

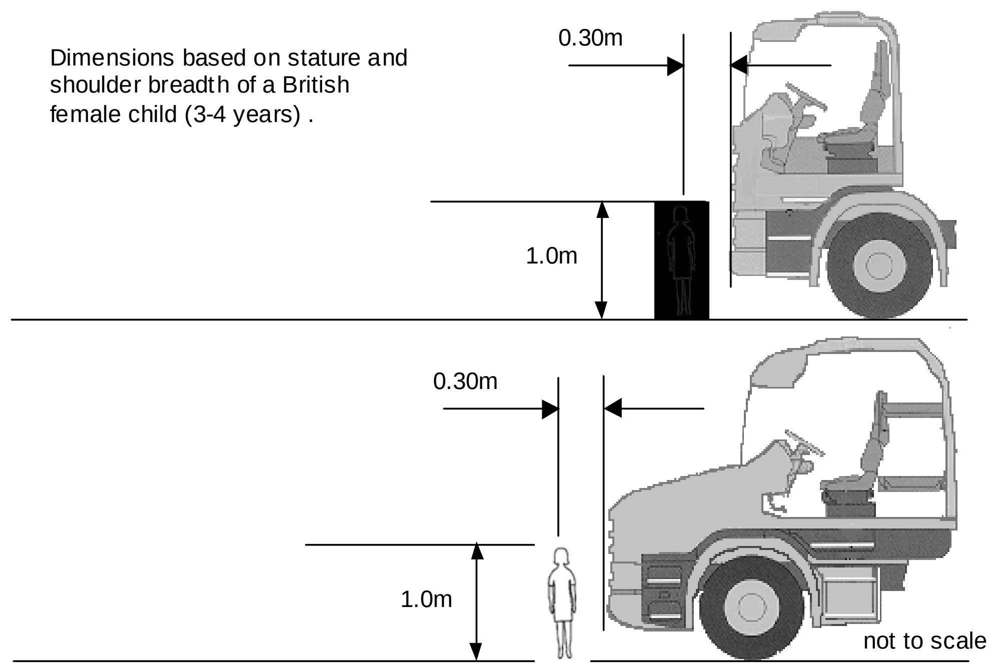

Figure 15. Proposed minimum requirement for forward indirect vision

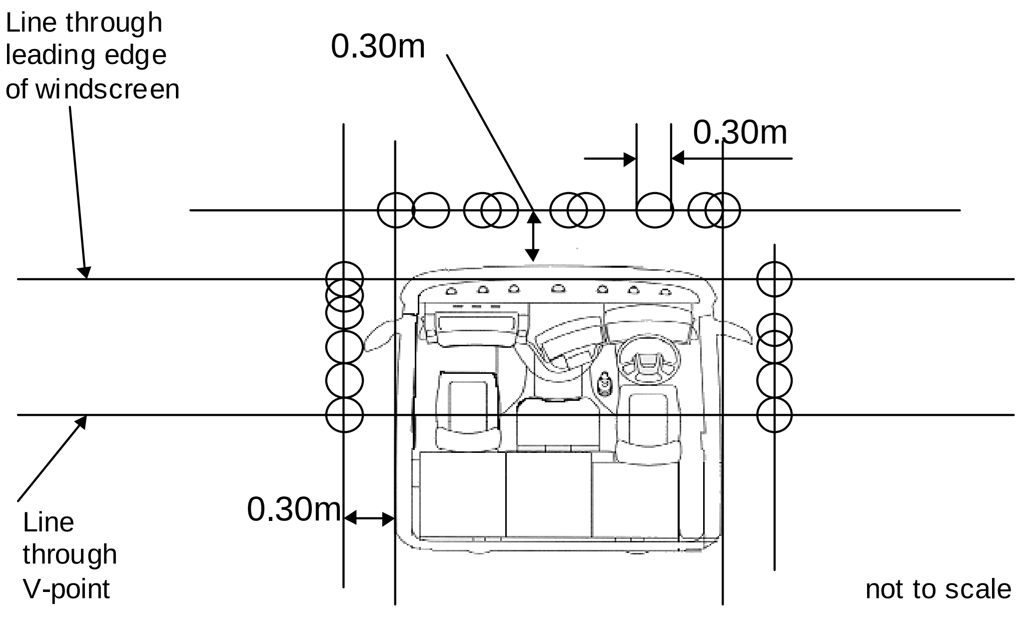

Figure 16. Proposed minimum requirement for forward and side indirect vision.

6.0 Cost/Benefit Analysis

Data that can directly relate insufficient or ineffective driver's vision as causal factors in road traffic accidents is sparse or incomplete so an alternative cost/benefit methodology is proposed.

First, the implementation cost of the field of view improvement specification to the UK's new, large vehicle fleet is calculated. This cost is then expressed in terms of the number of lives that would have to be saved as a result of the improvement specification to recoup the cost (DETR-RAGB97 - 'Average value of prevention per casualty'). Finally, from various sources of literature and some extrapolation of accident data, the likelihood of achieving the reduction in fatal accidents, attributable to the field of view improvement specification, is assessed.

In calculating the cost of implementation a number of assumptions and estimates have been made regarding the effects mass production and market forces may have on current unit prices and fitting costs.

The figures used to calculate costs are outlined below:

Approximate cost per additional mirror	£30
Approximate additional cost of electrically adjustable mirror	£20
Approximate cost per CCTV system (camera + monitor)	£150
Approximate cost per additional CCTV camera	£50

Large vehicles first licensed in 1997:	
• of which articulated	13200
• of which rigid	22000
Trailer stock	120000
New bus and coach registrations 1997	6600
Average value of prevention per fatal casualty	£902,500

The cost/benefit analysis is presented in three parts that consider separately the implementation of HGV mirrors only, CCTV as an HGV reversing aid and the combined near-side mirror/CCTV specification proposed for buses and coaches.

6.1. Implementation cost of mirrors to the UK's new HGV fleet

The improvement specification proposes three additional mirrors for rigid large vehicles and two for articulated tractor units.

Cost of fitting additional standard mirrors to the new HGV fleet.

£2,772,000

It is proposed that at minimum the near-side mirrors are remotely adjustable from the driver's seat.

Additional cost of converting to remotely adjustable near-side mirrors on new HGV fleet.

£1,408,000

Total implementation cost of HGV mirrors equates to a prevention value of:

5 fatalities

6.2. Implementation cost of CCTV reversing aids to the UK's new HGV fleet

Implementation cost of CCTV system to the HGV fleet

£5,280,000

Implementation cost of reversing aid CCTV systems equates to a prevention value of:

6 fatalities

6.3. Implementation costs to UK's new bus and coach fleet.

For the bus and coach specification, it is proposed that a two-camera CCTV system be used. One camera to monitor directly behind the vehicle and a second housed in the near-side mirror.

Implementation cost of bus and coach improvement specification.

£1,518,000

Implementation cost of bus and coach improvement specification equates to a prevention value of:

2 fatalities

From the above estimates, the cost of implementing to all large vehicles the drivers' field of view improvement specification compares to the average value of prevention of 13 fatal casualties.

The likelihood that 13 fatalities a year could be saved, as a result of improving driver fields of view from the UK's large vehicle fleet, would seem reasonable in light of a recent TRL report (Robinson 1994). This report studied 1049 fatal accidents involving at least one HGV and concluded that 16 lives a year might be saved simply by improving drivers' vision to the immediate frontal area. When improvements to the drivers' visual coverage in all other areas around the vehicle are also considered, especially whilst reversing, then a reduction in fatalities greater than 13 would seem realistic and feasible.

When the monetary savings from reduced non-fatal and vehicle damage only accidents are also taken in to account then the cost benefit associated with the field of view improvement specification becomes increasingly favourable.

7.0 Conclusion

The results from this research project support a conclusion that real, effective and cost efficient improvements can be made to the drivers' field of view from large vehicles. Preliminary recommendations, proposed as a result of the theory based investigation methodologies, required little modification after the validation road trials. Where modification to the preliminary specification was required, this has not significantly compromised drivers' visual coverage of the benchmark field of view requirement. During the validation trials, nearly all drivers considered that their field of view had been improved as a result of the modifications.

Future evaluation work in this area would require involvement and investment from large vehicle manufacturers to investigate the cost effectiveness of improving on the aesthetic aspects of the mirrors, CCTV, glazed area and cab furniture presentation. Increased glazed areas and mirror arms integral with the cab's design could eliminate safety concerns regarding mirror heights on some large vehicles. Aerodynamic, colour co-ordinated mirror housings may also make vehicles more aesthetically pleasing and improve driver acceptance and overcome resistance to change.

Future designs for large road vehicles may wish to investigate field of view improvement strategies which involve central and forward located driving positions or take advantage of improved technology to remove visual obscuration from drivers' cabs. However, the recommendations proposed in this report achieve the aim of improving drivers' fields of view and do so in a way that is cost efficient and easily incorporated on the majority of the UK's large vehicle fleet.

Ultimately, the full benefits of any field of view improvement specification will depend upon the driver having the capacity to attend to it. This attentional capacity is increased by reducing the workload imposed on the driver by other aspects of the driving task.

8.0 References

EEC Directive 77/649, relating to the field of vision of motor vehicle drivers (category M_1 vehicles only).

EEC Directive 71/127, relating to the rear-view mirrors of motor vehicles.

The Road Vehicles (Construction and Use) Regulations, 1986. No. 1078. Road Traffic. London: HMSO

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9.0 Acknowledgements

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