Drivers' field of view from large vehicles

Phase 3: Report

Undertaken on behalf of

The Department of Environment, Transport and the Regions (DETR)

Prepared by

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Executive Summary

In response to DETR's request to investigate ways and means of improving the drivers' field of view from HGV's, coaches and buses, nine representative vehicles were evaluated using CAD man-modelling techniques. Evaluation was made against a benchmark field of view requirement which was developed by ICE Ergonomics and based upon the swept path envelopes of large vehicles whilst manoeuvring and on road layout and design considerations. Each vehicle was assessed using eye-points for the 5th %ile female and 95th %ile male driver.

Where a driver's field of view fell significantly short of the benchmark requirement a number of improvement options were investigated. Predominantly, the options selected were those which were most cost-effective and entailed the use of additional and modified wide angle mirrors on both the near-side and off-side of the vehicle. When reversing, driver's visual coverage of the blind zone to the immediate rear was provided by a CCTV system.

To ensure that the CAD modelled solutions did not have a detrimental effect on other aspects of the driving task, and before road trials were conducted on the public highway, a number of user tests were carried out under controlled experimental conditions. Results showed that the minimum radii of curvature, currently stipulated for rear view mirrors, could be reduced without causing significantly greater numbers of driver judgement errors compared with existing mirror specifications.

Final verification of the field of view improvement specification proposed was achieved through road trials using drivers in modified large vehicles.

Contents

1. Introduction

The objective of this phase of the study is to carry out a detailed evaluation of the drivers’ fields of view from a sample of nine large vehicles, representative of the U.K.’s current HGV, bus and coach fleets. Drivers’ fields of view from each of the nine vehicles is evaluated, using a CAD man modelling system, against a field of view requirement developed by ICE Ergonomics in Phase 2 of this study. Any shortfalls in drivers’ fields of view against the requirement are identified and options for their improvement are investigated. The aim of any improvement is to maximise the driver’s view of the requirement either by direct or indirect means.

When a field of view improvement strategy is identified, a number of user (driver) trials of the proposed methods are tested to ensure they are not detrimental to driver’s judgements required in the driving task.

From this identification, improvement and testing process a number of field of view improvement strategies are proposed for each of the vehicles evaluated. The required changes to existing legislation or any new legislation that will be required to permit the improvement strategies to be implemented are also outlined

Finally, the implementation cost for the proposed field of view improvement strategy in the new, large vehicle fleet and its subsequent potential for casualty savings in the vulnerable road user population are analysed.

2. Detailed field of view requirement

2.1 Dimensions for drivers' field of view requirement

The initial field of view requirement, proposed in Phase 2 of this study, was in part defined using dimensions based on an estimated stopping distance for large vehicles travelling at 56mph - approximately 90m - and on the recommended lane width for district distributor roads - 3.65m (see Figure 1 below). These dimensions can be considered as generic in that they are independent of the vehicle type being considered.

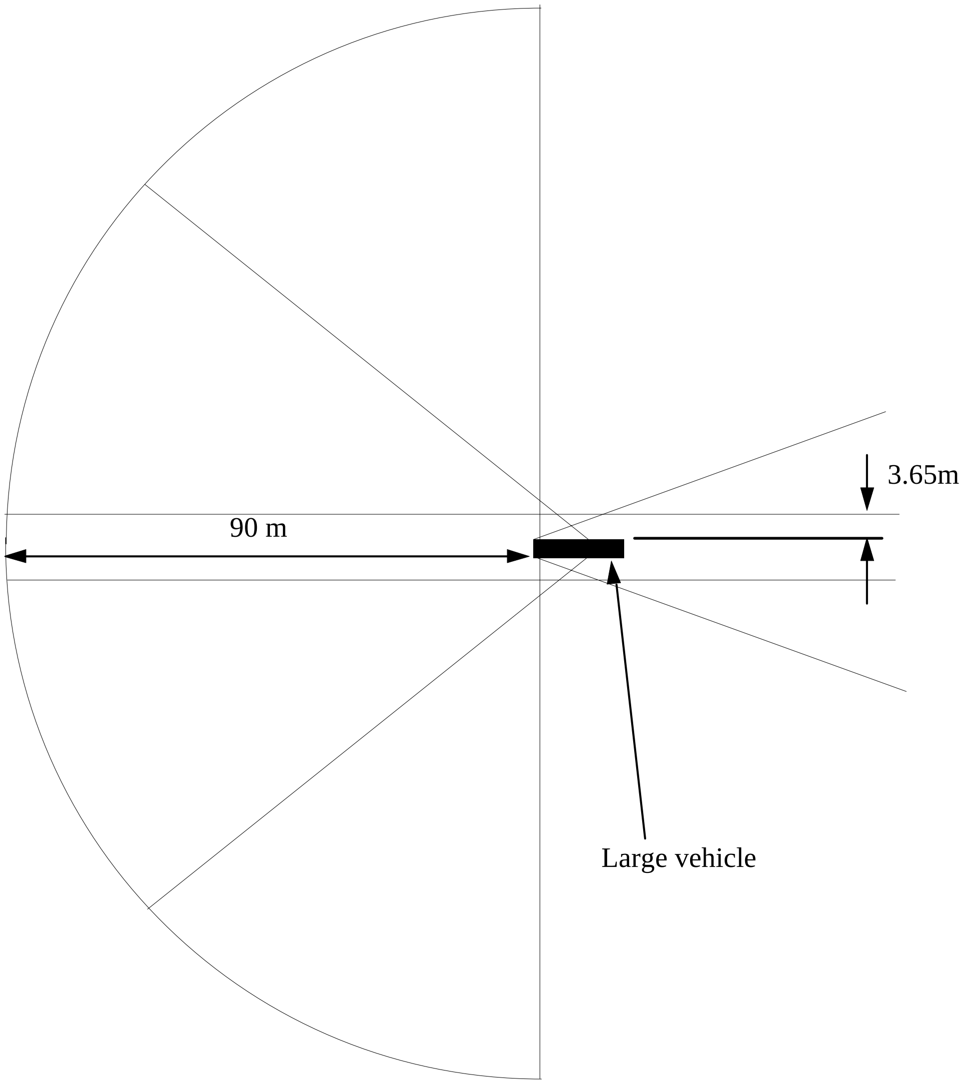


Figure 1. Field of View Requirement

However, the field of view requirement also includes areas covered by a vehicle when making left and right turning manoeuvres in either a forward or reverse direction. The angles of the lines defining these areas will differ with vehicle type. The ground area covered by a forward turning articulated vehicle is different to that described by a forward turning rigid vehicle or draw-bar vehicle.

Therefore, the angle of the lines will be defined in terms of vehicle lengths and widths with a different configuration for rigid, articulated or draw-bar vehicles. Inter-group variability should be eliminated as the dimensions proposed always err on the side of caution. The dimensions defining the left and right turning element of the requirement in both forward and reverse directions are shown below (Figures 2 to 7) for each of the vehicle types.

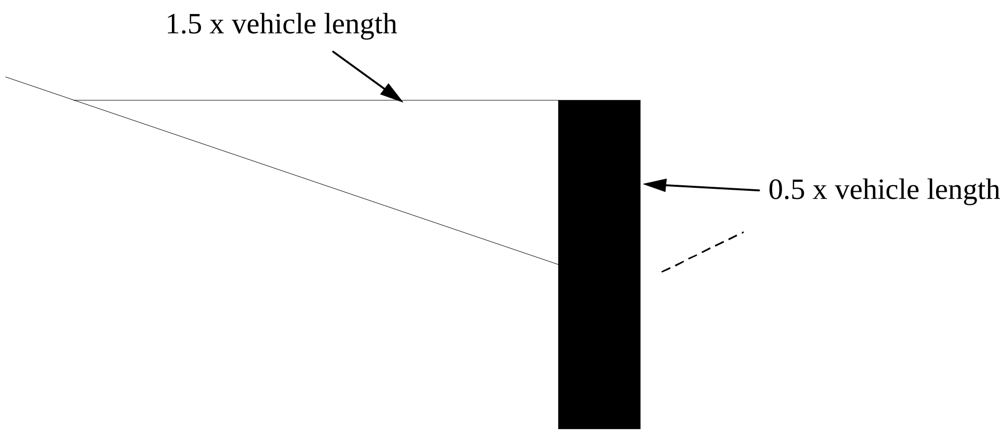


Figure 2. Rigid vehicle - forward turn fov requirement dimensions

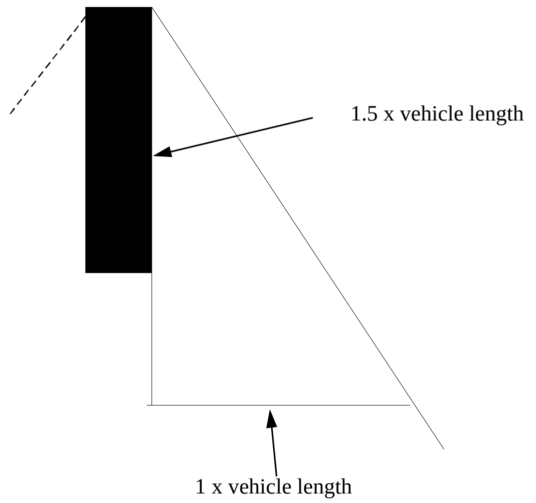


Figure 3. Rigid vehicle - reverse turn fov requirement dimensions

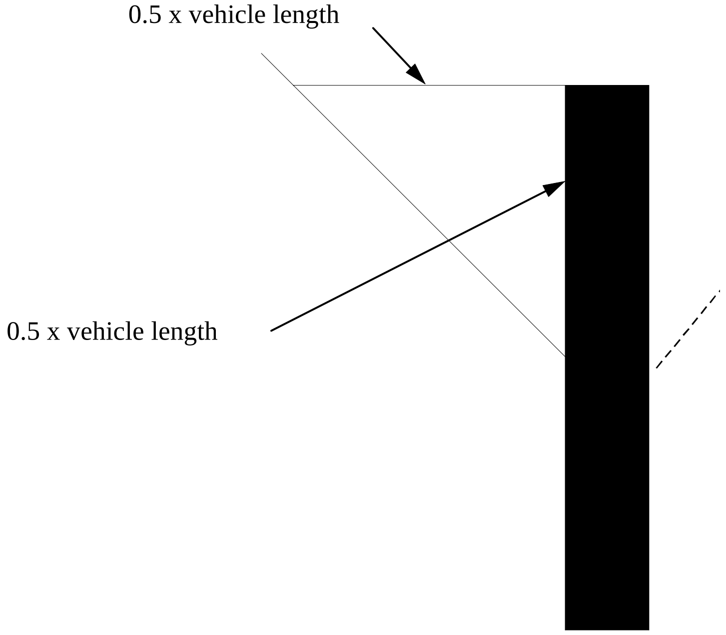


Figure 4. Articulated vehicle - forward turn fov requirement dimensions

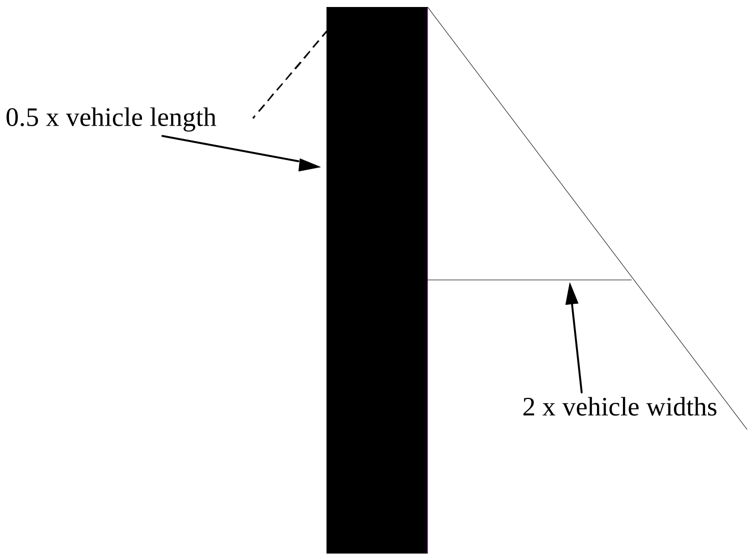


Figure 5. Articulated vehicle - reverse turn fov requirement dimensions

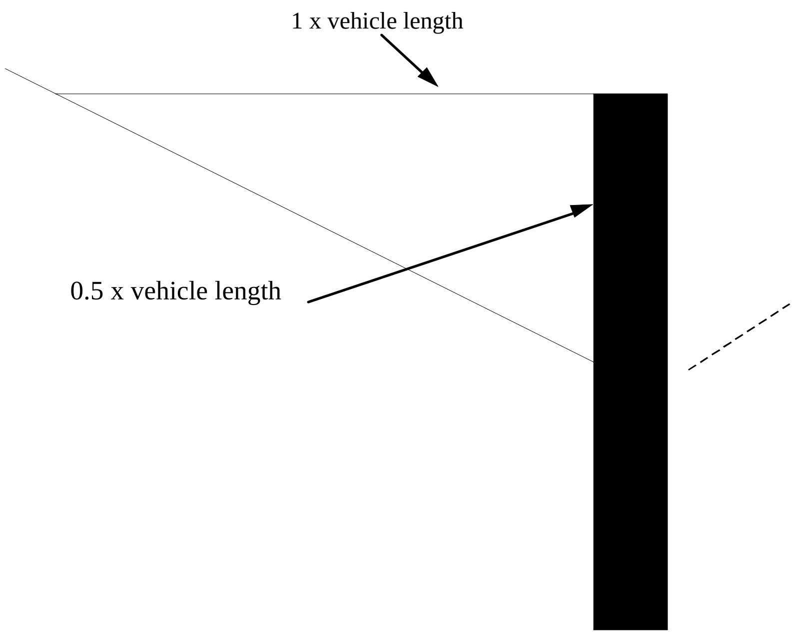


Figure 6. Draw bar trailer vehicle - forward turn fov requirement dimensions

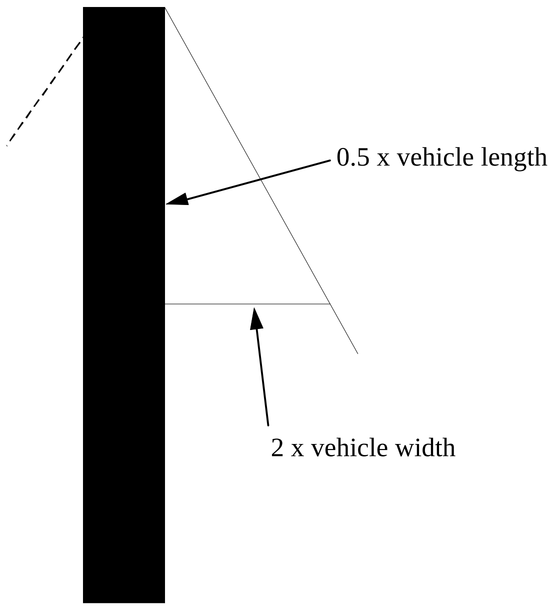


Figure 7. Draw bar trailer vehicle - reverse turn fov requirement dimensions

The dimensions outlined above will be used in the CAD evaluation of driver's field of view from large vehicles in the next chapter. Each vehicle's current field of view will be compared with the relevant requirement dimensions.

3. SAMMIE CAD Analysis

Computer evaluation of 9 large vehicles was carried out using the SAMMIE CAD ergonomics design system.

3.1 Vehicle selection and modelling

The nine large vehicles were selected by ICE Ergonomics for driver's field of view evaluation, predominantly on the basis of their high numbers of vehicle sales and registrations. The three HGV's, three buses and three coaches selected (see Table 1 below) were generally at the top of listings compiled by SMMT, BRF, and vehicle manufacturers for large vehicles operating on British roads and were considered to be representative of the current large vehicle fleet.

The nine vehicles were digitised using a Faro Co-ordinate Measuring Arm. The digitised data was imported to SAMMIE and was developed to provide 3D solid CAD models. All glazed apertures, mirror surfaces, display surfaces and the location of controls are accurately modelled. Other exterior surfaces, which do not affect driver vision, are included purely to improve the visual realism of the vehicles and are not necessarily accurate.

During the digitisation process the vehicle's seat motion envelope was established and H-point drops were recorded using a standard SAE H-point manikin. Additionally, approximate hip and eye points from human subjects were recorded in order to help establish realistic seated positions and eye points for the CAD human models.

For each vehicle a 5th percentile UK female and a 95th percentile UK male driver human model was developed. These were placed on the seat according to the measured H-point locations. The seat was then moved, within its known motion range, such that each human model could operate the accelerator pedal and could reach the steering wheel from a reasonably comfortable driving posture.

Table 1. Vehicles selected for driver's field of view analysis.

 **Figure 8. Scania 4 series**	 **Figure 9. Ford Iveco Eurotrakker**
 **Figure 10. Leyland Daf FA45**	 **Figure 11. Plaxton Palatine II**
 **Figure 12. Optare Excel**	 **Figure 13. Alexander L1000**
 **Figure 14. Plaxton Premiere**	 **Figure 15. Vanhool Alizee**
 **Figure 16. Jonckheere Mistral**	

Examples of CAD plots for a 95th %ile male driver and a 5th %ile female driver seated in the Scania HGV cab are shown in Figures 17 and 18 below.

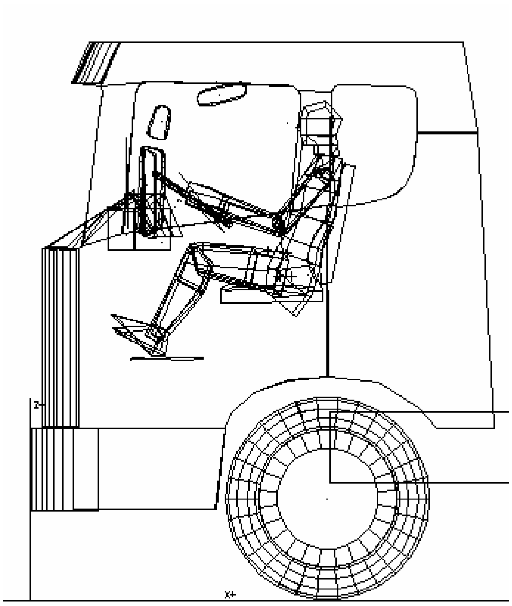


Figure 17. 95th %ile male driver

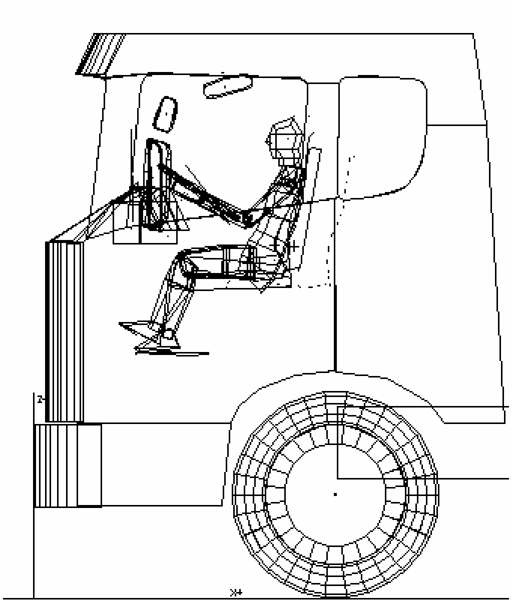


Figure 18. 5th %ile female driver

3.2 Direct fields of view

For each human model, in each vehicle, the direct fields of view through each glazed structure (windscreen and side windows) were projected on to horizontal planes at ground level and at 1m height above the ground (1m was decided on as a suitable test standard, corresponding to the approximate stature of the youngest school bus user). This was accomplished by projecting a vector from the human model's eye point to the edges of the glazed areas or to the edges of any object that formed an obscuration to the driver's field of view (such as the dashboard binnacle or steering wheel rim) and determining where these vectors intersected with either of the exterior horizontal planes. This produces a set of points that can be sequentially joined to produce a contour line of points which map the direct field of view from the vehicle. The fields of view produced represent binocular vision from fixed eye points. An example of a CAD plot showing the 95%ile male drivers direct field of view from the Leyland DAF truck is shown at Figure 19 below. Areas A to E are seen directly through the windscreen and side windows at ground level. The areas marked F are obscured by the mirror housings while only targets greater than 1m in height are visible to the driver in the white areas.

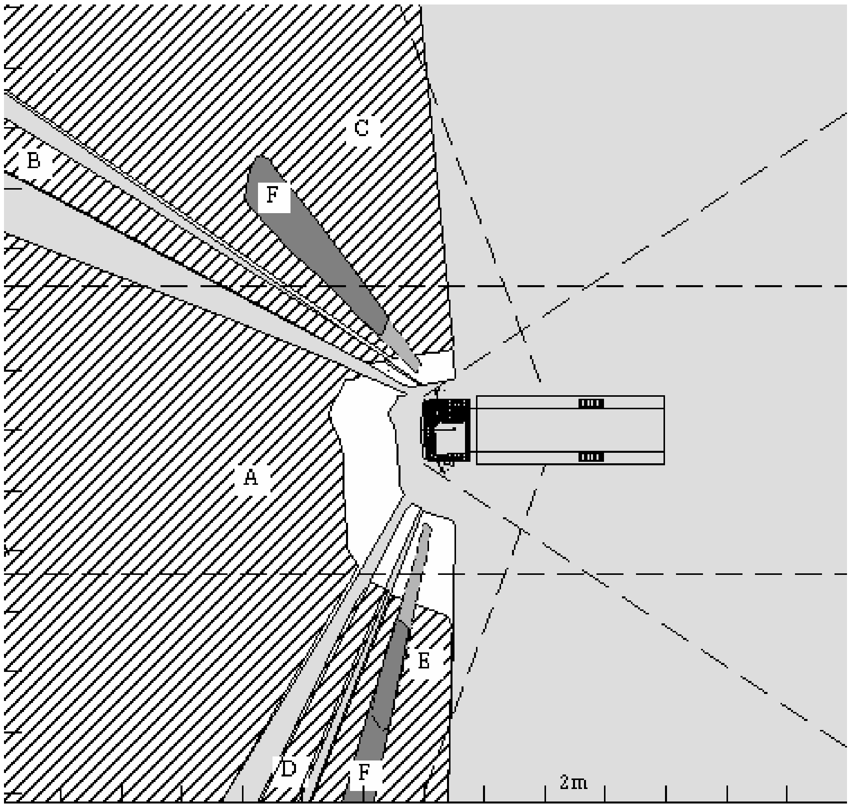


Figure 19. Example of a Direct field of view plot (Leyland Daf truck)

The dashed line in the above plot shows ICE Ergonomics field of view requirement.

3.3 Indirect (reflected) fields of view

The indirect fields of view from each mirror and for each driver in each vehicle were projected onto a horizontal plane at ground level. This was accomplished by projecting a series of vectors from the driver's eye point to each vertex around the rim of the glazed surface of a mirror and then projecting a second series of reflected vectors which then intersect with the horizontal plane at ground level. By joining the intersection points together a 2D contour map is produced which represents the area of ground surface which will be visible as a reflected image in the mirror. In this instance each human model was made to look directly at the relevant mirror by turning their head, neck and or eyes. Figure 20 below shows the indirect field of view plot from the Ford Iveco truck.

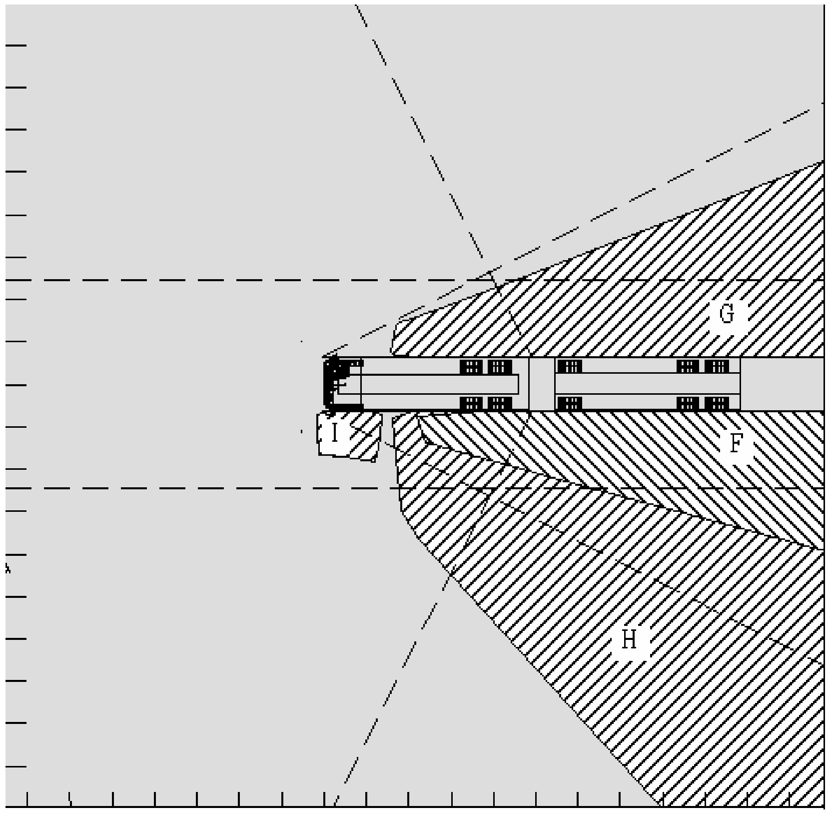


Figure 20. Example of an Indirect field of view plot (Ford Iveco truck)

Areas F and G are the indirect fields of view for the rear-view mirrors. H is the view from the wide angle mirror and I from the close proximity, kerb mirror.

4. CAD field of view analysis

The direct and mirror fields of view were plotted for each driver size and for each vehicle against the Field of View requirement developed by ICE Ergonomics. Where fields of view were assessed to be less than satisfactory, potential improvements were developed and demonstrated with additional plots. Where it is deemed useful, in support of the evaluation explanation, a number of additional plots are used to provide a general image of each vehicle model, views of each driver's posture and position and direct views from the driver's perspective.

The full array of CAD plots are shown in Appendix 1. Summarised below are the main findings of the field of view analysis with example CAD plots to illustrate the key points.

5. CAD evaluation - results and discussion

The CAD evaluation has shown that most of the vehicles covered have some deficiencies in respect of the driver's visual field, many of which are common to all the vehicles.

5.1 Driver's direct vision to the immediate frontal area of large vehicles

All three trucks, all three coaches and one of the busses have limited fields of view to the area immediately in front of the vehicle. It is in this area where pedestrians crossing the road close to the front of the vehicle, might go undetected, with the potential for an accident should the driver move off (see Figure 21 below). This limited view to the immediate frontal area is worse for drivers with long legs but a short seated height as they would tend to sit with the seat in the lowest and most rearward position.

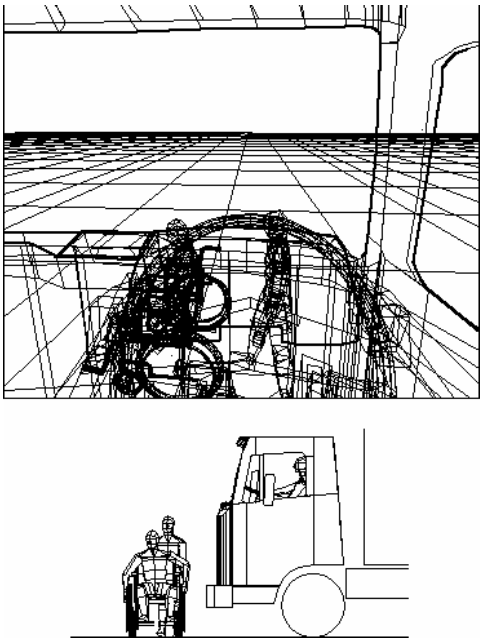
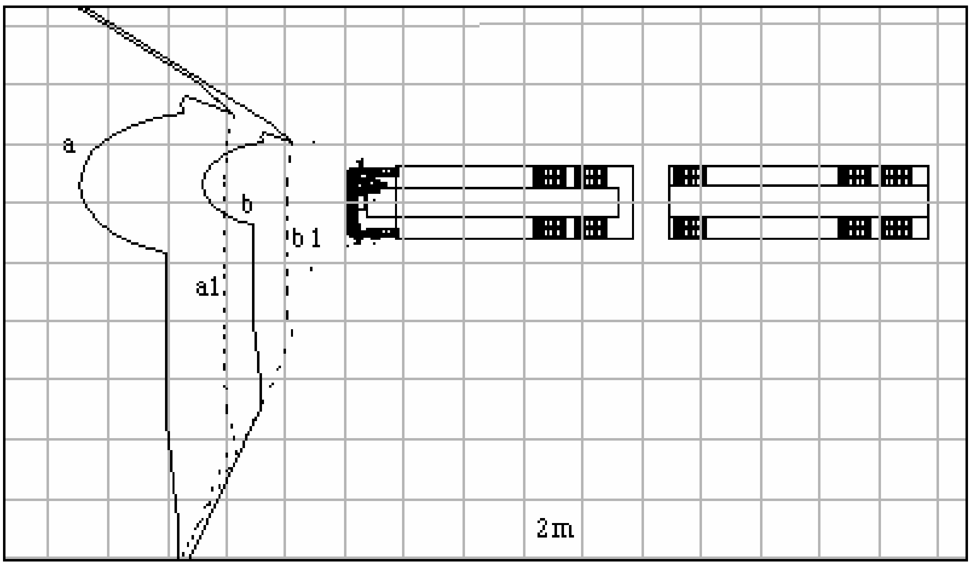


Figure 21. Blind zone to the immediate front of HGVs

Typically, it is the top of the display binnacle which limits the driver's immediate forward line of sight. In most cases, if the whole of the lower edge of the existing windscreens could be seen then this would substantially improve the situation. Improved vehicle designs might entail changing the form and location of the displays and their surrounding binnacle as well as possibly moving the driver's position in the cab and consequently his controls. However, the aim of any redesign should be to permit the driver's line of sight to lie across the bottom edge of a windscreen, as opposed to the top of the display unit.

The CAD investigation of improvements to direct frontal fields of view has tended not to consider design changes such as redesigning display binnacles, cabs or the driver's position. Instead, it considered mirror based solutions first, as these would not have such radical vehicle design implications, could be retro-fitted and may be less costly. However, it is a relatively straight forward process to demonstrate that without the binnacle being present the immediate frontal field of view is improved (Figure 22 below).



5th %ile female field of view
Solid line (a) = actual field of view at ground level (b) at 1000mm
Dashed line (a1) = field of view at ground level with binnacle removed and (b1) at 1000mm

Figure 22. Effect of display binnacle intrusion on immediate frontal vision

5.2 Driver's indirect vision to the immediate frontal area of large vehicles

In respect of the improvements that were investigated using CAD, perhaps the most promising option is the provision of a very wide angle, semi-circular shaped, convex mirror of about 175mm radius of curvature, mounted internally on the near-side A-pillar (see Figure 23 below). This mirror configuration provides a field of view that is wide enough to cover the entire external width immediately in front of the vehicle.

Whether the reflected image in such a mirror is suitable for daily driving tasks and would permit a clearly perceived image when viewed at cross cab widths must necessarily be tested. Driver trials using wide angle mirrors are covered later in this report. However, an additional benefit, in comparison to any other options mentioned below, is that being internal the mirror remains clean of the dirt that can tend to accumulates on external vehicle mirrors.

Figure 23. Internally mounted, small radius of curvature mirror viewing immediate frontal area of an HGV.

Alternatively, a rectangular or circular shaped wide angle convex mirror, with radii of curvatures between 175mm to 250mm, mounted on stalks forward of the windscreen and aimed at the front of the vehicle (such as found on the Jonckheere Mistral coach) can achieve a suitable field of view across the width of the vehicle's immediate frontal zone.

In the case of both internal and external mirror options mentioned above it is highly desirable that their orientation can be remotely adjusted by the driver whilst remaining in his/her preferred driving position and posture.

The exact design requirements, in terms of shape, form, radius of curvature and mounting locations, for both these mirror options would be vehicle specific, but as lack of vision to the immediate frontal area of large vehicles represents a potential hazard to other more vulnerable road users then it follows that the situation should and could be remedied. Consequently, it might be preferable to combine a direct and indirect frontal field of view requirement, defined in terms of an appropriate visual volume, that should be visible to all drivers from their normal driving position.

For example, the volume might be defined as starting at the most forward extremity of the vehicle and extending forward at a 1m height from the ground and over the entire width of the vehicle.

5.3 Driver's direct vision to the far frontal area of large vehicles

5.3.1 Obscuration due to vehicle body

European Directive 77/649, governing direct field of view requirements for category M1 vehicles, currently states that the angle of binocular obstruction of each A-pillar shall not exceed 6°. The CAD field of view evaluations, on the nine selected vehicles, indicate that it is not uncommon for the A-pillars of large vehicles to obscure more than 6° of the visual field e.g. Optare Excel bus 7.2°, Iveco Ford truck 8.2°. Whilst European Directive 77/649 does not cover direct field of view requirements for large vehicles in categories M2, M3, N2, N3 it would seem reasonable to apply similar standards. Additionally, the Optare Excel bus would further contravene the Directive by having 2 A-pillars per side.

5.3.2 Obscuration due to mirrors

Conventional rear-view mirrors, separately mounted on a tubular steel arm, form a significant obstruction to the forward direct field of view, blocking as much as 10° of the visual field in some cases. However, some large vehicles now have forward mounted mirror 'pods' which form a long, continuous housing (see Figure 24 below)

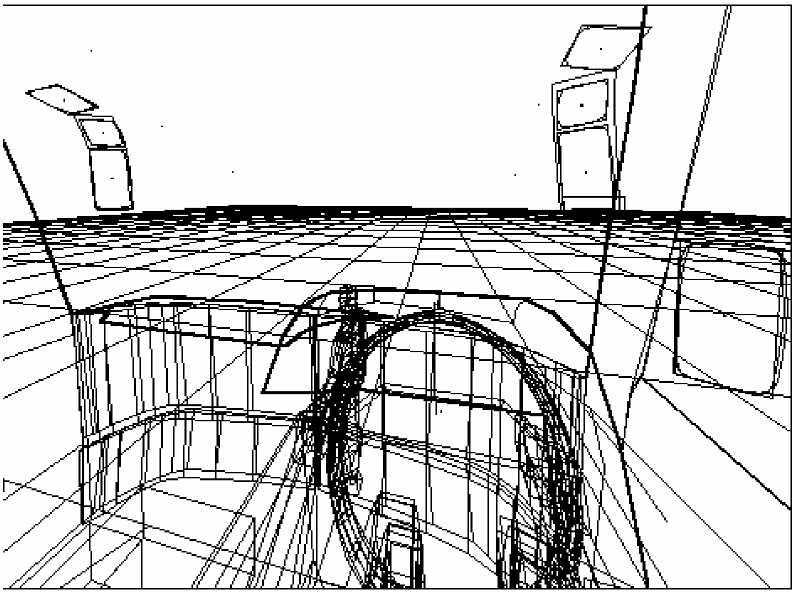


Figure 24. Frontal obscuration due to rear-view mirrors and display binnacle

Whilst these aerodynamic mirror pods can provide the driver with improved indirect fields of view to the near-side, off-side and immediate front of the vehicle they also offer a substantially greater obscuration to direct fields of view. It is difficult to determine exactly what effect this obscuration has on the driving task and what level of hazard it may pose to the safety of pedestrians and other vulnerable road users. For example, in some instances, it is possible for a large vehicle's mirror units to completely obscure, from the driver's view, a car approaching from a distance at some road junctions. However, the extent of this phenomena as an accident causation is hard to identify as the duration of its existence is likely to be short. Also, accident data indicates that the ability to see down the sides of the vehicle is more important than the nominal improvement to forward vision that removal of the mirror pods would provide.

Perhaps of more importance is that the mirrors tend to obstruct objects moving at right angles to the vehicle, for example, people stepping off the kerb to cross the road some distance further on, vehicles joining from a side road or, commonly, vehicles joining a roundabout. In these scenarios it is possible that the vehicle driver may miss the opportunity to respond correctly to a given situation or to be left with insufficient time to take the required avoiding action because the mirrors obscured an active target from view at the critical moment. For example, in the case of joining a roundabout, there comes a point during the approach at which the vehicle driver must determine whether or not to halt before joining or to roll directly on without stopping. The critical `stop or go' decision must be taken at some distance from the entry to the roundabout, dependent on approach speed. The decision is based on the position and the relative speed of vehicles already on or about to join the roundabout from the right. It is this critical area of the roundabout that is often obscured by large, forward mounted mirror pods.

A possible solution to the problem of obscuration from mirrors would involve mounting them higher up. However, one of the benefits of having mirrors lower down is that they lie closer to the driver's normal forward line of sight and consequently can be more quickly scanned, thus reducing the amount of time that the driver's attention is diverted from his primary visual field. Mounting the mirrors higher up may significantly increase the amount of time that the driver's attention needs to be diverted from information potentially more important to the immediate driving task.

5.4 Direct driver vision to the near-side of large vehicles

Direct driver's vision of the immediate near-side area of all the vehicles under evaluation was insufficient. In HGV's the structure of the cab side is usually so high as to preclude direct vision to areas close to the near-side.

In the buses evaluated, driver's vision by direct means to the area immediately rear of the passenger entry/exit doors was restricted (see Figures 25 and 26 below). This area, next to the front wheels, is considered of particular importance in relation to buses since pedestrians, cyclists and potential passengers are likely to be occupying this space, especially in an urban environment. While the potential for direct driver observation of this area through windows exists, very often this is obstructed by bus furniture, such as destination display boxes, luggage racks, passenger seating and the passengers seated in them. In all three buses the security screen defining the driver station blocks direct vision to the first saloon window requiring that the driver leans both forward and sideways to view this area. In the Optare bus this structure can also obstruct direct vision to the doors for larger drivers who sit further back from the controls.

Figure 25. Direct near-side vision obscuration in buses (observer's perspective).

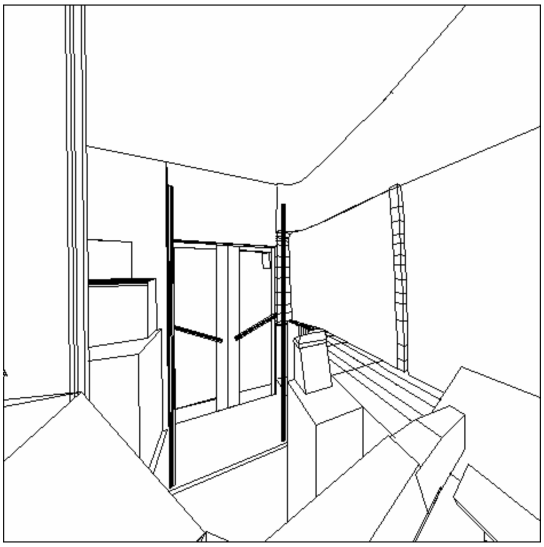


Figure 26. Direct near-side vision obscuration in buses (driver's perspective).

Solutions to the restricted direct field of view in this area might include the replacement, in clear glass, of the security screening around the driver's station, eliminating the need for the driver to lean forward out of their seat. Additionally, the removal of all obstructions in the area of the first saloon window combined with a lowering of the window's bottom edge. However, these options are potentially expensive and just as effectively remedied with mirrors or CCTV.

Direct near-side vision in coaches is extremely limited due to the low driver position and raised passenger seating. The only useful direct vision, to the near-side, is through the relatively narrow passenger entry/exit door. However, vision through the lower near-side door windows can be almost fully obscured when a co-driver's occupies the seat positioned in the entry/exit area (see Figure 27 below).

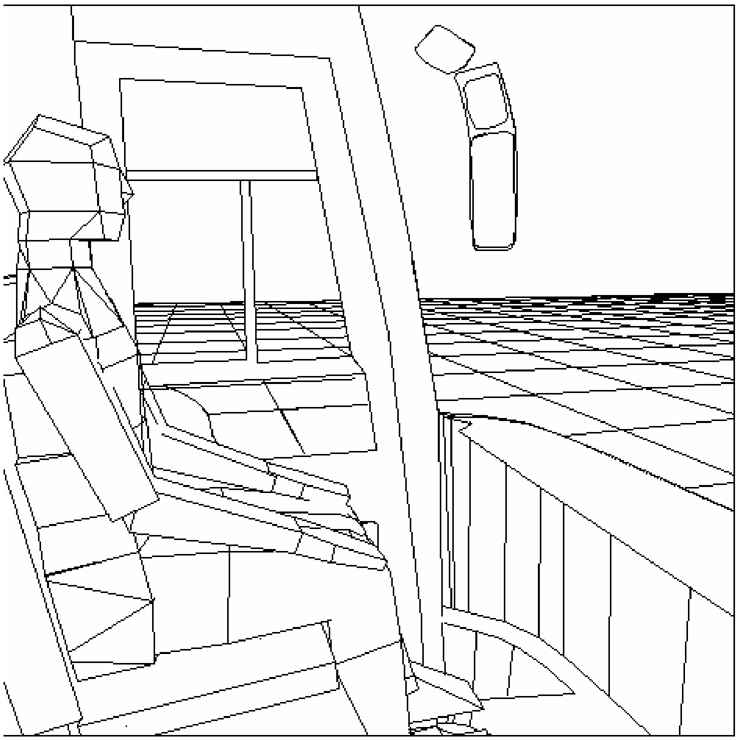


Figure 27. Direct near-side vision obscuration due to co-driver.

5.5 Indirect driver vision to the near-side of large vehicles

All the mirrors fitted to the HGV's and coaches proved capable of providing fields of view in accordance with the existing EC Regulations for Class II, IV and V mirrors from the estimated design eye point. This remained true for eye points generated for the large male and small female drivers given that each of the mirrors incorporated a sufficient range of 2 axis adjustment. However, two of the buses (Plaxton and Alexander) have side mirrors that are not capable of providing the required near-side field of view. In both cases the mirrors would need to be some 5cm taller in order to provide a field of view that met the requirements.

5.5.1 Indirect near-side vision from HGV's

CAD evaluation of HGV near-side mirrors identified a zone blind to the driver between the fields of view provided by the Class IV 'wide angle' mirror and the Class V 'close proximity' mirror. This blind zone can be substantial if the driver is short and the choice of mirror angle adjustment is poor. Pedestrians or cyclists positioned in this zone may go undetected by the driver and would be at risk, especially during left turn manoeuvres. The danger is even greater when the HGV is towing a semi-trailer or draw-bar trailer and there is trailer cut-in (see Figure 28 below).

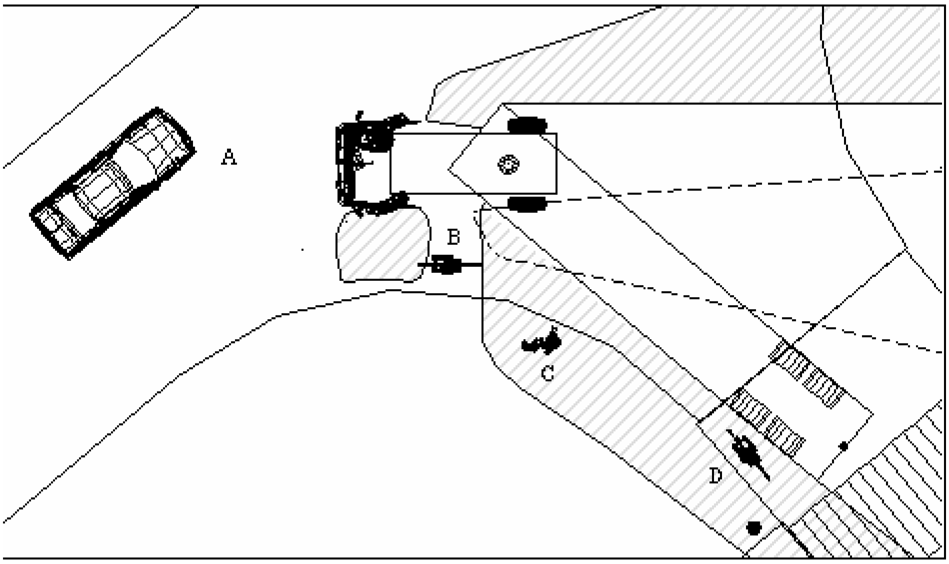


Figure 28. Indirect blind zone on HGV near-side with regulation mirrors

The size of this blind zone can be reduced or entirely eliminated by increasing the dimensions of the mirrors, by angling the mirrors such that their fields of view overlap and by mounting the mirrors forward of the A-pillar such that they are viewed through the windscreen.

Alternatively, if the radius of curvature of the Class V 'close proximity' mirror was reduced from its current minimum of 450mm to approximately 200mm then this would provide a field of view covering almost the entire length of an articulated tractor unit. This field of view would easily overlap with the standard 'wide angle' mirror's field of view, even with a poor choice of adjustment angle (see Figure 29, plot area 'B', below). An assessment of the use of such mirrors in field trials is necessary to determine that the image they produce is usable under normal driving conditions (see Section 5 'Tests of mirrors and reversing aid technologies').

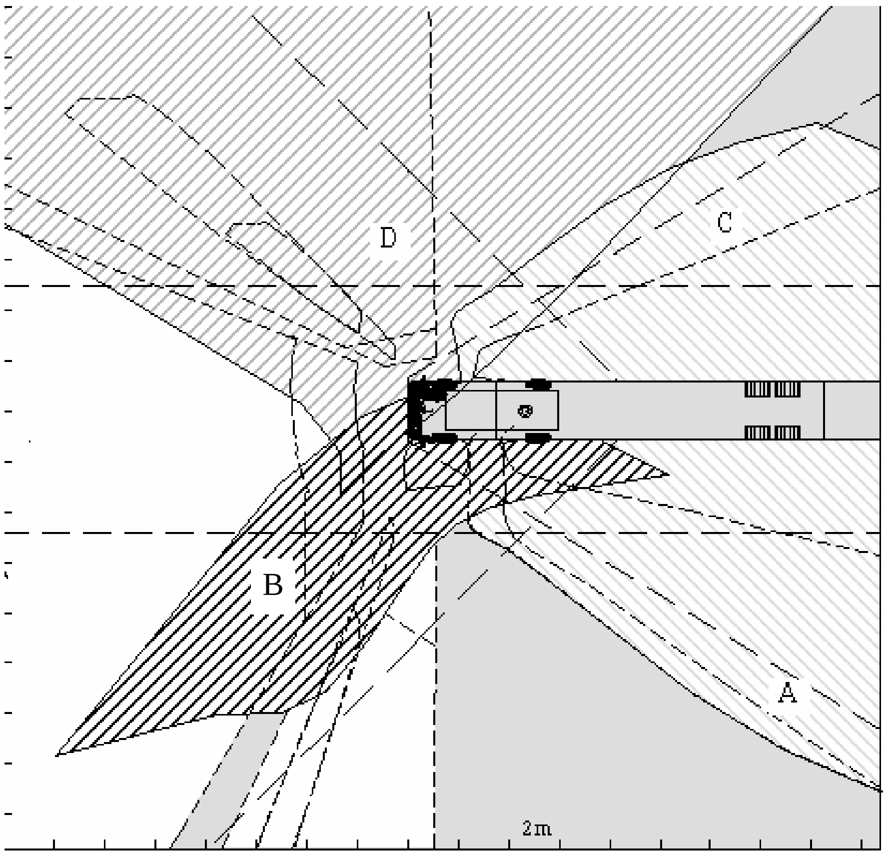


Figure 29. Field of view from Class V 'close proximity' mirror with 175mm radius of curvature.

The currently defined field of view requirements for rear-view mirrors fitted to HGV's (defined in EC OJ No. L90/21) permit the blind zone described above. Future regulations should improve upon the current situation by clearly defining larger, overlapping fields of view for the close proximity and wide angle mirrors.

5.5.2 Indirect near-side vision from buses

The safety critical near-side area, rear of the passenger entry/exit doors and adjacent to the front wheel, was inadequately covered by indirect mirror fields of view in all the buses evaluated. A wide angle rear-view mirror and a very wide angle ‘close proximity’ mirror (as tested on the trucks and coaches) could be used to provide a clear view across the door area and the area adjacent to the front wheels. The addition of a wide angle mirror would also improve the level of compliance for buses with the field of view requirement developed by ICE Ergonomics.

In all three buses the existing side mirror is viewed through the saloon door glazing which becomes dirty in service, reducing the clarity of the mirror’s reflected image. Importantly the mirror arm’s position can be such that portions of the mirror are obscured from view by the door’s structure. It is advantageous to mount the near-side mirrors forward of the A-pillar such that they can be viewed through the windscreen (see Figure 30 below) preferably through the area swept by the wipers.

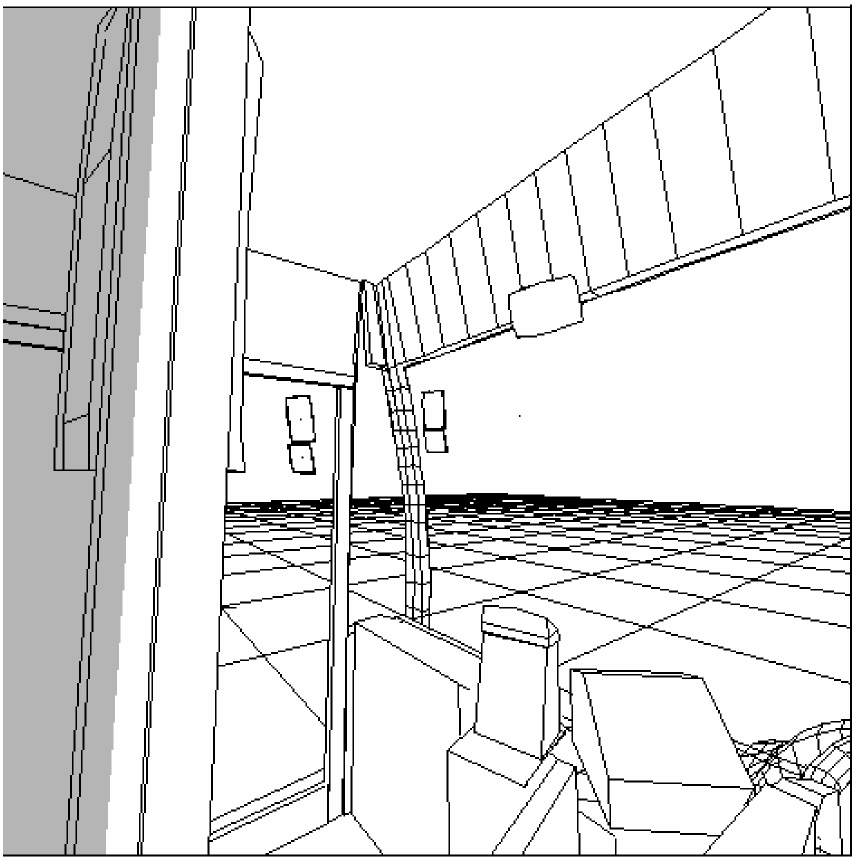


Figure 30. Additional wide angle mirror mounted forward of A-pillar

Regulations should ensure that mirror fields of view cover the near-side of buses comprehensively. Also that mirror positioning permits unobstructed vision to all driver sizes and that the driver station screening does not affect easy direct vision to the doors and preferably to the first, near-side saloon window.

5.5.3 Indirect near-side vision from coaches

The indirect fields of view to the near-side of the coaches that have been evaluated have similar limitations to those of the HGVs. Of the coaches only the Jonkheere Mistral had a wide angle mirror, the others had only the standard Class II rear-view mirror. For most coaches a large near-side blind zone exists at ground level, running from the front passenger entry door to around 4m rearward where the rear-view mirror field of view starts. This is an area where high interaction between coach passengers and the vehicle is likely and where other road users are most at risk when the vehicle turns left.

The provision of both close proximity and wide angle mirrors would reduce this blind zone and would provide a field of view closer to the requirement for large vehicles, defined by ICE Ergonomics. Solutions tested, using CAD, included a close proximity mirror of approximately 175mm radius of curvature for the kerb view and a combination of rectangular mirrors with 400mm radius of curvature for both kerb views and wide angle views.

It is perhaps worth stating that the Jonckheere Mistral coach has the best indirect field of view of any of the vehicles evaluated, enhanced by its having 7 mirrors. The only area not adequately covered is the rear of the vehicle. The only improvement to the fields of view on the near-side, with regards to the ICE Ergonomics requirement, might be to reduce the radius of curvature of the close proximity mirror to about 200mm.

5.6 Driver vision to the off-side of large vehicles

All the vehicles tested exhibited visual limitations in their direct and reflected fields of view on the off-side, with the exception of the Jonckheere Mistral coach. The construction of HGVs and buses usually means that a solid panel prevents drivers from directly seeing anything over their shoulder, unless they lean out of a side window. With the exception of the Mistral coach most vehicles have a blind spot in the region of the first off-side wheel which is not clearly covered by the rear-view mirror. Most vehicles fail to fully comply with the off-side element of ICE Ergonomics field of view requirement.

This short fall in the off-side visual requirement presents a hazard to other road users when the vehicle pulls out from the curb, changes lane or turns right. It may also be important in off-road situations, such as bus stations, building sites, maintenance and factory yards and loading bays where pedestrians may be moving in the vicinity of the vehicle.

The primary solution to provide vision in this area is the provision of a standard wide angle mirror. Additionally, glazed areas rearward of the B-pillar would improve the driver's direct vision capability. The wide angle mirror satisfies a greater region of the developed field of view requirement and would also enable the drivers of articulated vehicles to keep the rear end of their semi-trailer units in view when turning right.

5.7 Driver vision to the immediate rear of large vehicles

The immediate rear of all large vehicles is essentially blind to their drivers. Even in buses, where there is often a rear window, the ground is not visible for about 40 to 50m. Trucks and coaches have, effectively, no vision to their immediate rear. The only obvious means of providing a field of view to the rear of vehicles is by using a CCTV system. Typical fields of view that are achievable with CCTV camera systems are illustrated in Figure 31 below.

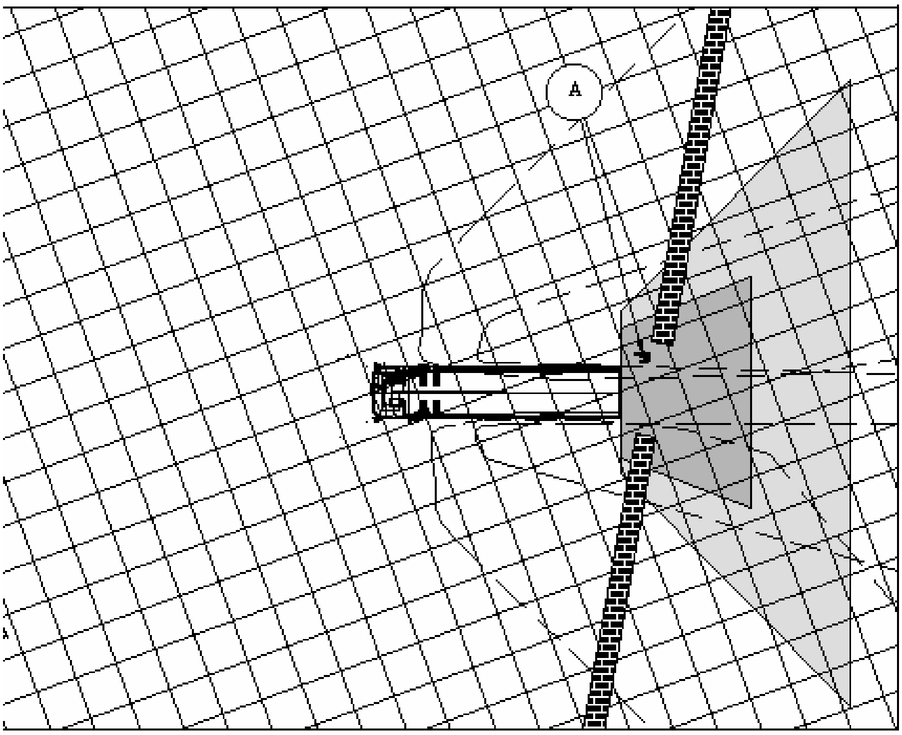


Figure 31. CCTV fields of view

A CCTV camera and monitor system may be considered as a mirror, unhindered by the necessity for direct lines of sight. However, the fields of view achieved with CCTV systems have similar problems to those associated with mirrors. Whilst monitor dimensions remain relatively constant between CCTV systems the viewing angles of the cameras can vary in both the horizontal and vertical planes. Necessarily, monitor image sizes must become distorted to display the additional information received from wide angle cameras. Also, the shape of the camera's field of view is not that of the monitor's screen so the image deformation is not uniform across the display.

The fitting of CCTV systems to articulated vehicles with separate tractor unit and semi-trailers poses a number of significant problems. Each semi-trailer would require its own camera so that rear vision could be achieved regardless of tractor unit and semi-trailer combination. Also, there is limited capacity through the electrical coupling connecting the tractor unit and semi-trailer, requiring additional vehicle modification. There is also security element to consider, with semi-trailers left unattended for long periods of time, cameras would, ideally, have to be integral with the trailer body.

5.8 Summary

Many of the field of view problems, found during the CAD analysis of the nine large vehicles, were to some degree common to them all. Therefore, the proposed recommendations for improvements and any changes that would be required to current Regulations to permit the proposals are also common across the vehicle types. The summary below outlines the problems of each large vehicle group, a recommended solution and the regulation changes that would be required.

5.8.1 Large Vehicles - Problems found

- On all large vehicles (categories M2, M3, N2, N3) an off-side, wide angle (Class IV) mirror is not a requirement.

- On all large vehicles (with the exclusion of N3 category articulated tractor units) the fitting of near side, wide angle (Class IV) mirrors and close proximity (Class V) mirrors is not a requirement

- For the majority of large vehicles the driver's seated height and eye level are such that a large, direct vision blind zone exists to the immediate front.

- For the majority of large vehicles, the current minimum radius of curvature for Class II rear-view mirrors, combined with their often high mounting point, means that optimal adjustment of the mirror for far rear vision necessitates that a blind zone is left at ground level directly below the mirror and often extending beyond the vehicles front wheels.

- The current Regulations for Class IV and Class V mirrors permit a blind zone to exist at ground level between their respective defined fields of view.

- On many large vehicles, the driver's display binnacle often protrudes in to the area at the lower edge of the windscreen, blocking the driver's direct line of sight to the vehicle's immediate front.

- The view to the immediate rear of all large vehicles is obscured to their drivers.

- Most large vehicle mirrors are not adjustable from the driver's position.

5.8.2 HGV specific problems

- In the majority of HGVs the driver's seated height and eye level are such that a large direct vision blind zone exists in the vicinity of the vehicle cab's immediate front and near-side.

- The blind zone permitted between the defined fields of view for near-side Class IV and Class V mirrors often corresponds to the area between an articulated tractor unit's front and rear, near-side wheels.

5.8.3 Bus specific problems

- Direct and mirror fields of view to the near-side of buses is particularly poor considering the high degree of passenger and vehicle interaction that is designed to occur on this side.

- Obscuration of direct driver's vision to the passenger's entry and exit door and to the external near-side area can be caused by internal bus furniture such as destination boards and driver's security screening.

- Direct driver's vision to the near side, rear-view mirror can be obstructed by the solid portion of the passenger's entry and exit door or by dirty door window glass.

- Mirrors fitted to buses are, as a result of operational and vehicle constraints, usually too small, positioned badly and not easily adjusted.

5.8.4 Coach specific problems

- Current coach construction methods favour a low driver's position and high seating for passengers starting directly behind the driver. Direct driver vision is immediately restricted to the front 180° arc.

- Further direct vision obscuration to the near-side door glass is provided by the co-driver's station positioned in the entry door's foot well.

- Large, aerodynamic, forward mounted mirror pods, currently fitted to some coaches, can cause direct vision obscuration to the far, forward region in areas critical to the timing of stop/go decisions when joining major roundabouts and junctions.

5.8.5 Large vehicles - Recommended solutions

- Compulsory fitment of wide angle (Class IV) mirrors to both the off-side and near-side of all large vehicles in categories M2, M3, N2, N3.

- Compulsory fitment of a wide angle, small radius of curvature (approximately 200mm) mirror to the inside, top region of the near-side A-pillar, such that it gives drivers a view to the immediate front of their vehicle.

- Fit Class II rear view mirrors with a minimum radius of curvature not less than 1200mm.

- Where possible ensure that all near-side mirrors are mounted forward of the A-pillar and viewed through the windscreen area swept by the wipers.

- Make all mirrors remotely adjustable, in at least two planes, such that mirror views can be adjusted from the driver's normal driving position and posture.

- Ensure that display binnacles do not intrude in to the driver's direct line of sight to the windscreen's lower edge.

- Fit CCTV cameras and monitors to all large vehicles such that drivers can see the immediate rear of their vehicles prior to and whilst reversing.

5.8.6 HGV specific solutions

- Compulsory fitment of Class V close proximity mirrors, with a minimum radius of curvature not less that 200mm, to the near side door cant rail.

5.8.7 Bus specific solutions

- Reduce the intrusion of bus furniture into the driver's direct line of sight to the immediate front and to the immediate near-side area.

- If driver's security screens are required then provision should be made to provide a mirror or CCTV view of the buses near side length, including any passenger entry and exit doors and wheel arch areas.

5.8.8 Coach specific solutions

- Reduce the intrusion of coach furniture into the drivers direct line of sight to the immediate front and to the passenger's entry and exit door area.

5.8.9 Large vehicles - Required changes in Regulations

- Council Directive 71/127/EEC - Regulations concerning the minimum number of mirrors required on large vehicles; the minimum radius of curvature of each class of mirror. Modify the existing rear-view mirror field of view Regulations such that the fields of view for each mirror overlap. This can easily be achieved with the proposed changes to minimum radii of curvature detailed above.

- Regulations defining indirect vision requirements should ensure that the area directly behind HGV's is covered by the fitting of a CCTV system and that all mirrors can be remotely adjusted from the driver's position.

- European Directive 77/649 - defines the minimum direct driver vision requirements for M1 category vehicles. A development of this Directive will be needed to incorporate vehicles in categories M2, M3, N2 and N3. The Regulations in this new Directive should define the driver's minimum direct vision requirements such that it takes in to account the height of the driver's eye points above the ground and the envelope of eye points generated by the range of possible driver sizes and seat positions.

- A direct field of view Regulation should minimise the degree of intrusion any cab furniture can make into the drivers line of sight to the lower edge of the windscreen. A-pillars and mirror clusters etc. should meet similar standards for maximum obscuration imposed on M1 category vehicles.

- Regulations permitting a combination of direct and indirect viewing methods to cover the area immediately in front of a large vehicle should be considered.

5.8.10 Buses - Required changes in Regulations

- Buses are required to comply with Construction and Use Regulations and do not come under the auspices of the Vehicle Certification Agency for type approval. However, in many instances regarding mirror vision, Construction and Use refers readers to the relevant EU Regulations for compliance requirements. As such, the proposed change to HGV and coach regulations should influence bus field of view compliance.

6. Review of viewing and detecting technologies

6.1 Direct driver vision

Direct driver's vision is the view achieved by the driver through the glazed areas of the large vehicle's cab with out the aid of additional technologies. Its effectiveness is related to features of the vehicle's construction such as body type and design and layout of internal cab furniture.

6.1.1 Vehicle body modifications

Improvements to direct driver's vision from large vehicles can be achieved through modifications to the vehicle's body-work and internal fittings. Alterations which increase glazed area and reduce obscuration of the glazed area can both prove beneficial. However, body modifications may have implications on such factors as the vehicle cab's strength, driver's crash survivability (either perceived or actual), vehicle security or, in the case of public service vehicles, passenger viewing satisfaction.

6.2 Indirect driver vision

Indirect driver's vision is the view achieved by the driver as a result of using some assisting technology. Commonly, this is achieved with mirrors but additional technologies, such as closed circuit television (CCTV), can enable drivers to 'see' those areas not easily covered by mirrors.

6.2.1 Rear-view mirrors

Large road going vehicles are required to fit rear-view mirrors that comply with EU and British Construction and Use Regulations. EU Regulations currently control such factors as the mirror's minimum size, mounting height, radius of curvature and the number of mirrors required.

6.2.1.1 Planar (flat) mirrors

The image characteristics of flat mirrors are such that the image appears at the same distance behind the mirror as the object is in front of the mirror and that the dimensions of the image are the same as the dimensions of the object, i.e. a magnification of 1. This means that a driver's perception of the position of objects viewed through flat mirrors should be relatively accurate. However, the field of view (visual angle) that can be achieved with flat mirrors is relatively small.

6.2.1.2 Spherical convex mirrors

One way to overcome the limited field of view achieved with planar mirrors is to use mirrors that are sections of the surfaces of a sphere. Spherical convex mirrors have wider fields of view than planar mirrors of the same size but suffer from a diminished image quality. The fields of few achievable with the convex rear-view mirrors used during this research are illustrated in Figures 32 and 33 below.

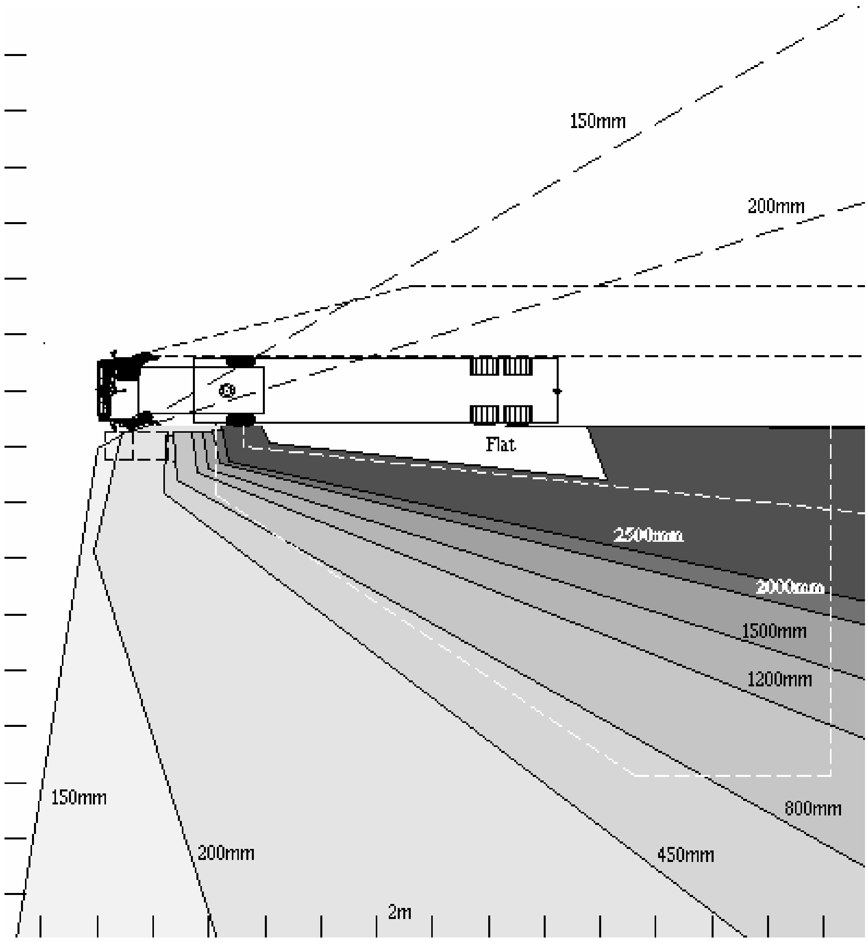


Figure 32. Near-side mirror fields of view

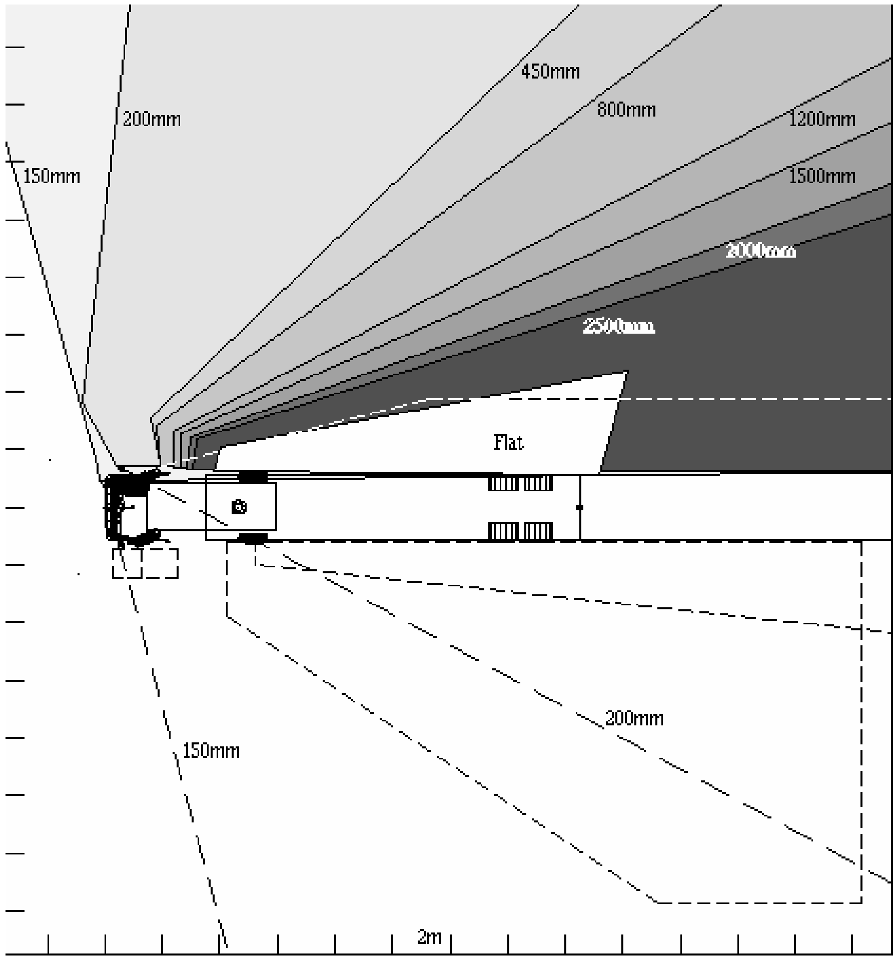


Figure 33. Off-side mirror fields of view

Seen through convex mirrors, the dimensions of the image are smaller than that of the object i.e. have a magnification of less than one. The diminishing of the image size is inversely proportional to the mirror's radius of curvature (roc). This characteristic of convex mirrors has implications for a driver's ability to accurately judge the distance to an object viewed through them. An image size smaller than expected may cause drivers to assume the object is further away. The extent of this distance overestimation with convex mirrors relative to a flat mirror has been studied on a number of occasions in the past. The results from eight studies, including the ICE trial carried out for this report, are shown at Figure 34 below.

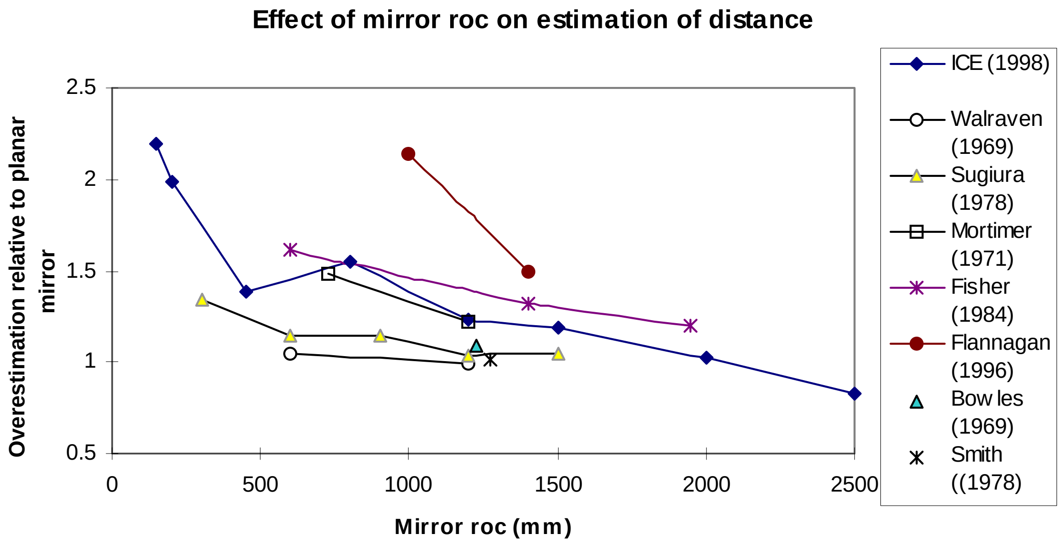


Figure 34. Graph showing the degree of object distance over-estimation using convex rear-view mirrors relative to a flat mirror.

It can be seen that in virtually all instances a decrease in the convex mirror's radius of curvature corresponds to an increase in the driver's overestimation of the distance to the object.

6.2.1.3 Aspheric mirrors

Aspheric mirrors are becoming more widely available and are being used to eliminate the 'blind zone' on the vehicle's off-side, encountered when overtaking or lane changing. Generally, aspheric mirrors are constructed such that the radius of curvature across their horizontal dimension is more gently curved (i.e. has a long radius of curvature) on the inboard side and more strongly curved (i.e. has a short radius of curvature) on the outboard side. The majority of the mirror's surface is of the long radius of curvature, used for normal rear-view use with little image distortion, while the outboard edge has a short radius of curvature, used for wide angle visual coverage of the overtaking blind zone.

The extent to which driver's can cope with the conflicting distance information these type of mirrors present, as the object's image moves from the long to short radius of curvature portion of the mirror, has not been fully evaluated. However, it would appear that a clearly defined boundary between the two different mirror radii is a desirable feature to avoid confusion.

6.2.1.4 Mirror environmental conditions

Mirror performance can also be degraded by the environmental conditions in which they operate. The effects of atmospheric conditions, such as rain, snow and ice, can be reduced by heating elements running under the mirrors surface.
The air flowing past side mounted, external rear-view mirrors can cause low pressure air pockets to form in front of the mirror which drag road dirt on to it's surface. Mounting the mirrors on arms which protrude forward of the vehicle's A-pillar can create air turbulence conditions which have a cleaning effect and also enable more comprehensive fields of view. However, mirrors mounted nearer to the driver's normal, forward line of sight can themselves present a large obscuration to the direct field of view. Additionally, mirrors which are constantly seen in the drivers peripheral vision may cause distraction and annoyance if the image displays a continual flicker due to passing road markings or glare from sun and headlights.

6.2.2 CCTV

The availability and sophistication of CCTV systems has increased as a result of Health and Safety legislation requiring workplace vehicles to be manufactured so that visibility from the vehicles' driving position is such that operators can drive vehicles both for their own safety and that of personnel in the immediate vicinity. With a higher demand, mass production and cheaper electronic components CCTV systems have become relatively low cost items.

CCTV cameras can have visual fields approaching 120° in the horizontal plane although distortion at the edge of the monitors image becomes greater with wide angle camera lenses. For vehicle use, camera housings should be resistant to water ingress, vibration, shock loads, humidity and temperature variations. It is also preferable to have some means of remotely cleaning the lens face of road dirt and rain droplets as they accumulate. Operation in low light levels of 0.1 lux are claimed by some systems.

Monitors are commonly monochrome with screen resolutions ranging from 400 to 1000 lines. A desirable feature on reversing aid CCTV monitors is to be able to laterally invert the image. This gives the driver looking forward at the monitor a mirror-like image of the view behind.

6.3 Reversing Aids

In the context of this report, reversing aids are considered to be technologies that give an acoustic and visual indication to the vehicle driver (not an alarm to other personnel in the area), when he selects reverse gear, of whether there are objects in the monitoring range. Commonly they have sensors which detect objects using one of three emission types in either the ultrasonic, infrared or radar band of frequencies. In all systems the height and angle of the sensors from the vertical is critical to the range and accuracy of the detection zones. Most systems use a combination of increasing auditory tone frequency and increasing flash rate of coloured LEDs to signal a closing object.

6.3.1 Ultrasonic

Ultrasonic based systems commonly consist of a pair of sensors fitted to the rear of the vehicle and linked to an audio-visual display in the cab. This may also include a digital read out of distance information from about 3m down to 0.4m. This detecting space is usually divided in to three zones. Information about the detection of objects and the zone it is in are relayed to the driver by auditory and visual signals increasing in frequency as the object gets closer. The 3m warning range of current ultrasonic systems is a concern as this equates to only a 2.2 second interval between an object entering the outer detection zone and reaching the vehicle when travelling at 5km/h (approximately walking speed).

Faulty indications and blind spots can be caused by misalignment of sensors, deflected signals (e.g. from sloped car windscreens), heavy rain, and external sources of ultra-sounds such as the discharge of compressed air (large vehicle air brake systems?), and high pitched noises.

6.3.2 Infrared

Infrared based systems commonly consist of a number of sensors spread across the full width of the vehicle (typically seven for large vehicle use). The infrared signal range is approximately 3m and is divided in to three detection zones. The system tested for this report had a synchronised internal driver's bleeper and external pedestrian warning horn which both rose in tone frequency as the vehicle got closer to the detected object. A steady tone sounded when the object had entered the last 1m before contact.

Faulty indications or blind spots can be caused by sensor misalignment and bright sunlight on white reflective surfaces (e.g. snow).

6.3.3 Radar

Radar based systems can only detect objects moving relative to the source/receiver unit. However, sensitivity to movement can be high. The radar reversing aid tested for this report had a software based control system which could define the range and closing speed sensitivity of each of the three detection zones. Typically, for off-road quarry vehicles the detection range of the outer zone might extend to 8m but may be programmed not to respond in that zone unless the closing speed exceeds a predefined limit. Whilst being the most accurate and customisable of the available systems this sophistication comes at a price which would probably preclude it from wide spread acceptance in the large vehicle market. However, it is claimed that mass production techniques could significantly cut the cost of a reversing aid based on radar technology.
The driver interface again consisted of a combination audible and visual display.

Some combinations of shape and material are invisible to radar e.g. a plastic or metal vertical tube, and the vertical element of the fan shaped detection pattern can be very narrow making the alignment and height of the source/receiver unit critical.

7. Tests of mirrors and reversing aid technologies

The preceding CAD analysis made recommendations that mirror radii of curvatures should be reduced from the current minimum to increase the field of view so that ICE Ergonomic's field of view requirement could be achieved. The effect of reducing a convex mirror's radius of curvature is to reduce the image size. This has implications for the driver's ability to accurately make estimations of object distance, lateral positioning and closing speed. The following tests aim to identify when the benefits of an increased field of view are outweighed by the disadvantages associated with reduced image quality.

7.1 Test 1 - Effect of mirror radius of curvature on distance estimation

7.1.1 Aims

The aim of this test was to establish if the radius of curvature (roc) of a spherical convex rear-view mirror has an effect on a driver's ability to judge the distance to static targets viewed through them. In order to develop recommendations for improved rear-view mirrors it is necessary to determine when the advantages of the increased field of view with smaller radii of curvature are out-weighed by the disadvantages associated with the decreased image quality.

7.1.2 Method

7.1.2.1 Subjects

Twenty subjects participated in the test. Fourteen males and six females with an average age of 38 years. All subjects passed the eye sight requirements for eligibility to hold an HGV driving license and were active, licensed car drivers.

7.1.2.2 Test site and vehicle positions

The test was conducted on a straight, flat length of private road. The road surface was new asphalt with no road markings. A Volvo FL 618, rigid, heavy goods vehicle with a box body (overall length 10m) was used as the vehicle from which the mirrors were tested. The vehicle was parked in the left hand lane of the road when testing off-side mirrors and on the right hand side of the road when testing near-side mirrors (see Figure 35 below).

Figure 35. Test vehicle and reference board

7.1.2.3 Rear-view mirrors

Nine convex rear-view mirrors were tested. The nominal radius of curvature (roc) for each mirror was 150mm, 200mm, 450mm, 800mm, 1200mm, 1500mm, 2000mm, 2500mm and flat/planar (∞ roc). Except for the 450mm and 2000mm roc mirrors the remainder were manufactured from 3mm thick, cast acrylic blanks with silvered concave faces. The manufacturer claims all mirror radii are within 5% of those specified. The 450mm (class IV) and 2000mm (class II) mirrors were of a construction commercially available to vehicle manufacturers and carrying the 'e' mark complying with EEC regulations. The planar (flat) mirror was cut from a sheet of mirrored glass by a local glazier. The 150mm, 200mm, and 450mm roc mirror dimensions were approximately 14cm x 24cm while the remainder were 18cm x 36cm. When fitted to the vehicle, the height to each mirror centre was approximately 2m. The order in which mirrors were presented to subjects was randomised.

The mirror image views of the target object standing at 0.5 vehicle lengths behind the truck are shown in Figures 36 to 53 below.

	
Figure 36. View from 150mm roc mirror - near-side	**Figure 37. View from 150mm roc mirror - off-side**
	
Figure 38. View from 200mm roc mirror - near-side	**Figure 39. View from 200mm roc mirror - off-side**

Figure 40. View from 450mm roc mirror - near-side

Figure 41. View from 450mm roc mirror - off-side

Figure 42. View from 800mm roc mirror - near-side

Figure 43. View from 800mm roc mirror - off-side

Figure 44. View from 1200mm roc mirror - near-side

Figure 45. View from 1200mm roc mirror - off-side

Figure 46. View from 1500mm roc mirror - near-side

Figure 47. View from 1500mm roc mirror - off-side

Figure 48. View from 2000mm roc mirror - near-side

Figure 49. View from 2000mm roc mirror - off-side

Figure 50. View from 2500mm roc mirror - near-side

Figure 51. View from 2500mm roc mirror - off-side

Figure 52. View from flat mirror - near-side

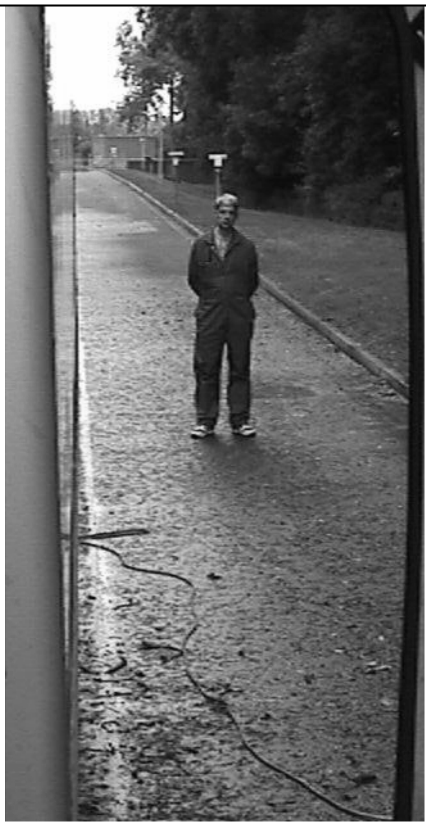


Figure 53. View from flat mirror - off-side

7.1.2.4 Target description and positions.

The target used in this test was a standing, adult male dressed in blue overalls and white training shoes. For each test condition the target stood at one of four distances behind the truck and in the lane not occupied by the truck . The four distances equated to 0.5, 1.0, 1.5 and 2.0 vehicle lengths from the rear most part of the truck. A vertical, lateral marker board was positioned in the target's lane at one half vehicle length in front of the truck cab. Subjects were informed of the marker board's significance so that it could be used by them as a reference (see Figure 54 below).

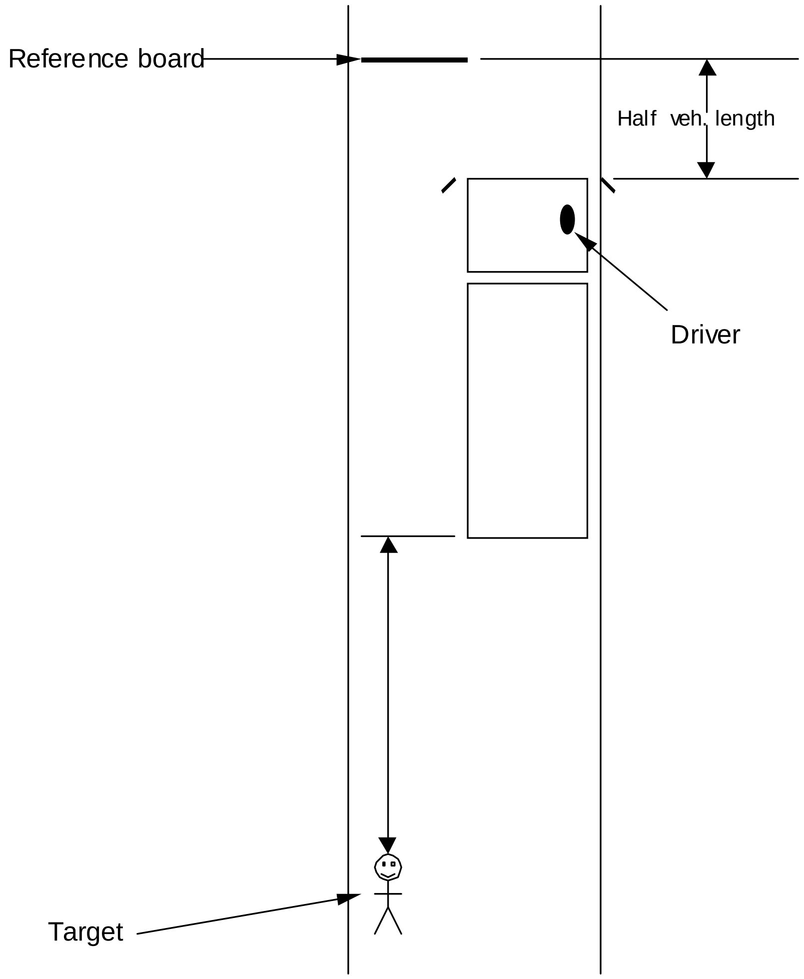


Figure 54. Plan view of Test 1 layout

For each mirror, the target stood at each distance three times, giving 12 conditions per mirror. The conditions were presented in a randomised order. The test procedure of 12 conditions for each of the nine mirrors was repeated with the mirrors mounted on both the near-side and off-side of the vehicle.

7.1.3 Procedure

The subject sat in the driver's seat and gave their estimation of the distance to the target, as viewed through each of the mirrors. They were instructed to give their answers in terms of the number of vehicle lengths behind the truck and with an accuracy to the nearest half a vehicle length. After the subject had responded to each condition and their response recorded, the subject was instructed to look away briefly from the mirror while the target moved to his next position. After the

12 target conditions had been delivered, the mirror was changed and another set of conditions displayed. When all nine mirrors had been viewed, the position of the vehicle and the reference marker board were swapped and the test procedure was repeated for mirrors mounted on the opposite side of the vehicle. All sessions were conducted in daylight.

7.1.4 Results

The analysis of variance results, in Table 2 below, show a significant difference between group means exist, indicating that at least one of the mirrors causes greater errors in drivers' distance perception than the others.

Table 2. Results of static target distance estimation using convex mirrors.

Distance (vehicle lengths)	Near-side mirrors	Off-side mirrors
0.5	$F(8,171) = 11.17$, $p < 0.05$	$F(8,171) = 5.41$, $p < 0.05$
1.0	$F(8,171) = 9.55$, $p < 0.05$	$F(8,171) = 6.68$, $p < 0.05$
1.5	$F(8,171) = 12.54$, $p < 0.05$	$F(8,171) = 6.19$, $p < 0.05$
2.0	$F(8,171) = 11.21$, $p < 0.05$	$F(8,171) = 5.65$, $p < 0.05$
	$F_{crit.} = 1.99$	$F_{crit.} = 1.99$

Table 3 (near-side mirrors) and Table 4 (off-side mirrors) below, show t-probability values for comparisons between the means of the distance estimations achieved with the flat mirror, against the mean distance estimations for each of the other mirrors and at each test distance.

Table 3. t-probability values comparing mean distance estimations with convex mirror against those achieved with the flat mirror (near-side mirrors)

	Near-side 0.5	Near-side 1.0	Near-side 1.5	Near-side 2.0
150	0.00004	0.00006	0.00002	0.00002
200	0.000001	0.00001	0.000004	0.000006
450	0.0018	0.00871	0.00128	0.00055
800	0.00009	0.00013	0.000003	0.00004
1200	0.03231	0.00242	0.00142	0.03795
1500	0.14277	0.00285	0.35784	0.0033
2000	0.42368	0.26576	0.19710	0.15976
2500	0.01444	0.01197	0.000006	0.00661

Table 4. t-probability values comparing mean distance estimations with convex mirror against those achieved with the flat mirror (off-side mirrors)

	Off-side 0.5	Off -side 1.0	Off -side 1.5	Off -side 2.0
150	0.00022	0.00005	0.000006	0.000004
200	0.00007	0.00005	0.00004	0.00019
450	0.00813	0.00093	0.00005	0.00012
800	0.00005	0.00011	0.00132	0.00035
1200	0.08733	0.01737	0.00197	0.11968
1500	0.00575	0.01349	0.06067	0.03640
2000	0.41261	0.34382	0.29233	0.06942
2500	0.18963	0.02325	0.01185	0.00022

In Tables 3 and 4 above, the values in the shaded cells are greater than the accepted significance level and, therefore, indicate convex mirror radii of curvature where the subjects mean estimated distance performance was not significantly different to that of the flat.

It would appear, from these results, that no significant degradation in distance estimation performance exists with spherical convex rear-view mirrors, compared to a flat mirror, down to a radius of curvature of 1200mm.

In Figures 55 to 62 below, the means of all 20 subject's three attempts at estimating each distance, using each of the mirrors on both the near and off side, is plotted.

It can be seen that there is a general trend to over estimate the object distance with the smaller radii of curvature mirrors. However, these data plots reveal a number of anomalies.

An assumption that the best distance estimation performance will be achieved with a planar (flat) rear-view mirror does not always hold true. In fact, with the near-side mirrors correct estimations of the test distances were only achieved with mirrors of radii of curvatures between 1000mm and 1200mm, while on the off-side the most accurate estimations were achieved with mirrors of radii of curvatures between 1500mm and 2000mm.

A possible explanation of this anomaly might be that drivers are generally aware of the image diminution phenomena associated with spherical convex rear-view mirrors and that they attempt to make the appropriate corrections. However, at some point, the mirror's image size of the target object eventually wins over what they know to be, probably, true about the corresponding object's distance. This point would appear to be somewhere between 1000mm and 2000mm roc.

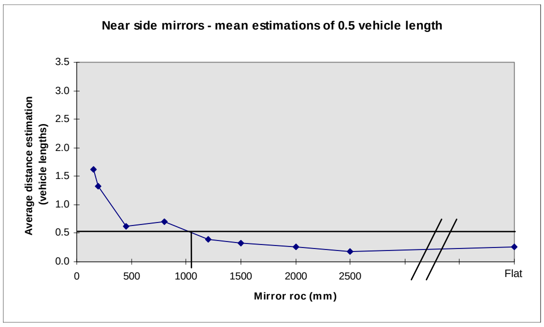


Figure 55. Graph of mean estimation of 0.5 vehicle lengths - near-side

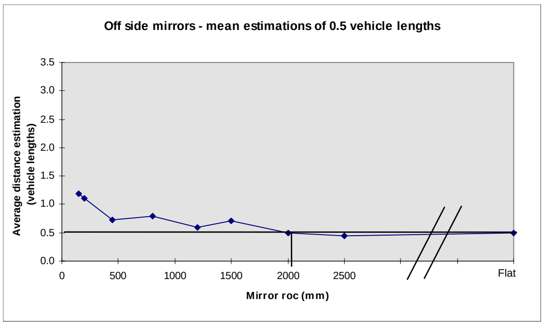


Figure 56. Graph of mean estimation of 0.5 vehicle lengths - off-side

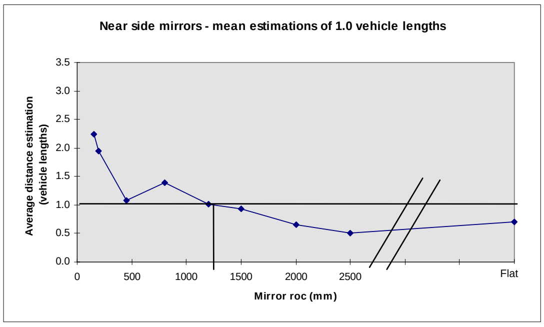


Figure 57. Graph of mean estimation of 1.0 vehicle lengths - near-side

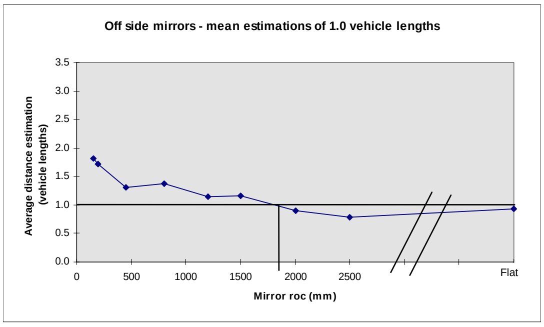


Figure 58. Graph of mean estimation of 1.0 vehicle lengths - off-side

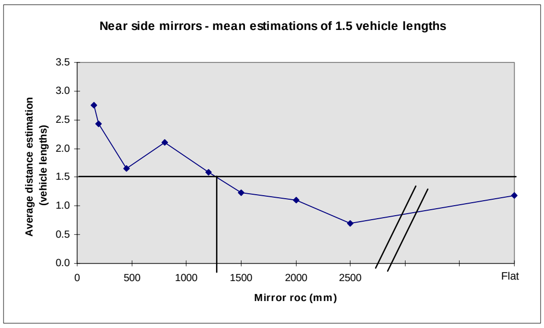


Figure 59. Graph of mean estimation of 1.5 vehicle lengths - near-side

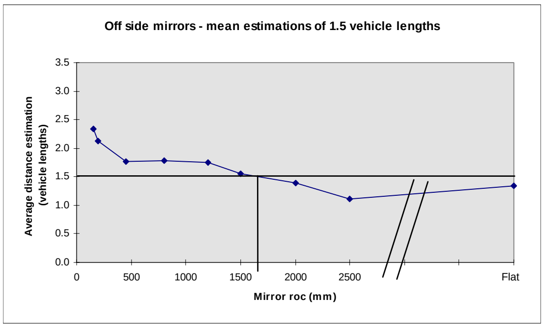


Figure 60. Graph of mean estimation of 1.5 vehicle lengths - off-side

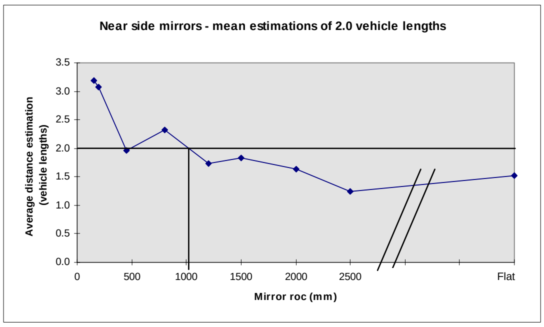


Figure 61. Graph of mean estimation of 2.0 vehicle lengths - near-side

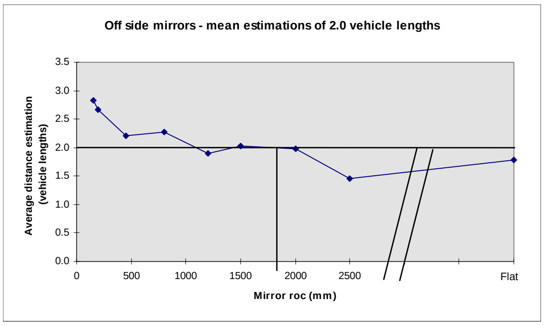


Figure 62. Graph of mean estimation of 2.0 vehicle lengths - off-side

In most road or traffic scenarios it is safer for a driver to underestimate the distance at which they perceive a target object to be when using rear-view mirrors. A best compromise, for a convex rear-view mirror, between a wide field of view and image quality would appear to be at about 1200mm radius of curvature

A further anomaly, seen in Figures 55 to 62 above, is the consistently better relative performance of the 450mm roc mirror. This may be due to the fact that this mirror was a commercially available item and that its materials of construction and subsequent image quality were superior to those of the silvered, cast acrylic blanks of the other test mirrors. Although the 2000mm radius of curvature mirror was of a similar quality and origin its improved image quality became less significant as the mirrors tended towards flat.

7.1.5 Conclusion

Convex rear-view mirrors with radii of curvature down to1200mm have no detrimental effect on a driver's ability to make static target distance judgements compared to current mirrors.

7.2 Test 2 - Effect of mirror radius of curvature on reversing accuracy

7.2.1 Aims

The aim of this test was to establish if the radius of curvature of a convex mirror had an effect on a driver's ability to accurately judge the distance of the rear of their vehicle to an object behind it by effectively simulating a reversing task.

7.2.2 Method

The subjects, test site, vehicle positions and rear-view mirrors were the same as described in Test 1.

7.2.2.1 Target description and position

The target was a black plastic tube, 0.07m in diameter and 2.4m tall, with a diagonal wrapping of red and white safety tape, mounted vertically on a wheeled trolley. The trolley had a length of light rope attached to it so that it could be pulled by the experimenter towards the rear of the vehicle from a remote position (see Figure 63. below).

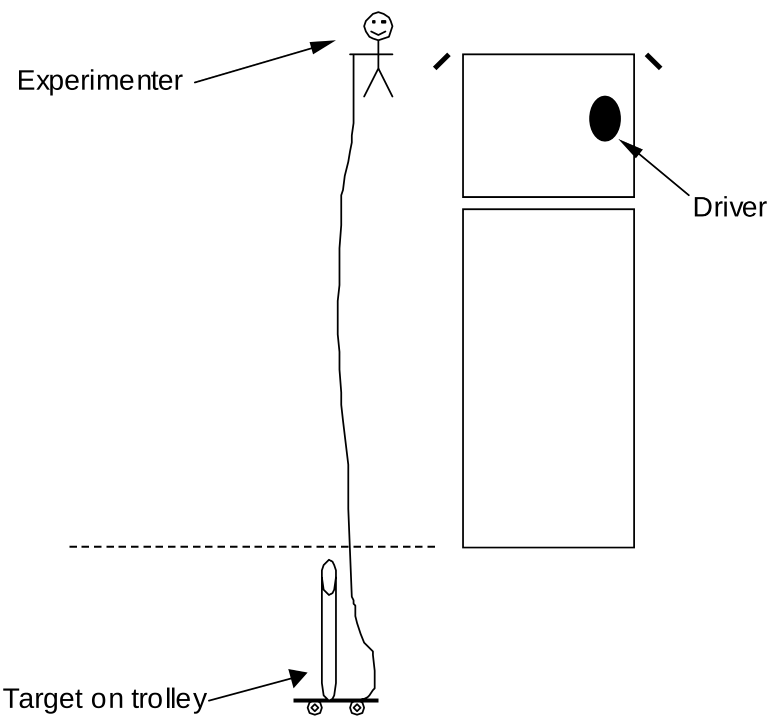


Figure 63. Plan view of Test 2 layout

7.2.3 Procedure

Each subject sat in the driver's seat of the truck while the experimenter stood to the side of the vehicle on which the mirrors were being tested. For each mirror, on both the near-side and off-side, the experimenter pulled the target pole, on its trolley, towards the rear of the truck. Using only the rear-view mirror, subjects were instructed to tell the experimenter to stop pulling the trolley when they considered that the target pole was aligned with the rear most part of the vehicle. For each mirror, the under or overestimation of the pole's alignment to the rear of the vehicle was measured (see Figure 64 below). Stopping the pole short of the vehicle corresponded to a positive estimation and taking the pole past the rear of the vehicle, i.e. towards the cab, gave a negative estimation.

Figure 64. Measuring reversing error using a simulated reversing task

7.2.4 Results

The mean reversing error of all 20 subjects, using each mirror on the near-side and off-side, was calculated. The resultant means were then plotted against their respective mirror's roc to generate the graphs shown in Figures 65 and 66, below.

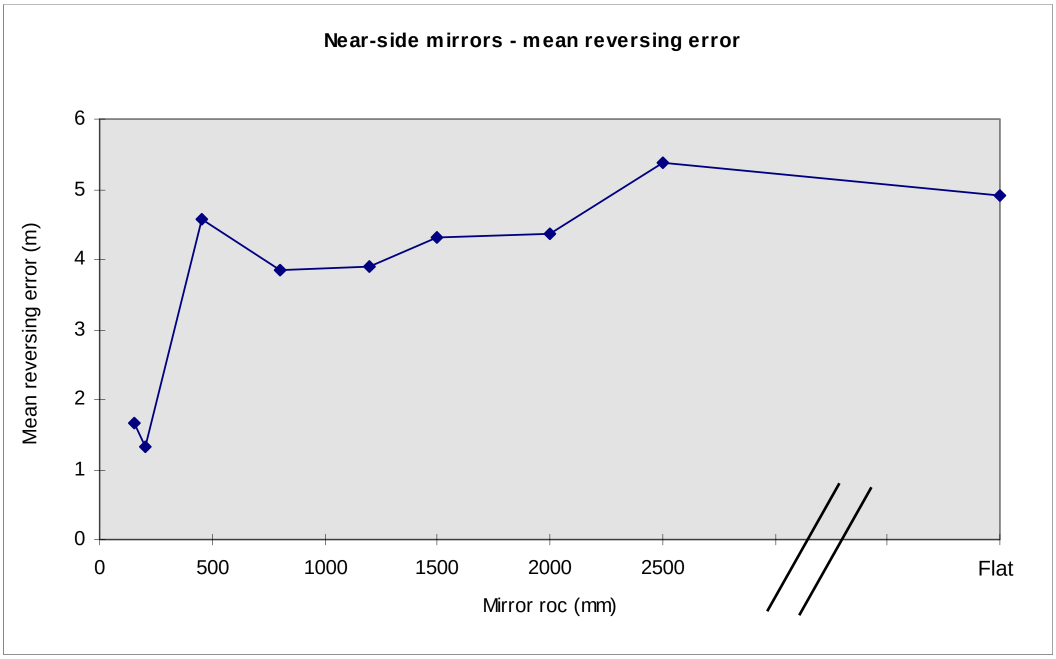


Figure 65. Graph showing the mean reversing error using near-side mirrors

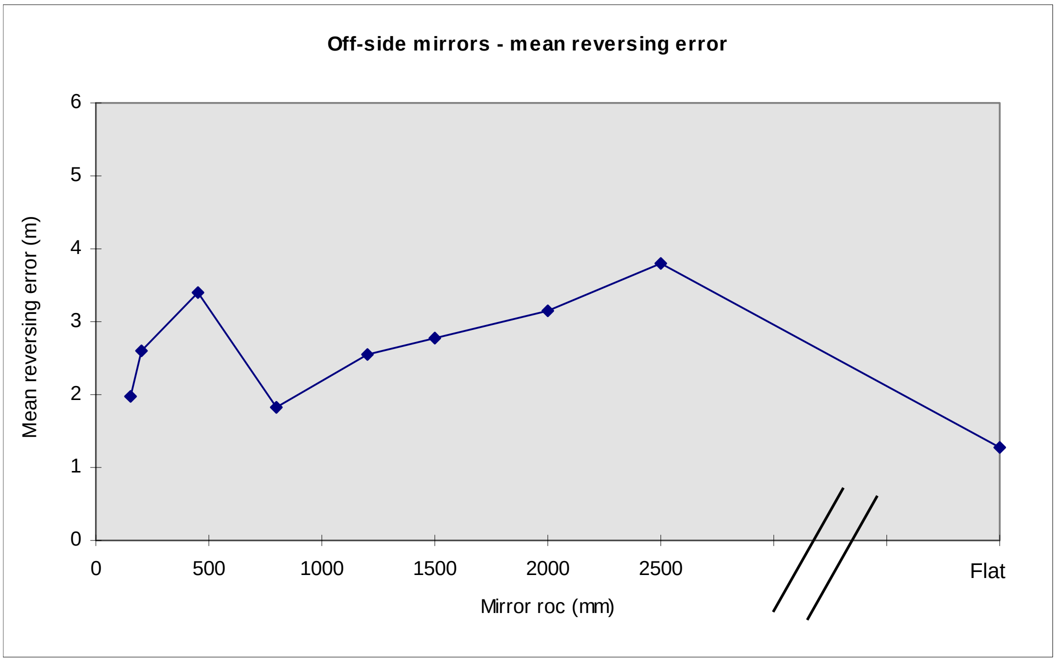


Figure 66. Graph showing the mean reversing error using off-side mirrors

It might be expected that the degree of reversing error would increase with a reduction in a convex mirror's roc. However, in this test, this is not the case. In fact, there would appear to be a general trend in the opposite direction.

One explanation of this phenomena might be that the wider fields of view, obtained from more highly curved mirrors, also afford greater spatial awareness at closer ranges. As can be seen from Figure 67 below, with a small roc mirror (e.g. 150mm) at close range a small change in the target's distance from the mirror gives a relatively large change in the target's image magnification, i.e. a steeper curve, when compared with the larger roc mirror (e.g. 2500mm). This will, therefore, give a greater indication to the driver of a changing target position.

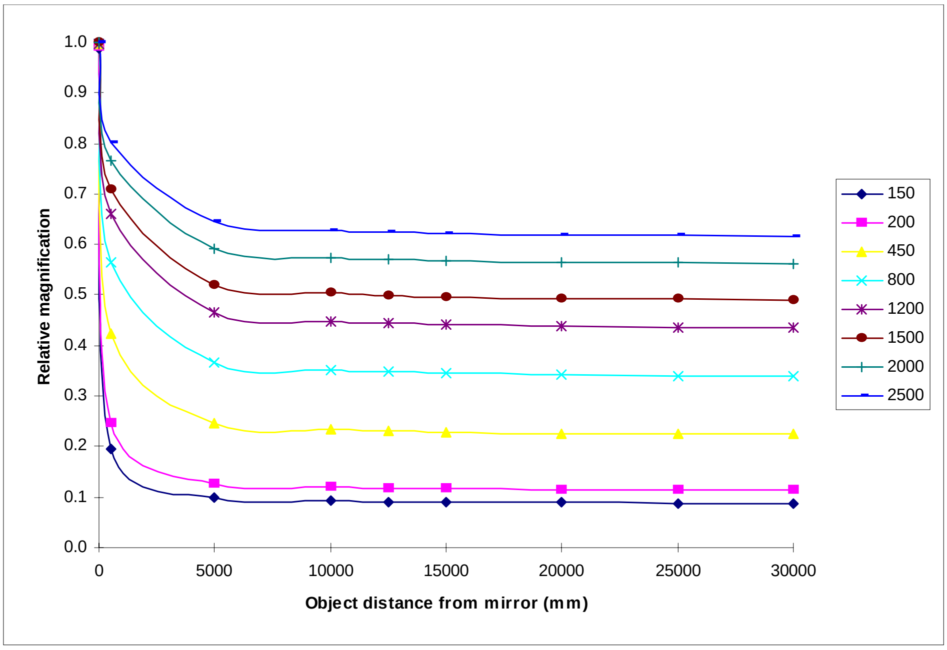


Figure 67. Graph showing relative magnification of convex mirrors

An additional factor adding to the difficulty of drivers trying to accurately position the rear of their vehicles, relative to an external features (target pole), is the close mounting of the mirrors to the edge of the vehicle. While this reduces the overall width of the vehicle it also reduces the reflected image of the vehicle's length to a very thin, vertical strip. This is illustrated in Figures 68 and 69 below.

Figure 68. Foreshortening of vehicle's length through 200mm roc mirror

Figure 69. Foreshortening of vehicle's length through 200mm roc mirror

From these mirror views it can be seen that the rear most part of the vehicle is almost impossible to see, regardless of the rear-view mirror's roc. Subsequently, it is difficult to accurately position a target relative to the back of the vehicle. While it is necessary to keep the vehicle's overall width down and to limit the extent of protruding items the position of the rear-view mirrors, relative to the driver's eye points and to the longitudinal plane formed by the vehicle's length, has implications for a driver's ability to judge vehicle length. However, it would appear that reducing the radius of curvature of rear-view mirrors, in an attempt to provide a wider field of view, does not adversely affect a driver's ability to position the rear of their vehicle when reversing. In fact, based on the results of this simulated reversing test, performance with all mirrors was relatively poor but the general tendency is to stop short of hitting the target i.e. a positive error.

7.2.5 Conclusion

Convex rear-view mirrors with radii of curvature down to 450mm have no detrimental effect on a driver's ability to make safe reversing judgements compared to current mirrors.

7.3 Test 3 - Effect of mirror radius of curvature on judging lateral displacement.

7.3.1 Aims

The aim of this test was to establish if the radius of curvature of a spherical convex mirror has an effect on a driver's ability to judge the lateral positioning of a static target viewed through them e.g. the clearance between the side of a large vehicle and a cyclist.

7.3.2 Method

The subjects, test site, vehicle positions and rear-view mirrors were the same as described in Test 1.

7.3.2.1 Target description and position

The target was a standing, adult male dressed in blue overalls and white training shoes. For each test condition, the target stood at one of 7 lateral positions (B to H) and at one of 4 distances behind the truck (0.5, 1.0, 1.5, 2.0 vehicle lengths). For each mirror, the target was presented 12 times in a randomised order, such that each distance was represented 3 times and each lateral position a maximum of twice. The whole test procedure was repeated for off-side and near-side mirrors.

7.3.3 Procedure

A vertical board with 9 lateral markers, labelled A to I, was positioned across the road in the lane not occupied by the truck and at one half vehicle length in front of the truck's cab. For each of the 12 target exposures per mirror the subject was asked to judge with which lateral marker, displayed on the board in front of their vehicle, the target most closely aligned. For the purpose of analysis of results, an estimated lateral positioning error in the direction of the vehicle was deemed to be negative while an error in the opposite direction, towards the curb, was deemed positive (see Figure 70 below).

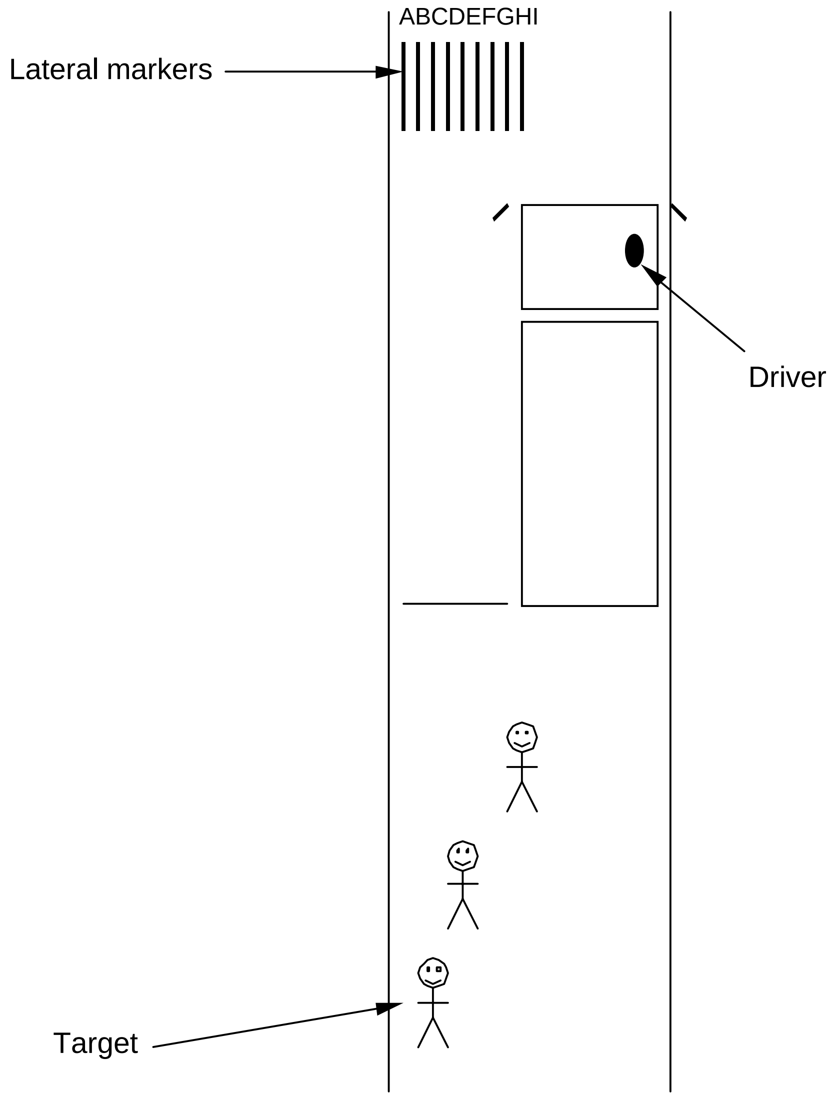
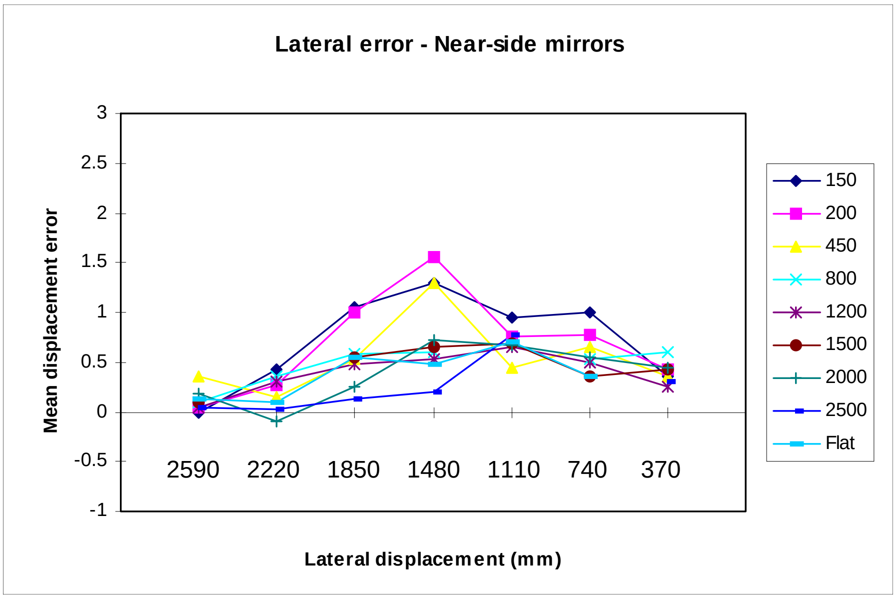


Figure 70. Plan view of Test 3 layout

7.3.4 Results

The graphs below (Figures 71 and 72) show the average error for all the mirrors, on the near-side and the off-side, plotted against the positions represented by the letters A to I on the lateral marker boards. On the near-side, position A is furthest from the vehicle and position I is closest, while on the off-side, letter A is closest and letter I is furthest from the vehicle. The distance between each lateral marker was 370mm.



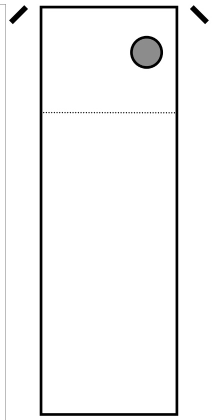


Figure 71. Graph showing lateral displacement error using near side mirrors

The results for near-side mirrors, Figure 71 above, are broadly what might be expected. That is to say, overall as mirror radius of curvature decreases the mean error increases and the extent of that error becomes greater with a lateral positioning of the target furthest from any term of reference i.e. the vehicle or roadside (curb). Additionally, all the mean errors, with the exception of one, were in a positive direction, indicating that subjects tended to estimate that a target's lateral positioning was further from their vehicle than was the case. However, in terms of actual distance the maximum lateral position error, with any mirror, was 573mm in a positive direction (200mm roc mirror at lateral position E).

The results for the off-side mirrors, Figure 72 below, are less clear. It would appear that while in general the smaller radius of curvature mirrors give bigger errors the greatest of these errors now occur in the lateral positions furthest from the vehicle. Also, all but the three smallest radii of curvature mirrors (150mm, 200mm and 450mm) now have mean errors in the negative direction i.e. towards the vehicle, and these generally occur in lateral target positions closest to the truck.

The worst mean error occurred with the 150mm radius of curvature mirror at the lateral position G and equated to a positive misplacement of 1017 mm.

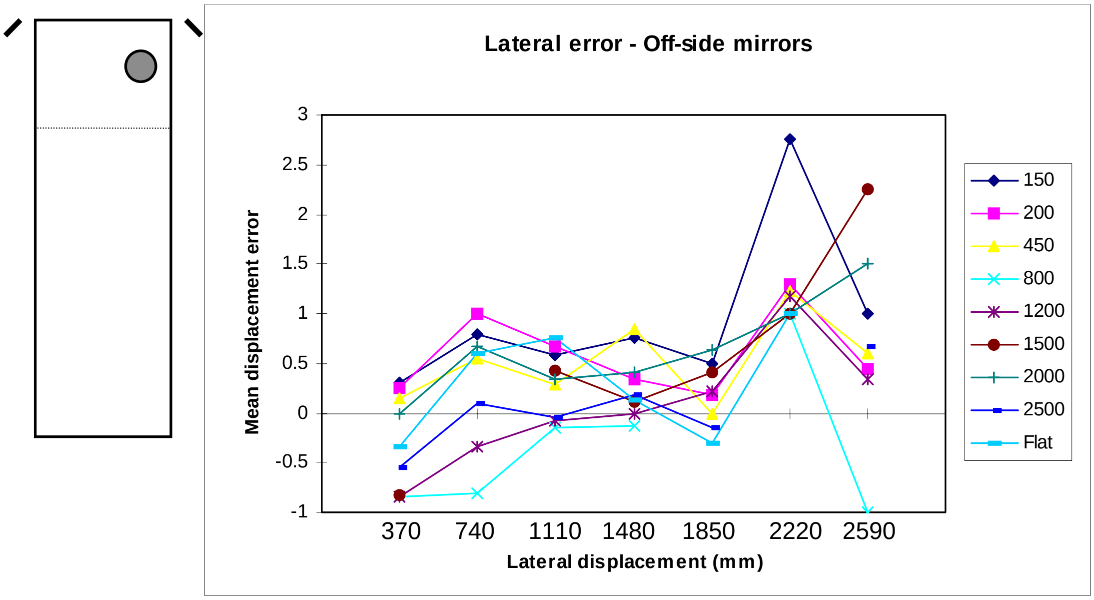


Figure 72. Graph showing lateral displacement error using off side mirrors

The fact that in this test there was a tendency by subject drivers to estimate that targets were further from the vehicle than was actually the case is of concern. Drivers will make decisions about the lateral positioning of their vehicle based upon their perceived estimation of the distance between themselves and another road user.

Off-side convex mirrors were, relatively, safer in terms of making lateral positioning errors in the negative direction i.e. perceiving targets to be closer to the vehicle than was the case. However, at best this equated to a target at 370mm from the vehicle being judged, on average, to be at 313mm from the vehicle (1200mm roc mirror at lateral position B) a difference of only 57mm.

7.3.5 Conclusion

Convex rear-view mirrors with radii of curvature down to 450mm have no detrimental effect on a driver's ability to making lateral placement judgements compared to current mirrors.

7.4 Test 4 - Effect of mirror radius of curvature on judging closing speed.

7.4.1 Aims

The aim of this test was to establish if the radius of curvature of a spherical convex mirror had an effect on a driver's ability to judge the closing speed of a target or the time until arrival of a moving target, e.g. a vehicle approaching from the rear.

7.4.2 Method

7.4.2.1 Subjects

Twenty subjects participated in the test. Fifteen males and five females, with an average age of 43.5 years. All subjects were licensed, regular car drivers.

7.4.2.2 Test site, vehicle and target positioning

The test was conducted on a private, disused airfield, on a straight length of perimeter road. The road was constructed of concrete slabs and had no surface markings. The vehicle used in this test was a Ford transit van. This was fitted with a pair of rear facing seats, positioned such that the seated subject could view a forward facing mirror through the window of the rear door (see Figure 73, below).

Figure 73. Bracket arrangement for forward facing mirrors

The road was marked out and targets positioned by the road side, as shown in Figure 74 below. The targets were vertical, rectangular boards, painted matt black and white in alternate triangles, formed by the board's diagonals. The target size was 1.7m x 1.3m which approximates to the frontal area of a small car.

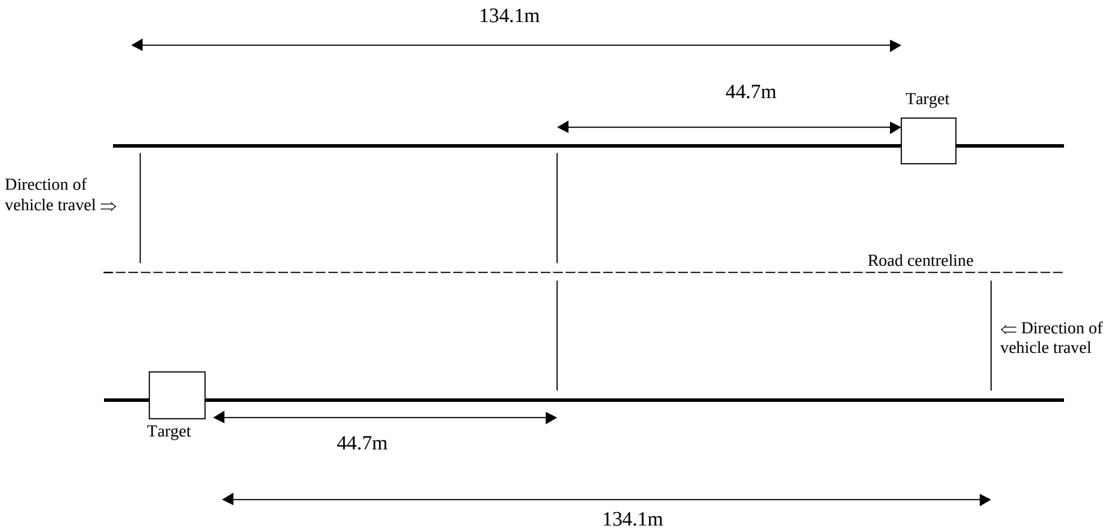


Figure 74. Plan view of Test 4 layout

Marker lines were painted on the road at distances of 44.7m and 134.1m from each target. These distances are the distances travelled in 12 seconds by a vehicle travelling at 10mph and 30mph, respectively. The marker lines were painted so that the subjects were not aware of them or their significance. (Speeds of 10mph and 30mph were selected because they encompass the range of differential speeds likely to be encountered, on dual carriageways and motorways, by large vehicles being passed by smaller, faster moving traffic).

7.4.2.3 Rear-view mirrors

The rear-view mirrors used in this test were the same as described in the previous tests, except that the 150mm roc mirror was omitted. This was due to the image size of the target in this mirror being to small to detect at the test distances involved.

7.4.3 Procedure

Each subject participated in a single, individual session that lasted about 45 minutes, including instructions and debrief. All sessions were conducted in daylight. The subjects sat in one of a pair of rear facing seats which were mounted, side by side, in the back of a van. An experimenter sat in the seat next to the subject. The only windows in the back of the van were in the rear doors. On the rear, near-side corner of the van was bolted an adjustable mirror arm bracket. This permitted mirrors to be mounted such that the subject could view the approaching, forward road scene. The van's rear door windows were covered by a roller blind so that the experimenter could open and close the blind to give the subject a limited, visual exposure of the forward facing mirror.

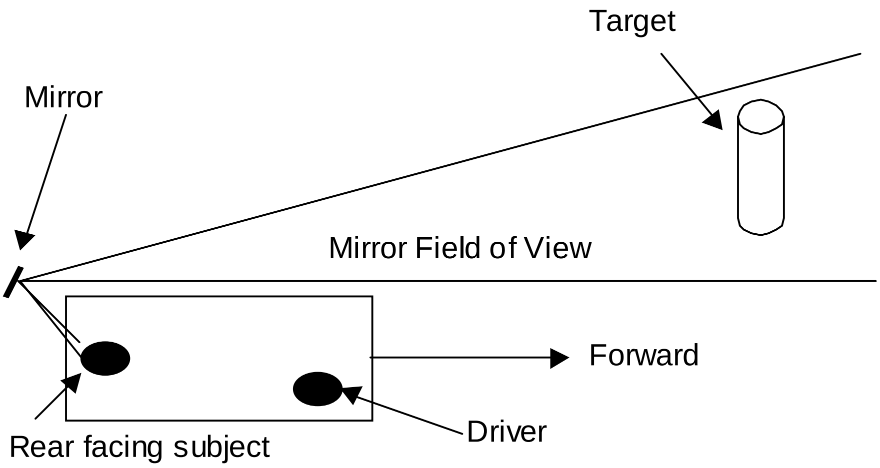


Figure 75. Plan view of forward facing mirror arrangement

Positioned in the front of the van, so that the subject could not see it, was a digital stop clock. The clock was wired so that it could be started by the driver and stopped by the subject via remote, hand held, push button controls. The second experimenter drove the van at a constant speed of either 10mph or 30mph towards the target, starting the clock when he crossed the appropriate 12 seconds to target line. Simultaneously, the first experimenter, in the back of the van, started a two second exposure of the forward facing mirror. At the end of two seconds the blind was drawn back across the window and the subject was then required to stop the clock when they considered the target would be level with them i.e. the van was passing the target.

7.4.4 Results

Figures 76 and 77 below show the average estimated time to target results for all mirrors at 10mph and 30mph. (N.B. the actual time to target for both speeds was 10 seconds).

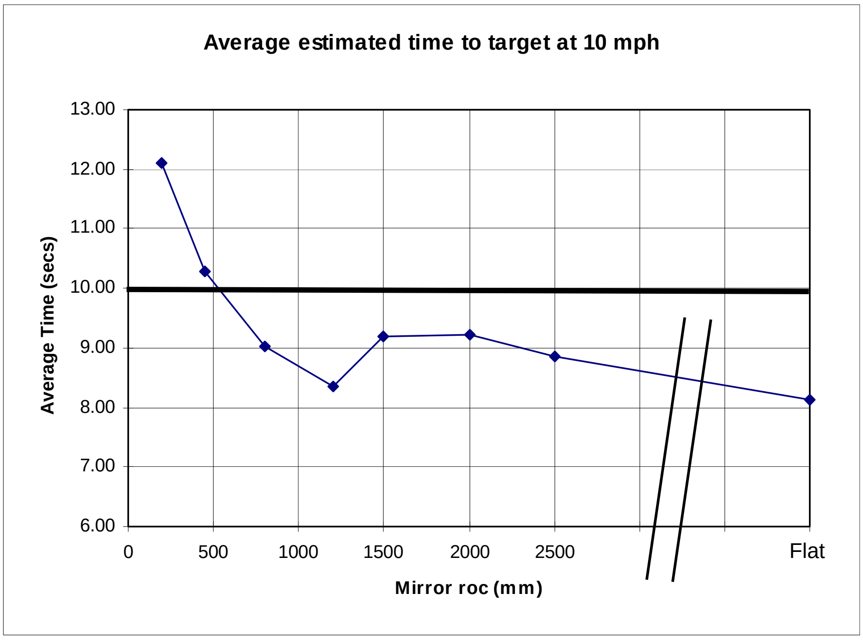


Figure 76. Graph showing average estimated time to target at 10mph

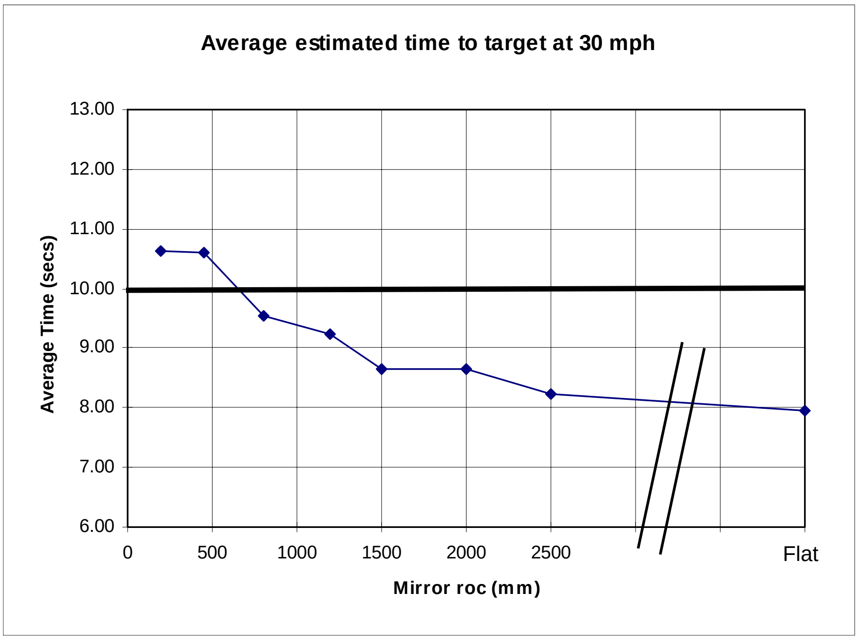


Figure 77. Graph showing average estimated time to target at 30mph

Table 5 below shows t-probability values for comparisons between the mean of the time to target estimations for the flat mirror against the mean time estimations for each of the other mirrors and at both test speeds.

Table 5. t-probability values comparing mean time to target estimations for convex mirrors compared with the flat mirror

	10mph	30mph
200	0.000001	0.00008
450	0.00253	0.000007
800	0.02753	0.03023
1200	0.25858	0.00597
1500	0.01378	0.10106
2000	0.00726	0.03371
2500	0.06326	0.26079

In Table 5 above, the values in the shaded cells are greater than the accepted significance level and, therefore, indicate convex mirror radii of curvature where the subjects mean estimated time to target arrival performance was not significantly different to that of the flat mirror. It would appear from these results that no significant degradation in time to target arrival performance exists with spherical convex rear-view mirrors, when compared to the performance of a flat mirror, down to a radius of curvature of 800mm.

However, a problem arises from our assumption that best time to target estimation performance is achieved with a flat mirror. It is known that in this test the time to arrival of a target, at both 10mph and 30mph, was always 10 seconds after the end of the mirror's exposure but the average time to target estimation for the flat mirror was 8.12 seconds at 10mph and 7.95 seconds at 30mph. The mirror that subjects most accurately used, with respect to estimating 10 seconds to target arrival, was the 450mm roc mirror at 10mph (10.28 seconds) and the 800mm roc mirror at 30mph (9.53 seconds).

In all the tests using spherical convex rear-view mirrors, subjects seem to be aware of the image diminution phenomena. Therefore, they tend to build in a correction factor when giving their estimations of perceived object distance based on mirror image size. In most instances it would appear that there is an over correction in the direction of caution i.e. targets are reported as closer than in reality or the time to arrival of an approaching target is reported as shorter than in reality. The extent of this over correction diminishes with a decrease in the mirrors radius of curvature.

7.4.5 Conclusion

Convex rear-view mirrors with radii of curvature down to 800mm have no detrimental effect on a driver's ability to make closing speed judgements compared to current mirrors.

7.5 Test 5 - Assessment of reversing aids

Four types of proprietary reversing aid were tested: infra-red, ultrasonic, radar obstacle detectors and CCTV rear vision. All the tests were undertaken in the laboratory with the systems mounted on a rig representing the rear of a large vehicle. All the systems were installed in accordance with the manufacturers instructions.

7.5.1 Obstacle detectors

Tests of the infra-red, ultrasonic and radar obstacle detectors were developed to assess each system on the following criteria:-

- field of detection
- ability to detect objects moving into their path
- detection time from system activation to the driver responding to a signal. Typically the systems are activated when reverse gear is selected and should therefore respond before the driver begins to reverse.

The tests considered the auditory warnings rather than any visual display because the drivers will still need to use their rear view mirrors and any additional visual display will compete with this.

7.5.2 Method

The tests were based on ISO TR 12155 which defines three distances behind the vehicle at which the system should be tested:

600mm – collision range
1600mm – main warning range
2700mm – pre-warning range.

These are based on reversing speeds of 5km/h (approximately walking speed).

A 1037mm tall child was employed as the target in place of the 1000mm tall, 75mm diameter, grey pipe specified in ISO TR 12155 as the pipe would be invisible to the radar system. Additionally, the child target corresponds more closely to the target developed for other parts of this study.

The tests of the field of detection were undertaken at a number of points at each of the three detection distances. The target detection points extended beyond the width of the vehicle at 400mm intervals from the vehicle's centre line. As the radar system only detects relative movement the target rocked back and forth for these tests. The tests were repeated as the child walked across the rear of the vehicle at each of the detection distances.

Response time tests were undertaken with the subjects (drivers) located such that they could hear the warning device but could not see the rear of the vehicle. Three people took turns to be drivers. A large person acted as the target and locations were found at which the target would evoke the system to respond at each of the warning levels available. Twelve trials were undertaken; on six of these a target was present and on six there was no target. The order of the trials was randomised so the subject could not guess the warning he was about to hear. For each trial, after the target was in position, the system was switched on and a timer simultaneously started. The subject stopped the timer with a remote control as soon as he was able to determine the level of warning (responding, 'go', 'caution' or 'stop').

Figure 78. Reversing aid test rig and child target

7.5.3 Results

None of the obstacle detector systems was able to reliably detect the 1m tall child behind the vehicle.

The infra-red system only detected (i.e. gave a high level warning) when the child was 600mm behind the vehicle and on its centre line. It failed to warn if the child was at the same distance but 400mm to the side of the centre-line i.e. still within the vehicle’s path.

The Ultra-sonic system failed to detect the child in any location behind the vehicle when mounted at 1250mm. When lowered to 1000mm the child was only detected when standing at the closest position (600mm) near the centre of the vehicle. It failed to detect the child when he was more then 600mm laterally from the centreline.

The radar system could detect the child at 1600 and 2700mm distance but failed to detect at 600mm.

These results were found with the reversing aid sensors mounted at 1250mm or 1000mm above the ground and were not overcome by adjusting the angles of the sensors.

In light of the above findings the detection times are of less significance, however they provide some guidance to the design requirements of an effective system.

Table 6 below shows the results for three subjects (the values in the cells are the averages of 2 presentations). The results demonstrate the classical reaction time principle that reaction time is dependant on the number of response choices available. The Ultra-sonic system had two auditory signals (effectively corresponding to 'go' or 'stop') and was responded to more quickly than the infra-red which had three ('go', 'warning', 'stop'). The slower times of the radar system are due to the longer delay between switching on and the audible signal.

The differences between the infra-red and Ultra-sonic response times become larger when considering the more critical response times, i.e. to a 'stop' signal. This is due to the delay of about one second after switching on before the ultra-sonic system responds. The infra-red system's response is almost instantaneous.

Table 6. Average times for interpreting reversing aid audible warnings

	Overall			'Stop'		
	Infra-red	Ultra-sonic	Radar	Infra-red	Ultra-sonic	Radar
S1	3.01	2.20	4.98	0.97	2.14	5.66
S2	3.35	2.27	4.65	0.96	2.22	4.78
S3	2.41	2.14	4.25	0.70	1.79	3.95

7.5.4 CCTV systems

Two proprietary vehicle CCTV systems were tested, a less expensive (CCTV1) and a more expensive, higher quality system (CCTV2).

7.5.5 Method

Each camera unit was mounted on the test rig at a height of 4.25m, (approximately the height of an articulated semi-trailer carrying an ISO container). Each camera's position was adjusted in its mounting bracket so that the lower edge of the vertical viewing angle aligned with the rear face of the test rig i.e. vertically downwards.

Target detection tests were conducted with three subjects. The CCTV monitors were positioned behind a mechanical shutter device so that their screen could be revealed to the subjects for approximately 0.5 seconds. This short duration was used to represent glimpse viewing, as a driver may make when shifting his/her view between the mirrors and CCTV monitor. After the exposure the subjects had to state whether a target was present. Twelve presentations were made to each subject: on six of these the target was present at either of the three detection distances on the vehicle's centre line. On six occasions no target was present. The target conditions were randomly presented.

A control condition was also tested to provide a baseline against which to compare the CCTV results. In this condition a 450mm radius convex mirror, showing a side view to the rear of the vehicle, replaced the CCTV monitors. The mirror was used not because it is proposed as a rear view system, but because it offers a control for the effects of viewing through the shutter.

The target was a 1m high, 75mm diameter grey plastic pole as required in the test procedure set out in ISO TR 12155. The tests were undertaken in both daytime and night time, with the vehicle reversing lights on during the night time tests.

7.5.6 Results

Table 7 below shows the number of times a target was missed (out of a total of 6 presentations for each cell).

Table 7. Target detection failure rates using CCTV systems

	Day			Night		
	CCTV1	CCTV2	Mirror	CCTV1	CCTV2	Mirror
S1	1	1	0	3	4	0
S2	0	2	1	2	2	1
S3	1	0	0	3	1	0
Totals	2	3	1	8	7	1

Whilst CCTV does provide a view to the rear, which the driver would otherwise not have, it is evident from these findings that it is not wholly safe. In good lighting conditions our subjects were failing to detect targets on about one in six occasions but this rose to around one in two at night-time.

Part of the problem with the CCTV system is due to the high camera position reducing the apparent size of an object close to the rear of the vehicle. Sixteen of the fourteen missed targets occurred when the target was closest to the rear of the vehicle. No targets were missed at the furthest distance. However the high camera position is required so that the rear of the vehicle is within view and so that a closing distance to the rear of the vehicle can than be judged.

7.5.7 Conclusions

Most reversing aids, that are currently available, come with warnings that they are only a driver aid and that they do not exempt the driver from taking every normal precaution when reversing. The results of this work would confirm this: the driver cannot rely on these systems to ensure it is safe to reverse. There must be concern, however, that the driver of a vehicle fitted with such a system would be encouraged to rely less upon other safety procedures, such as mirrors or asking for another person to check the way is clear. For these reasons we are very reluctant to recommend the use of such systems.

8. Cost/Benefit Analysis

8.1 Methodology

An accurate cost/benefit analysis that will establish a break even point for the cost of implementing a proposed field of view improvement to all large vehicles, balanced against the benefit of any casualties saved as a direct result of that improvement, has proved problematic. Whilst the total cost of implementation is a relatively easy figure to estimate, as is the cost of all casualties involving large vehicles and vulnerable road users, what is much harder to establish is the potential casualty savings directly resulting from a vehicle improvement. Accident data does not provide sufficient detail to establish lack of driver vision or poor driver awareness as a contributory cause of an accident. Therefore, it is difficult to determine to what extent an improvement in driver's vision or awareness might save accident casualties.

The following cost/benefit analysis starts by estimating the cost of implementing the proposed field of view improvement. This implementation cost is then divided by the cost of prevention of a fatal casualty so that the resultant value gives a figure for the number of fatal casualties that would have to be saved as a result of the implementation to recoup the cost.

Having established the number of casualties that would have to be saved to justify the implementation cost, the final stage of the analysis will attempt to assess the likelihood of such a saving and a time frame for break even. By necessity, the final stage analysis has been based on information that is, in some instances, subjective or has made some extrapolative assumptions based on more specifically focused accident research. For instance, a short, postal survey was distributed to personnel in organisations representing large vehicle and vulnerable road user groups asking their expert opinion of the extent to which poor driver's field of view from large vehicles might be a causation in accidents involving vulnerable road users. Perhaps, not surprisingly, the response rate was poor with a reluctance by people to make speculative assumptions. However, where responses were received, the percentage of accidents ranged from 1% to 80%.

8.2 Cost

To ensure that the driver's field of view requirement proposed by ICE Ergonomics is covered to the greatest extent by all large vehicles, this research has proposed that three additional wide angle mirrors be fitted to the entire new large vehicle fleet. One mirror mounted internally on the near-side A-pillar to view the immediate front of the vehicle and an additional wide angle mirror on the off-side. A near side, wide angle mirror will also be fitted to all large vehicles, less articulated vehicle tractor units which already have one fitted. Also, it is proposed that to fully cover the field of view requirement a CCTV system would need to be fitted to cover the blind area immediately behind all large vehicles when reversing.

Table 8 below shows the likely cost of the technologies involved in the proposal. The prices quoted assume that a reduction in the unit price will apply with bulk ordering and mass production. However, the exact extent of this reduction is difficult to quantify at this stage so the figures quoted may in fact differ slightly if actual market forces were applied.

Table 8. Average cost of field of view improvement technologies

Technology	Average cost (£) per unit
Additional rear view mirrors	15
Electrically adjustable Class II mirrors	50
CCTV - single camera and monitor	175 (camera only 50)

Table 9 below, shows a breakdown of the UK large vehicle fleet first licensed in 1996 (the latest year for which figures were available).

Table 9. GB large vehicle stock - total and annual first licensed.

Year ending 1996	Total UK licensed stock(thousands)	First licensed in 1996 (thousands)
Large vehicle total	497.3	50.7
Rigid	311	28.4
Articulated	109.6	15.8
Bus & Coach (public use)	76.7	6.5
Trailers (all axle configurations)	226.7	

Source - Table 15 p39, Table 19 p42 Transport Statistics Report - Vehicle Licensing Statistics:1996 DETR.

By multiplying the average cost of a technology by the number of large vehicles first licensed in a year an implementation cost for the new large vehicle fleet can be calculated.

In Table 10 below, the additional mirror implementation cost has been calculated by summing [2 x the cost of one mirror (£15) by the total new large vehicle fleet (50700)] + [1 x the cost of a mirror (£15) x the total new large vehicle fleet less new articulated HGVs (50700-15800)]. HGV articulated tractor units already have an additional mirror on the near-side.

This research also recommends that large vehicle mirrors should be adjustable from the drivers position. Currently, electrically adjustable Class II rear-view mirrors, as a factory fitted optional extra, cost approximately £85 per side. If compulsory fitment forced mass production then a cost per vehicle of £100 might be reasonable. The cost of implementation of the electrically adjustable class II rear view mirrors is based on [2 x cost of electrically adjustable mirror (£100) x new, large vehicle fleet per year (50700).

The CCTV implementation cost is based on [1 x the cost of a CCTV system (£175) x the total new large vehicle fleet (50700)] + [1 x the cost of a CCTV camera (£50) x total UK trailer stock (226700) less total UK articulated tractor unit stock(109600)]. Additional semi-trailers will require their own cameras.

Table 10. Cost of technology implementation to the annual new large vehicle fleet

Technology	Total cost to large vehicle fleet
Mirrors (additional)	£2,044,500
Electrically adjustable Class II mirrors	£5,070,000
CCTV systems	£14,727,500

This equates to a total implementation cost, for the whole new large vehicle fleet per year, of £21,842,000.

The average value of prevention per fatal casualty is currently estimated to be £902,500. If the implementation costs are divided by this figure then the cost can be expressed in terms of the number of fatal casualties that would have to be saved as a direct result of the implementation to recoup its cost. The implementation cost of the additional mirrors equates to 2 fatalities, the adjustable mirrors to 6 fatalities and the CCTV system to16 fatalities. The total implementation cost being equivalent to 24 fatal casualties that would have to be saved as a result of the implementation to recoup the cost. The feasibility of making such a casualty saving as a result of these proposed driver's field of view improvement strategies is investigated below.

Due to there being little statistical data it is difficult to assess precisely the effects of improved driver fields of view on casualty savings. However, by means of extrapolation from alternative accident data sources and from previous, related research it is possible to make some reasonable estimates as to the likely casualty savings that might be expected as a result of an improvement in large vehicle driver's field of view.

In a detailed study by the Transport Research Laboratory (Robinson 1997) of 1049 fatal accidents causing 1194 fatalities, between 1991 and 1993, and involving at least one HGV it was concluded that two of the most common accident scenarios also involving vulnerable road users were:

- HGV drivers failing to see cyclists or motorcyclists as they enter a major road or roundabout.
- Pedestrians attempting to cross the road directly in front of a stationary HGV, which strikes them as the driver pulls away.

The report went on to state that the estimated annual GB savings from improved forward vision from HGV cabs through lowering the windscreen's lower edge would approximate to 10 lives saved per year. There is little reason to believe that a similar or greater fatal casualty saving could not be made as a result of fitting a mirror that improves the immediate frontal vision of all large vehicles when buses and coaches are also included in the calculation. If the accident reductions as a result of fitting the two wide angle mirrors are also considered it would seem a conservative estimate to claim a potential life saving of 15 lives a year as a result of fitting the additional mirrors to the entire large vehicle fleet.

In 1997 there were 1144 large vehicle accidents where the manoeuvre prior to the accident was recorded as changing lane; 971 where the manoeuvre was described as overtaking a moving or stationary vehicle; and 258 recorded as reversing prior to accident. All of these manoeuvres require the vehicle's driver to check areas where the proposed near-side and off-side mirrors and CCTV will improve their field of view. Of the 2373 accidents recorded as occurring during these manoeuvres it would seem reasonable to assume a similar fatal casualty saving of about 10 lives, as claimed for improved frontal vision, for improved near side, off side and rear vision.

This claim can be further supported when it is considered that in a recent study on reversing accidents in UK transport fleets (Murray et al, 1997) it is reported by a reversing safety equipment manufacturer that on-road accidents account for less than 10% of the total number of reversing accidents reported in RAGB (Hanson-Abbot, 1997). If a further 5 off-road reversing fatalities were saved as a result of fitting CCTVs then a total fatal casualty saving of 30 lives a year would seem a feasible and conservative estimate.

In Figure 79 below, the cost/benefit graph shows the cost of introducing the proposed field of view improvement strategy to the whole UK large vehicle fleet. It assumes a 10% new large vehicle replacement a year. Hence the cost of implementation remains constant while the benefit (savings in cost of fatal casualties) rises by 10% a year until a maximum estimated casualty cost saving is reached when the entire large vehicle fleet is equipped.

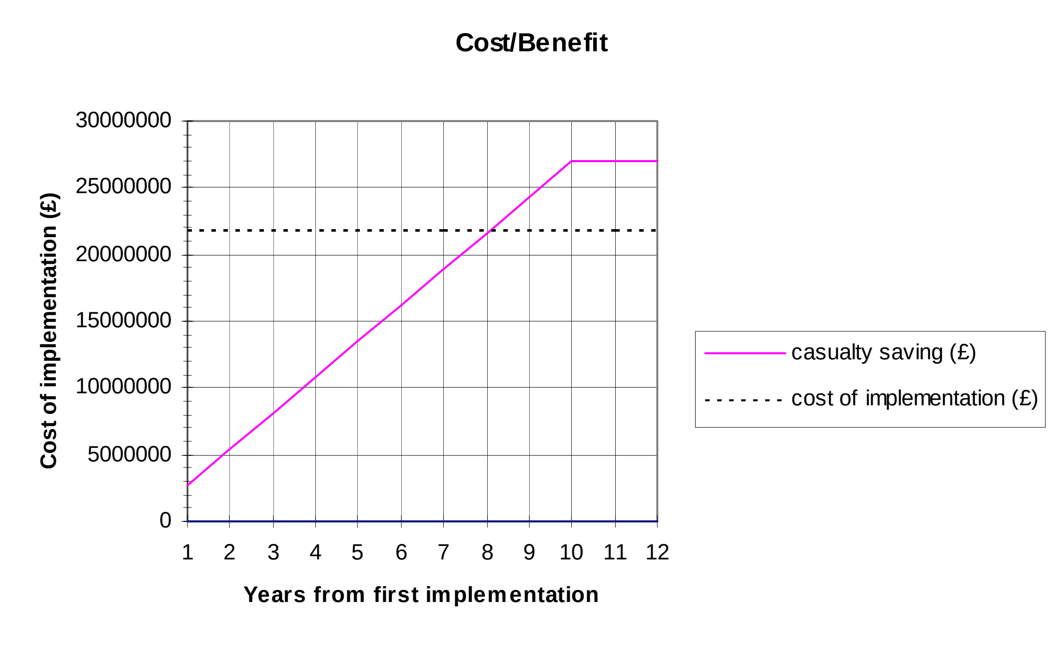


Figure 79. Cost of implementation against benefit of casualty saving

It can be seen that the net savings from the universal implementation of the additional wide angle mirrors, the electrically adjusted Class II mirrors and the CCTV systems starts a little after eight years and after 10 years becomes £5.2m per year.

In conclusion, the introduction of the proposed driver field of view improvement strategy to the entire large vehicle fleet would in the long term provide advantages with respect to both the potential for life and monetary savings.

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