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The Development of Improvements to Drivers' Direct and Indirect Vision from Vehicles – Phase 1

For: Department for Transport
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Prepared by: Loughborough Design School, Loughborough University and MIRA Limited

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MIRA

Loughborough University

The development of improvements to drivers' direct and indirect vision from vehicles. Phase 1. (AR2638)

Department for Transport [DfT]

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EXECUTIVE SUMMARY

This research project concerning 'The development of improvements to drivers' direct and indirect vision from vehicles' has been designed to be conducted in two phases:

- Phase 1 whose aim is to scope the existing knowledge base in order to prioritise and direct activities within Phase 2;
- Phase 2 whose aim is to investigate specific driver vision problems prioritised in Phase 1 and determine solutions to them.

This report details the activities, findings and conclusions resulting from the Phase 1 tasks undertaken.

The approach undertaken within Phase 1 was to use triangulated research methods to investigate the aspects relating to drivers direct and indirect vision by means of: a literature review; a review of previous accident data studies; consultations with major interest groups and a legislative review (Refer to section 2).

The data derived from these activities has been used to address the key issues raised within the project's work specification regarding:

- What should the driver be able to see (section 3);
- What do drivers need to see (section 4);
- What can drivers actually see (section 5);
- Blind spots (section 6);
- Accident scenarios (section 7);
- Solutions (sections 8, 9 and 10).

Using the data gathered, an assimilation activity was undertaken to identify the vision-related risk factors pertinent for each vehicle category and prioritise areas for further investigation within Phase 2 (section 12).

Based on these identified priorities, a preliminary research plan has been proposed for discussion with the Department (section 14).

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1 INTRODUCTION

1.1 Background

The Transport Technology and Standards (TTS) Division of the Department for Transport has a responsibility for providing technical support to policy formulation and development. This is achieved through a broad research programme pertaining to vehicle-related safety issues to support the development of vehicle standards and regulations and the enforcement of standards. Within this remit, TTS wishes to investigate the issues and implications for extending regulations relating to drivers' field of view requirements. Currently all M and N vehicles have to comply with European legislation with respect to indirect vision (vision through mirrors and cameras); however when direct vision (through the windscreen and side windows) is considered this is only mandated for M_1 vehicles. If the legislation is to be extended then the Department needs to be able to take an informed stance on any proposals to it. To facilitate this, it therefore wishes to understand:

- What the direct field of vision requirements for M_2, M_3 and all N category vehicles are, since it cannot be assumed that the requirements for M_1 can be directly transferred,
- The implications for RH drive and LH drive vehicles being used in LH drive and RH drive environments respectively,
- The effect of vehicle size,
- The relationship between direct and indirect field of view requirements in order to support as close as possible a 360° visual field requirement.

1.2 Aim

The over-arching aim of the project is to investigate the drivers' direct forward field of view and indirect field of view requirements for all 'M' and 'N' category vehicles with the intention to identify solutions to achieve, as far as is practicable, a 360° field of vision in which other road users can be easily seen.

1.3 Objectives

The stated objectives of the project cover:

Vision

The research needs to provide information on what drivers of 'M' and 'N' category vehicles:

- Should be able to see,
- What they actually see in the real world,
- How their field of vision may be affected by vehicle design.

Blind spots

The research needs to:

- Identify blind spots in both drivers' direct and indirect fields of view,
- Propose practical solutions to eliminate the identified blind spots.

Solutions

The solutions should facilitate drivers in easily seeing other road users at all times. The solutions should aim to:

- Minimise obscuration of the direct field of view relating to vehicle design, exterior mirrors and other vehicle features,
- Maximise the drivers' indirect field of view,
- Provide recommendations for amendments to the European legislations, where appropriate.

The context in which the objectives need to be considered includes:

- Right and left hand drive vehicles,
- Basic vehicle design and the drivers' environment,
- Future potential vehicle design features.

2 DESCRIPTION OF PHASE 1 APPROACH

2.1 Overview of Phase 1

The aim of this phase was to scope the existing knowledge base in order to prioritise and direct activities within Phase 2. The intention of the review was to consider the relevance of previous work to the current situation and to identify knowledge gaps where further investigation may be needed. To achieve this, the following tasks were undertaken.

2.2 Literature review

The aim is to identify and review data relevant to the project aim in order that the current state of knowledge is correctly understood and documented, thereby providing a reliable foundation to guide Phase 2. The review will be necessarily broad in scope in order to cover the range of factors identified in the project's Work Specification and some additional topics such as analysis of the driving task and driving psychology. It will draw upon previous research, accident analysis, risk assessment and the Department's relevant research programmes.

It is intended that the literature review will draw from four sources:

- Department for Transport – The references identified in the Work Specification relating to past research for the Department will form a good starting point for the review. Additionally any further knowledge held with the Department will be explored with the project officer in the kick-off meeting.
- Academic review – Both ESRI and MIRA have excellent facilities for, and can demonstrate competence in, conducting formal, academic literature reviews. Both have in-house libraries with dedicated staff members to undertake detailed searches; with ESRI also having additional links to Loughborough University's library where it is supported by an academic librarian specialising in scientific literature searches.

- Extended review – The academic review will be extended by reviewing written data sources outside of the published, academic arena via a web-based search. Whilst it is acknowledged that the quality of this data may be less reliable, it may nonetheless identify additional areas for consideration by the project team.
- Recommended reading resulting from consultations – Past experience indicates that one of the outputs from undertaking consultations is the identification of further written materials for review. It is therefore anticipated that this will be a further data source for the literature review within this project.

In addition, as part of this task, experts within the Vehicle Safety Research Centre (VSRC) at ESRI will review the findings of the literature review relating to relevant accident data analyses. The VSRC team has considerable experience in reviewing accident data with reference to specific research questions. Whilst published accident data and analyses do not always answer specific research questions directly, the VSRC's familiarity with accident data enables it to interpret and extrapolate information. Based on this experience, if directly relevant data analyses are not in abundance, the VSRC is expertly placed to provide valuable insights into the context of the findings.

2.2.1 Rationale

The aim was to identify and review data relevant to the project aim in order that the current state of knowledge is correctly understood and documented, thereby providing a reliable foundation to guide Phase 2. The review was necessarily broad in scope to cover the range of factors identified in the Invitation To Tender Work Specification.

2.2.2 Method

The sources used for the literature review were:

- Department for Transport – Relevant past research undertaken for the Department was identified and reviewed.
- Academic review – This covered a number of specialist databases including: Vision in Vehicles conference papers; Engineering Village (Compendex and Referex); CSA Illumina (ANTE (Abstracts in New Technologies and

Engineering), Mechanical & Engineering Transportation Abstracts and PyscINFO); TRIS – RITA (Transportation Research Information Service - Research and Innovative Technology Administration - National Transportation Library); TRL; Ergonomics (InformaWorld and Ergonomics Abstracts).

- Extended review – A review of written data sources outside of the published, academic arena via a web-based search.
- Recommended reading from consultations – Further documentation identified within the consultations was followed up and included within the review.

2.3 Accident data

2.3.1 Rationale

A review of accident data in the public domain was undertaken to establish the current state of knowledge with a view to identifying areas where further analysis may be required within Phase 2.

2.3.2 Method

The review of previous accident data analyses included documents provided by the Department as well as further sources identified by the Vehicle Safety Research Centre within ESRI.

2.4 Consultations

2.4.1 Rationale

The aim of the consultation task was to probe expert knowledge as a means to extend the knowledge base beyond what is available in a published form. A broad-based consultation was undertaken thereby enabling a range of key stakeholder groups to contribute.

2.4.2 Method

The consultations took the form of telephone interviews with a range of organisations directly or indirectly related to the motoring industry and / or road infrastructure or were deemed to have a view on the issue of driver vision. Organisations contacted for consultation in Phase 1 are summarised in Table 1 below.

Organisation	Contact	Area of Expertise / Responsibility
AA	Andrew Howard	Circulated internally but no contact established
(BRAKE) The Road Safety Charity	Cathy Keeler	Deputy Chief Executive
Brigade	Philip Hanson-Abbott	Managing Director
Cemex	Paul Clarke	Logistics Fleet Engineering Manager
Community Transport Association		Do not operate a national fleet. Independent operators serve different areas. Hackney Community Transport is one of largest.
(CPT) Confederation of Passenger Transport	Colin Coplin	Technical Executive
(CTC) Cycle Touring Club	Chris Peck	Policy Coordinator including specific responsibility for vehicle safety
(DSA) Driving Standards Agency	Ashleigh Bateman	Standards and Regulations Directorate and Chair of Driving Exam board, Assistant Chief Driving Examiner
(DVLA) Driving and Vehicle Licensing Agency	No contact	Nothing to contribute
(FTA) Freight Transport Association	Andrew Mair	Head of Engineering Policy
Hackney Community Transport(via Community Transport Association)	George Mutch	Regional Manager
(HSE) Health and Safety Executive	Jim Corbridge	Experienced Specialist Inspector, visibility of workplace vehicles including earth moving, fork trucks and also on-road vehicles when on-site
Highways Agency	Stuart Lovatt	Lead on development of road safety and training
Kings Ferry Coach Company	Danny Elford	No response
(LCC) London Cycle Campaign	Charlie Lloyd	Cycling Development Officer, part of campaigning team and lead on HGV issues
Parliamentary Advisory Committee on Transport Safety	Julian Hill	No response
RAC	John Clayton	Technical Liaison Manager, liaise with manufacturers of vehicles and equipment
(RHA)Road Haulage Association	Ray Edgely	Head of technical services
Roadpeace	Cynthia Barlow	Chair of Roadpeace and active in the area of road safety and cycling accidents
(RoSPA) Royal Society for the Prevention of Accidents	Duncan Vernon	Road Safety Manager for England, respond to government consultation and promote safety through legislation and directly to consumers

Royal Mail	Rami Mistry	Senior Technical Advisor, Fleet and Assets division – responsibility for procurement of vehicles
Society of Motor Manufacturers and Traders	Peter Davis	Circulated internally but general view is nothing to contribute
Tesco	Andrew Kemp	Tesco home delivery fleet, Occupational Road Risk Manager
Tesco	Cliff Smith	Tesco HGV fleet, Fleet Engineering Manager
Transport for London	Chris Lines	Area of responsibility related to road safety. Chris has left TfL so only brief discussions were had before he left. Re-structuring means that new roles are not yet clear so he is unsure who will be his successor.
(VCA) Vehicle Certification Agency	Stephen Trenoweth	No response
(VOSA) The Vehicle and Operator Services Agency	Andrew Tudor	Automotive Engineer, Vehicle Safety Branch

Table 1: Organisations consulted during Phase 1

The consultation began by identifying the appropriate contact either through a known contact at the organisation in question or by contacting the switchboard in the first instance. Interviews were then arranged with the contacts and scheduled to last between 30 and 60 minutes. Interviewees were provided with a participant information sheet via email (Appendix 1) so they could make appropriate preparations and consult with the relevant people within their organisations before the interview took place. The briefing document introduced the background to the research, the aims of the consultation, the scope of the questions that would be explored during the interview, and contact details of the interviewers.

The interviews were structured via an interview schedule with a total of 40 questions in 8 categories: initial thoughts; scale of problem, vehicle design, use of vision, indirect vision, driver issues, solutions, and any further points. The full schedule can be found in Appendix 2. The questions were designed to capture both the breadth and depth of the issues associated with both direct and indirect vision. Where necessary, terminology such as the vehicle categories was clarified in advance. Not all the questions were appropriate in all cases and the interview schedule was used flexibly to focus on the areas of research that an individual interviewee could usefully contribute to.

It should be noted that the individuals consulted shared views that were provided on a personal basis as an expert in their field and do not necessarily represent those of their organisations.

Not all organisations contacted felt they had anything meaningful to contribute and some declined to be involved. Some forwarded the information internally but this did not result in a contact for the research. In summary, 25 organisations were contacted and 20 interviews were conducted. Full details of the interviews, structured by question category, are available in Appendix 3.

2.5 Legislative review

2.5.1 Rationale

The objective is to support Work Package 1 of the project by reviewing the principal global regulations and standards that address drivers' direct and indirect vision from M- and N-category Vehicles, that is, all passenger and goods vehicles for use on the road, having four or more wheels.

2.5.2 Method

The general methodology adopted is to identify the most important technical criteria that affect driver vision and make a comparison of how different standards address these in different ways. It compares how different standards interpret and specify these criteria, and the differences in limits that are applied across the different regulations. The results are presented in a tabular format where possible, to enable easier identification of the differences. The effects that these differences might have in the accidents that have driver vision as a contributory factor is discussed.

2.6 Data assimilation and identification of risk factors

The information collected within the previous tasks was assimilated by collation within each vehicle category under headings including: field of view specification; accident data; bind spots and other limits to vision; legislation and solutions. This data was then analysed to identify field of vision issues and their characteristics, for each vehicle category, which could be considered for further investigation within Phase 2. All of the field of vision issues across all of the vehicle categories were then analysed to determine which should be prioritised within Phase 2.

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3 WHAT SHOULD DRIVERS BE ABLE TO SEE - LEGISLATIVE REVIEW

In order to control what drivers should be able to see, minimum requirements are laid down in regulations.

3.1 Scope

According to the project specification, the review must address direct and indirect vision standards for the drivers of M-and N-category Vehicles, or their equivalents in other territories. These vehicle category designations are defined in the United Nations Economic Commission for Europe (UN-ECE) Consolidated Resolution as the basis of the ECE Regulations and Global Technical Regulations produced by that organisation. As such, most territories base their standards either on these categories, or categories that are closely aligned with them. In effect, the scope includes all vehicles designed for use on the road, with the exception of motorcycles and quadricycles, agricultural tractors and military vehicles.

Most larger goods vehicles and some larger passenger-carrying vehicles are operated as tractor-trailer combinations, including both rigid/drawbar and tractor/semitrailer configurations. Vehicle combinations such as these are designated as separate vehicles in the ECE system, the towing vehicle being Category M (passenger) or N (goods), and the trailer or semitrailer Category O. Since a trailer can cause significant obscuration of the view towards the rear on such combinations while the vehicle is turning, Category O has also been included in the definitions which follow. Trailers are not currently mentioned in driver vision standards, but could be included in future developments of the standards, if rearward obscuration needs to be addressed. Although it is acknowledged that it might not be practical to implement legislative requirements that refer to the vehicle combination as a whole while the vehicle and trailer / semitrailer are approved as separate units, requirements could be more easily applied to combinations that are permanently coupled together, such as articulated buses.

The M-, N- and O-Categories have further sub-divisions according to the weight or carrying capacity. The full list is as follows:

Category M: Passenger Carrying Vehicles Having Four or More Wheels, (or 3 Wheels and a Maximum Mass greater than 1 tonne)

- M_1: Vehicles with 8 seats or less, not including the driver.
- M_2: Vehicles with more than 8 seats, not including the driver and a maximum mass of 5 tonnes or less.
- M_3: Vehicles with more than 8 seats not including the driver, and a maximum mass greater than 5 tonnes.

Category N: Goods Carrying Vehicles Having Four or More Wheels (or 3 Wheels and a Maximum Mass greater than 1 tonne)

- N_1: Vehicles with a maximum mass not exceeding 3.5 tonnes.
- N_2: Vehicles with a maximum mass exceeding 3.5 tonnes, but not exceeding 12 tonnes.
- N_3: Vehicles with a maximum mass exceeding 12 tonnes.

For simplicity, more complex definitions that apply to combined passenger / goods vehicles etc have not been included in the report.

Category O: Trailers, including Semitrailers

- O_1: Trailers with a maximum mass not exceeding 0.75 tonnes
- O_2: Trailers with a maximum mass exceeding 0.75 tonnes but not exceeding 3.5 tonnes.
- O_3: Trailers with a maximum mass exceeding 3.5 tonnes but not exceeding 10 tonnes.
- O_4: Trailers with a maximum mass exceeding 10 tonnes.

Where vehicle standards are applied to vehicle types that do not align with these categories, these instances are highlighted.

3.2 Overview

The engineering standards form a mandatory requirement for initial type approval of vehicles. Those that have been included within the review relate to direct and indirect vision, with some limited references to the requirements for wash-wipe. In addition to standards that are currently in force, reference is made to some earlier versions of the standards where these are still accepted by certain states for vehicles used on their own roads, or to demonstrate the trends of development that are taking place in developing technical requirements. In general, the review is limited to those requirements that directly affect driver vision so it does not cover the clauses in mirror standards covering impact safety etc.

As well as the mandatory standards for driver vision, there have been some moves to introduce consumer information standards for cars that include driver vision amongst the topics assessed. The most important example of this type of standard is the Primary New Car Assessment Programme, or PNCAP. Although this has not been promoted to the same degree as the EuroNCAP passive safety ratings, the standards developed for it are worthy of comparison with the mandatory requirements for type approval and are therefore included in the report.

In addition to the global standards applied to type approval, the review also includes references to the requirements for mirrors and glazing that are applied during the periodic roadworthiness checks carried out on cars and larger vehicles. The importance of good vision for larger vehicles and the possibilities of retrofitting improved mirrors on trucks and buses already in service had led to the extraordinary move by the European Commission in 2007 to mandate the retrofitting of additional Class V (close proximity) mirrors to some N_2 and N_3 vehicles which did not have these originally fitted. The Directive that enforced this move is included in the review.

As well as vehicle standards, the review summarises some of the engineering implications of the minimum standards for eyesight that are required for driving different categories of vehicle. In these, visual acuity is assessed by the ability to identify letters and numbers on a vehicle number plate or a Snellen Chart at a specified distance. By scaling the size of the characters identifiable in the tests, it is possible to make a rather crude assessment of the distance at which the driver would be able to distinguish pedestrians or other objects critical to safe driving. Other common defects in eyesight such as limited visual field might also be significant in their interaction with the technical specifications for direct or indirect vision.

3.3 Vehicle Type Approval Standards

3.3.1 List of Standards Reviewed

The following standards specify the requirements for rear view mirrors and other indirect vision devices, specified as part of their initial type approval:

- Great Britain: Road Vehicles (Construction and Use) Regulations, Section 33 "Mirrors and Other Devices for Indirect Vision".
- European Union "Type Approval of Devices for Indirect Vision and of Vehicles Equipped with these Devices", Directive 71/127/EEC, as amended by 2005/27/EC and 2006/96/EC.
- UN-ECE "Uniform Provisions for Devices for Indirect Vision and of Motor Vehicles with Regard to the Installation of these Devices", Regulation ECE46.02.
- Germany "Mirrors and Other Devices for Indirect Vision", StVZO Section 56, amended Dec 2008.
- USA "Rear-view Mirrors", Federal Motor Vehicle Safety Standard FMVSS111, amended to 8/4/2004.
- Canada "Rear-view Mirrors", Canadian Motor Vehicle Safety Standard CMVSS111.
- Japanese Vehicle Safety Regulations Article 44 (amended by other articles) for Rear View Mirrors.
- Korean Regulation on Rear View Mirrors, Article 50.

The following standard specifies requirements for the retrofitting of improved rear view mirrors on vehicles already in services:

- European Union "Retrofitting of Mirrors to Heavy Goods Vehicles Registered in the Community", Directive 2007/38/EC.

The following standards specify requirements for the driver's direct vision:

- European Union "Field of Vision of Motor Vehicle Drivers", Directive 77/649/EEC, amended by 81/643/EEC, 88/366/EEC and 90/630/EEC.
- UN-ECE "Motor Vehicles with Regard to the Forward Field of Vision of the Driver", Regulation ECE125, as amended to 3/2/2008.

- Japanese Safety Standards Attachment 29 “Technical Standard for Direct frontal Field of Vision”.

3.3.2 Subsidiarity of Standards

As a member state of the European Union, Great Britain is bound by the provisions of the Type Approval Framework Directive 70/156/EEC (amended to 2007/46/EC) insofar as it must accept all vehicles that are type approved under the European Whole Vehicle Type Approval Scheme. In practice, most vehicles are approved under this scheme because this permits a single, harmonised design to be sold throughout the EU. However, any member state is permitted to apply less rigorous standards to vehicles that are only sold in its own territories if it so wishes, but it may not refuse to accept vehicles that meet the European type approval standard, since this would be a barrier to trade. For this reason, the requirements of the United Kingdom Construction and Use Regulations are included in this report, as are the German national regulations as set out in Article 56 of the StVZO regulations.

The original Type Approval Directive required vehicles to comply with a number of separate directives covering different design aspects (including indirect vision). In some cases, vehicles were permitted to comply with the equivalent ECE regulation (if there was one), as an alternative to any of the separate directives. In most cases, the equivalent Directive and Regulation were closely aligned, and there were only small differences between them. However, as a signatory to the 1958 and 1998 Agreements of the United Nations Economic Commission for Europe (UN-ECE), the European Commission has decided to phase out its own Directives in favour of the equivalent ECE Regulation or Global Technical Regulation (GTR) as the basis of its type approval standards. The European Commission recently published the General Safety Regulation 661/2009 to implement these changes. This directly affects approval for direct vision, because prior to this move, there was no Regulation covering this topic. This has led to the introduction of a new Regulation, ECE125, as detailed below.

In the Japanese standards, there is a reference to a circular issued by JISHA on the modification of mirrors prescribed by “Standard Modification Procedure for

Preventing Accidents During Left-Turn of Large Sized Trucks", but this does not appear in the JASIC review of vehicle regulations. It is believed that this document was issued as an industrial health and safety initiative. However, no reference to the circular can be found after an extensive web search.

3.4 Comparison of Type Approval Technical Criteria

3.4.1 Applicability to Different Vehicle Types

Indirect Vision

X indicates applicability of the regulation to a given vehicle category.

Numbers in parentheses refer to the corresponding notes at the foot of the table.

Vehicle Category (or equivalent)	**GB C and U**	**71/127/EEC**	**ECE46.02**	**StVZO Section 56**	**FMVSS111**	**CMVSS 111**	**2007/38/EC (Retrofitting)**
M_1	x	x	x	x	x (3)	x	
M_2	x	x	x	x	x (4)(5)	x	
M_3	x	x	x	x	x (5)	x	
N_1	x	x	x	x	x (4)	x	
N_2	x	x (1)	x (1)	x (1)	x (6)	x	x (2)
N_3	x	x	x	x	x (6)	x	x (2)
Other vehicle types	x		x	x		x	

Table 2: Regulation applicability to vehicle category

Note 1: 71/127/EEC and ECE46.02 both distinguish N_2 vehicles of 7.5t maximum mass or less from N_2 vehicles with a maximum mass greater than 7.5t, for the types of mirror that must be installed

Note 2: These provisions only apply to vehicles in these categories that were first registered before 1/1/2000, but before the same requirements were not mandated as part of EU type approval.

Note 3: One set of requirements apply to passenger cars. Another set apply to multipurpose passenger vehicles and buses with a maximum mass less than 4.536 tonnes

Note 4: Apply to buses and trucks with a maximum mass less than 4.536 tonnes

Note 5: Different requirements apply to school buses

Note 6: These requirements apply to vehicles with a maximum mass between 4.536 tonnes and 11.34 tonnes

Direct Vision

The European Direct Vision standards only apply to M_1 category vehicles at the present time. Similarly, the Japanese standard only applies to passenger cars.

3.4.2 Classification of Mirror Types

ECE46.02 classifies different types of mirror according to the purpose for which they are used, as follows:

Mirror Class	Purpose
I	Interior rear-view mirrors
II	Main exterior rear view mirror (large)
III	Main exterior rear view mirror (small)
IV	"Wide-angle" exterior rear view mirror
V	"Close-proximity" exterior mirror
VI	Front mirror

Table 3: Summary of mirror classifications

3.4.3 Minimum Number and Class

The following table sets out the basic fitment requirements specified in ECE46.02.

The other standards are classified by comparison with this.

Comp = Compulsory. Opt = Optional. NP = Not permitted.

Letters in parentheses refer to the notes at the foot of the table.

Vehicle category	Class I (Interior)	Side	Class II (Ext large)	Class III (Ext small)	Class IV (Wide angle)	T Class V (Close prox)	Class VI (Front)
M_1	Comp (a)	Driver	Opt (b)	Comp	Opt	Opt (c)	Opt (c)
		Passenger	Opt (b)	Comp	Opt	Opt (c)	
M_2	Opt	Driver	Comp	NP	Opt	Opt (c)	Opt (c)
		Passenger	Comp	NP	Opt	Opt (c)	
M_3	Opt	Driver	Comp	NP	Opt	Opt (c)	Opt (c)
		Passenger	Comp	NP	Opt	Opt (c)	
N_1	Comp (a)	Driver	Opt (b)	Comp	Opt	Opt (c)	Opt (c)
		Passenger	Opt (b)	Comp	Opt	Opt (c)	
N_2<7.5t	Opt	Driver	Comp	NP	Comp	Comp (c)	Opt (c)
		Passenger	Comp	NP	Comp	Comp (c)	
N_2>7.5t	Opt	Driver	Comp	NP	Comp	Opt	Comp (c)
		Passenger	Comp	NP	Comp	Comp	
N_3	Opt	Driver	Comp	NP	Comp	Opt	Comp (c)
		Passenger	Comp	NP	Comp	Comp (c)	

Table 4: Summary of mirror requirements by class and number

Note a: Not required where the view is obscured by bodywork etc
Note b: permitted as an alternative to Class III
Note c: Must be fitted at least 2m above the ground

Directive 2006/96/EC, British and German Requirements

Directive 71/127/EEC (amended to 2006/96/EC), the German StVZO and Great Britain's Construction and Use Regulations specify the same minimum installation requirements as those given above for current vehicles.

US and Canadian Requirements

The FMVSS and CMVSS standards are less stringent for passenger cars than ECE46.02, insofar as they do not require the installation of a passenger-side exterior mirror, provided the interior mirror meets the field of view requirements. The same derogation also applies to multipurpose passenger vehicles, trucks and buses (except school buses) of less than 4.536 tonnes maximum mass. For most larger vehicles, they do not require any more than two exterior mirrors to be installed; however for school buses additional wide-angle mirrors are required on each side, as detailed in the later section on field of view.

Japanese Requirements

The Japanese regulations do not specify the minimum number of mirrors to be fitted to each type of vehicle or their characteristics, other than that which is necessary to satisfy the field of view requirements (described in the later section).

Korean Requirements

The Korean standard requires a flat or convex exterior mirror to be mounted on the driver's side for passenger vehicles and buses with less than 10 passengers. For buses, trucks and special-purpose vehicles, a flat or convex mirror must be installed on both sides.

3.4.4 Glass Curvature (Magnification)

Some mirrors incorporate glass which is flat, while in others the glass surface forms a segment of a sphere, which is always convex towards the viewer. Compared with a flat mirror, the image in a convex mirror will appear smaller but size for size will give a wider field of view. When viewed in a convex mirror, an object will appear to be further away than when it is viewed in a flat mirror, and there are concerns by some experts that this could cause drivers to misjudge the distance and speed of an approaching car when deciding whether to overtake. The US in particular is concerned about this. It requires that only flat (unit magnification) mirrors can be used for the interior mirror and the exterior mirror on the driver's side. Although it permits a convex mirror as an alternative to one that is flat on the passenger side, it requires a warning label to be printed on the glass to warn the driver against possible misjudgement. A similar labelling requirement applies to the additional wide angle mirrors on school buses, whenever the radius of curvature is less than 889mm. These are intended primarily for the driver to check that all passengers are clear of the bus before moving off, and the notice warns the driver against using the mirror for viewing traffic whilst on the move.

Alternatively, there may be instances where convex mirrors can enhance safety. Generally, because US mirrors use flat glass, they tend to be slightly larger than their European counterparts to achieve the same field of view. There may be cases where this could lead to the mirror obscuring an important part of the driver's forward field of view.

The following table gives the limits specified for mirror curvature in the different regulations for equivalent mirror types.

Numbers in parentheses refer to the notes at the foot of the table

	71/127/EEC	ECE46.02	FMVSS 111, CMVSS
Interior Mirror	>1200mm (2)	>1200mm (2)	Flat
Driver's side exterior mirror	>1200mm (2)	>1200mm (2)	Flat
Passenger side exterior mirror	>1200mm (2)	>1200mm (2)	Flat or 889mm < r < 1651mm
Wide angle exterior mirror	>300mm (2)	>300mm (2)	Not specified (1)
Close proximity exterior mirror	>300mm (2)	>300mm (2)	Not permitted
Front mirror	>200mm (2)	>200mm (2)	Not permitted

Table 5: Summary of mirror curvature requirements by mirror type and regulation

Note 1: Allowed only for school buses
Note 2: In some cases, the choice curvature will be limited by field of view and size requirements

3.4.5 Minimum and Maximum Size

ECE46-02 Requirements

In the case of Mirrors in Classes I, II and III, Regulation ECE46-02 specifies that the size of reflecting surface must be sufficiently large to inscribe thereon both a rectangle and a vertical line of specified dimensions, as shown in Figure 1. For Classes IV, V and VI, no minimum size requirements are specified, but the mirrors must meet the minimum field of view requirements appropriate to the type.

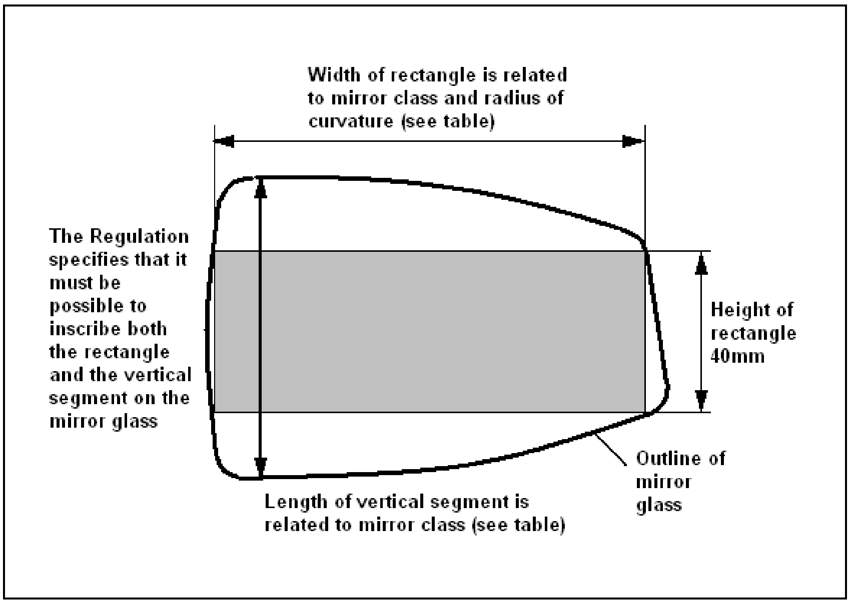


Figure 1: Minimum Dimensions of Reflecting Surface Specified in Regulation ECE46-02

The following table gives the dimensions related to the different mirror classes. Since the mirror curvature is specified for each class, the table also includes the values of rectangle height and segment length corresponding to the maximum and minimum curvature values for each class.

	Class 1 (Interior)	**Class II (Exterior Large)**	**Class III (Exterior Small)**
Height of rectangle, mm	40	40	40
Width of rectangle, mm	A = 150 / (1 + 1000/r)	A = 170 / (1 + 1000/r)	A = 130 / (1 + 1000/r)
Minimum radius of curvature, mm	1200	1200	1200
Width of rectangle for minimum radius of curvature, mm	81.8	92.7	70.9
Maximum radius of curvature, mm	Infinity (flat mirror)	Infinity (flat mirror)	Infinity (flat mirror)
Width of rectangle for maximum radius of curvature, mm	150	170	130
Length of segment, mm	Not required	200	70

Table 6: Mirror dimensions according to class

No minimum size requirements are specified for Class IV, Class V or Class VI mirrors. However, each of these must achieve a minimum field of view, and there will be implicit minimum size requirements associated with this.

US Requirements

For passenger cars, FMVSS111 specifies that the interior mirror must subtend a minimum horizontal angle of 20°. Since the mirror is of unit magnification, the horizontal angle viewed by the mirror will also be 20°. No minimum vertical angle is specified, other than an implied value to meet the minimum field of view requirements. For a typical eye-to-mirror distance of 500mm, this 20 degree angle corresponds to a minimum width of approximately 70mm. This is less than the minimum rectangle width of 81.8mm quoted in the table above for ECE46-02, and because this value corresponds to a 1200mm curvature mirror and the FMVSS mirror must be flat, the minimum field of view would be less. For the outside rear view mirror (the only requirement for passenger cars) no minimum or maximum size requirement is specified, except that the mirror may not project further than necessary to meet the field of view requirements.

For multipurpose passenger vehicles, trucks and buses less than 4536kg maximum weight, the interior mirror requirements (where applicable) are the same as passenger cars, and the driver's side exterior mirror must have a reflective surface area not less than 126cm^2. A mirror with rectangular shape and the minimum width and height dimensions specified in ECE46-02 would have an area of 91cm^2 (13cm x 7cm) in the case of a Class III mirror, or 340cm^2 (17cm x 20cm) in the case of a Class II. No size requirements are specified for the passenger side exterior mirror, where this is required. In the case of multipurpose passenger vehicles and trucks with a gross weight greater than 4536kg and all school buses, the exterior mirrors on both sides must have a minimum reflective area of 323cm^2, which corresponds closely with the value specified for Class II mirrors in ECE46-02.

In the case of school buses the front and wide angle mirrors that are required to see the field of view targets that cannot be viewed directly or with the other mirrors on the vehicle (see field of view section for details of this test procedure), the minimum area specified is 258cm^2.

Japanese Requirements

The Japanese regulations do not specify a minimum size for mirrors, other than that implied by the requirement to meet the field of view requirements.

3.4.6 Position of the Mirror in the Driver's Forward Field of View

In order to be easy to use by the driver, a mirror must be positioned so that it is possible to view the image with a comfortable combination of eye and head movement. This is normally addressed by specifying a maximum angle between the vertical plane joining the drivers' eyes and the centre of the mirror, and the longitudinal plane passing through the eye points. The limits for comfortable range of vision with and without head movement were first set out in SAE Standard J985 October 1988 "Vision Factors Considerations in Rear-view Mirror Design". This defines the binocular field of vision for a typical driver as extending 60° either side of the head's medial plane, corresponding to 45° of eye movement, plus 15° of head movement. In the vertical direction, the corresponding field of view extends 45° upwards and 65° downwards from the horizontal. Most of the standards specify horizontal angles between the driver's head and the mirrors that are close to these values, but none of them specify an angle in the vertical (up and down) direction).

The ECE46-02 Regulation specifies a maximum angle of 55° for the prescribed mirror on the driver's side of the vehicle. The FMVSS and CMVSS regulations do not specify any requirements for the positioning of rear view mirrors. The Japanese regulations specify a maximum angle of 55° on the driver's side and 75° on the passenger side.

3.4.7 Field of View

Regulation ECE46-02 specifies field of view for each different class of mirror, in terms of the geometry of the zone on the ground that can be seen from the eyes of a fiftieth percentile male driver. The amended Directive 71/127/EEC contains identical requirements to these.

FMVSS111 specifies field of view for interior mirrors and the driver's side mirror fitted to passenger cars in a similar way to ECE46-02 but related to a 95th percentile driver and with zones of different geometry. The field of view using the passenger side mirror on cars is not specified. For most other types of vehicle there are no defined standards for field of view, except for school buses, and for these, the field of view is specified in a different way. In this, an array of cylindrical targets is set out at defined points to the front and both sides of the vehicle. The standard specifies that all of the targets must be visible to a 25th percentile female driver, either directly through the glazed apertures of the vehicle, or through the mirrors provided.

The Japanese standard stipulates a performance-based standard for field of view. For light vehicles, rear view mirrors must provide a view of a zone on the nearside edge of the vehicle and rearward on each side. The regulation requires that the driver must be able to visually confirm the presence of a vertical cylindrical target, 1m tall and 0.3m in diameter (representing a 6-year old child) which is adjacent to the front of the nearside of the vehicle. This may be achieved either directly, or indirectly using mirrors, screens or other types of device.

ECE46-02 and 2006/96/EC Requirements

The minimum field of view through the interior mirror specified for M_1 and N_1 vehicles in ECE46-02 and 71/127/EEC (amended to 2006/96/EC) is illustrated (approximately to scale) in Figure 2 below.

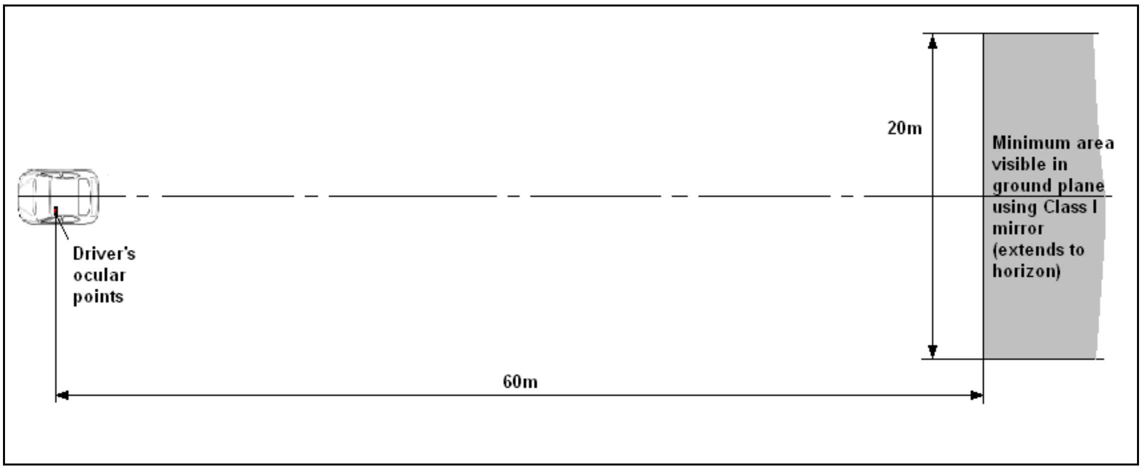


Figure 2: Minimum Field of View Specified in ECE46-02 and 2006/96/EC for Class I (Interior) Mirror

The corresponding requirements for passenger cars in FMVSS111 are that the ground must be visible 61m behind the vehicle, but with no overall width specified.

The minimum field of view using the exterior mirrors for M_1 and N_1 class vehicles is illustrated in Figure 3 below.

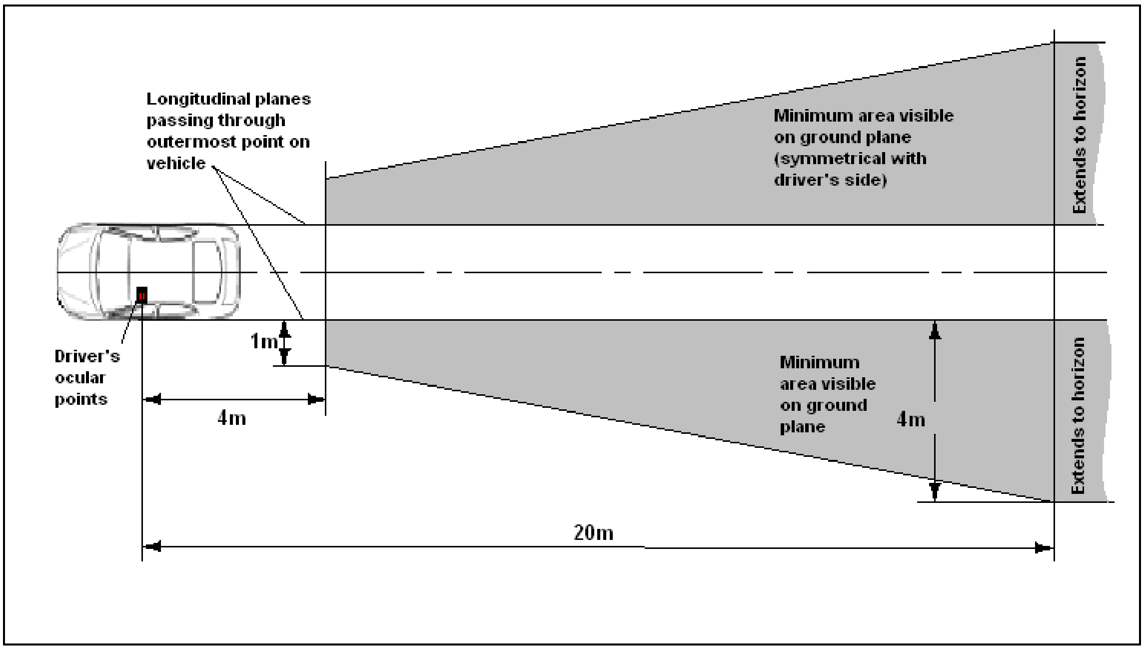


Figure 3: Minimum Field of View Specified in ECE46-02 and 2006/96/EC for Class III (Exterior Small) Mirrors

ECE46-01 Requirements

The corresponding requirements specified for passenger cars in ECE46-01 are shown in Figure 4 below. On the driver's side, these resemble the ECE46-02 requirements for the zone behind the 20m line, but do not require the tapering section in front of the 20m line to be visible. The zone that must be visible on the passenger side is narrower than the ECE46-02, but extends backwards from 10m behind the ocular points.

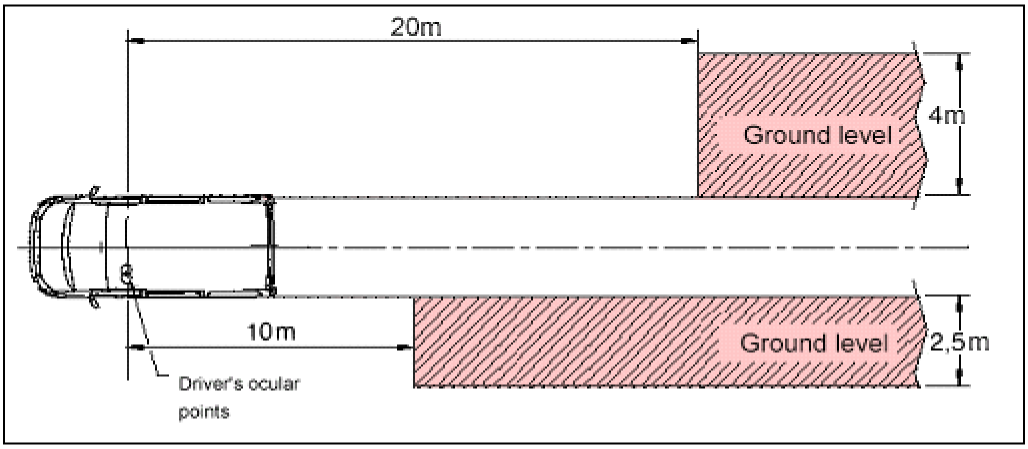


Figure 4: Requirements for Exterior Mirrors in ECE46-01

Comparison with US Requirements

The requirements for ECE46-02 and FMVSS111 are compared in Figure 5 below, approximately to scale. It can be seen that the zone specified in FMVSS111 is smaller than the corresponding ECE zone, and there is no requirement specified for the passenger side. Comparing these with the ECE46-01 requirements above, it can be seen that the FMVSS requirements for the driver's side are very similar to the ECE46-01 requirements for the passenger side.

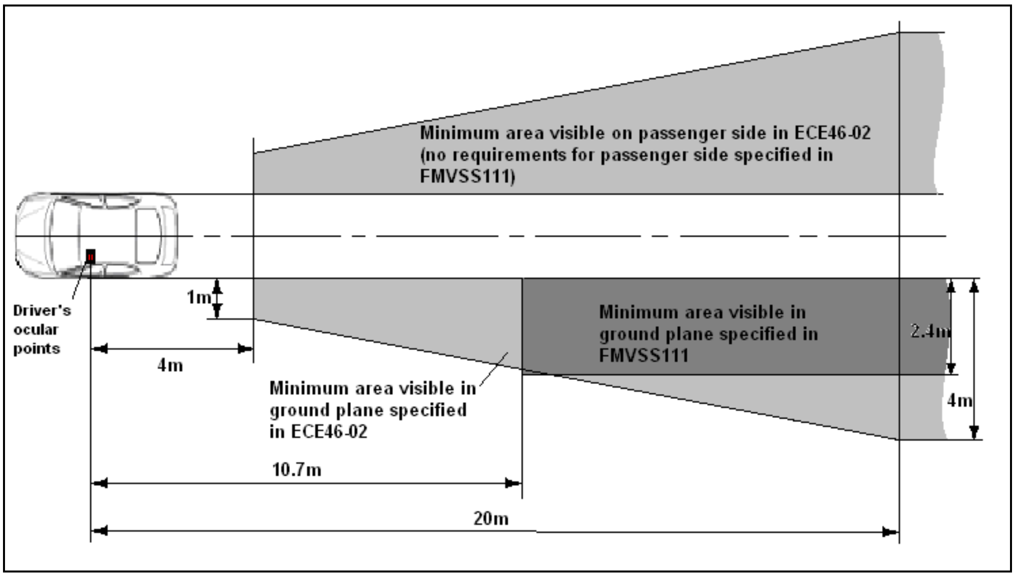


Figure 5: Comparison of Minimum Field of View Requirements for Passenger Cars Between ECE46-02 and FMVSS111

For larger vehicles, Figure 6 illustrates the overlap of the minimum field of view for the different mirrors specified for N_2 and N_3 vehicles in ECE46-02.

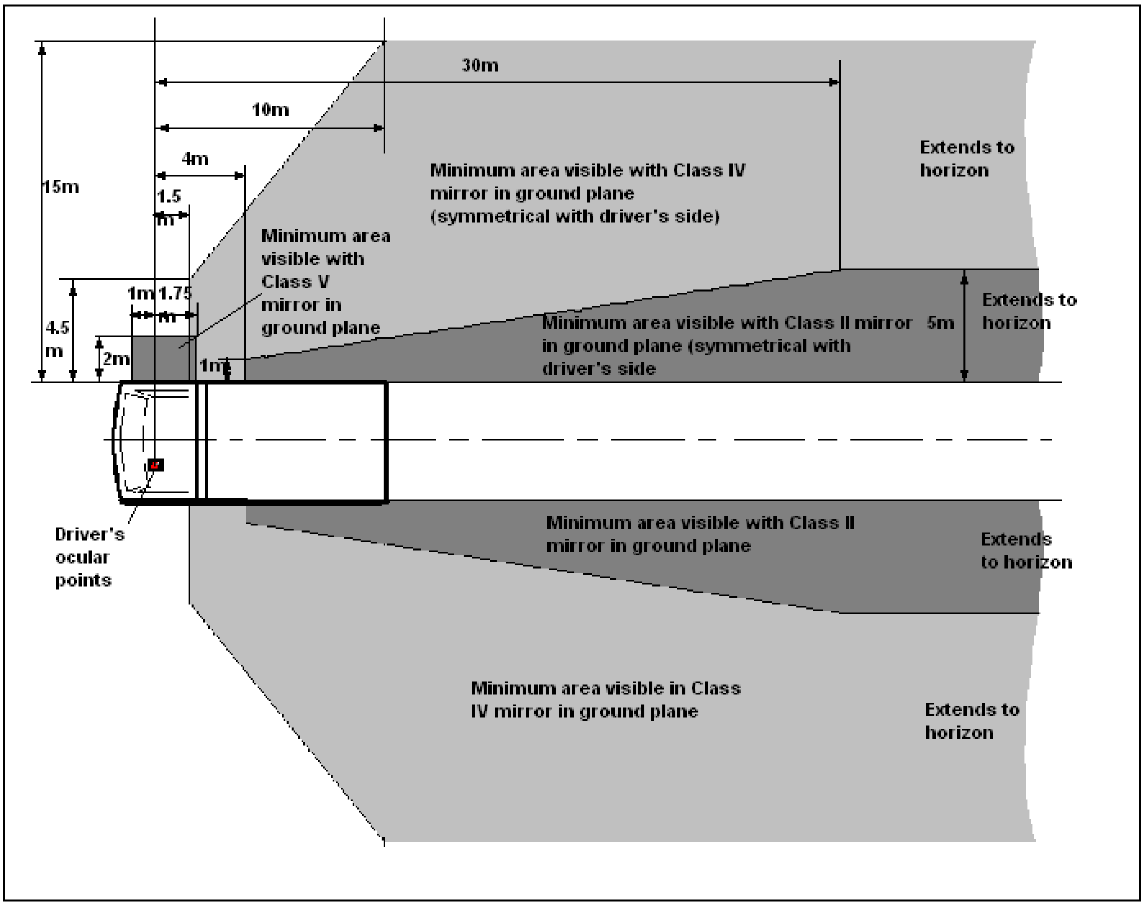


Figure 6: Overlapping Minimum Zones of Field of View for the Different Mirrors (Class II, IV and V) Specified in ECE46-02 and 2006/96/EC for N_2 vehicles. Requirements for N_3 are Similar, except that a Class VI Front Mirror must be Fitted.

Japanese Requirements

The Japanese requirements for field of view integrate the requirements for direct and indirect field of view into a single, performance-based standard. It does this by defining a target marker in the form of a vertical cylinder, 1m tall and 0.3m in diameter, representing a 6-year old child. Some portion of this target must be visible to an observer in the driver's seat, when the target is placed at any location within zones adjacent to the front or nearside of the vehicle, as illustrated in Figure 7 below. The target may be either directly visible, or else indirectly visible using mirrors, camera / monitor systems, or any other form of device. Two different zones are specified, according to the vehicle type. The zone for small-sized, mini-sized or ordinary sized vehicles (covering cars and light commercial vehicles) must comply with Figure 7(a), while trucks with a gross weight of 8 tonnes or more, and passenger vehicles carrying 11 or more passengers must comply with Figure 7(b).

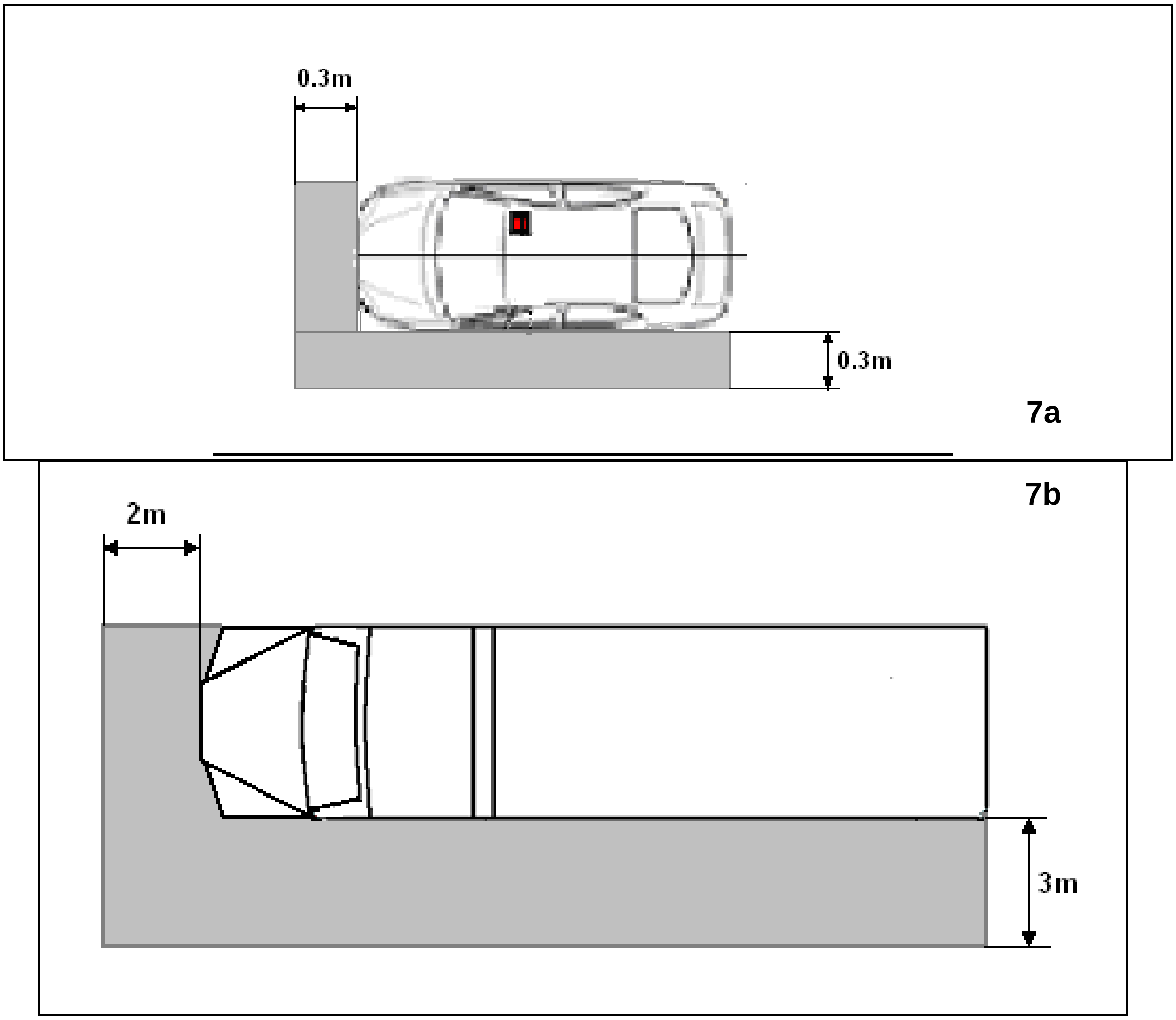


Figure 7: Japanese Standard target zones
(a): Lightweight Vehicles (b) Heavier vehicles

US Requirements for School Buses

The FMVSS111 standard for field of view in school buses applies a similar approach to this, in adopting a performance-based test. In this test, targets at specified locations around the front and on both sides of the vehicles, as well as certain areas of the road surface on both sides, must be visible to the driver, using either direct or indirect vision. The target markers are vertical cylinders of 0.3m diameter, with a length of either 0.3m or 0.9m. The targets are arrayed around the bus as shown below.

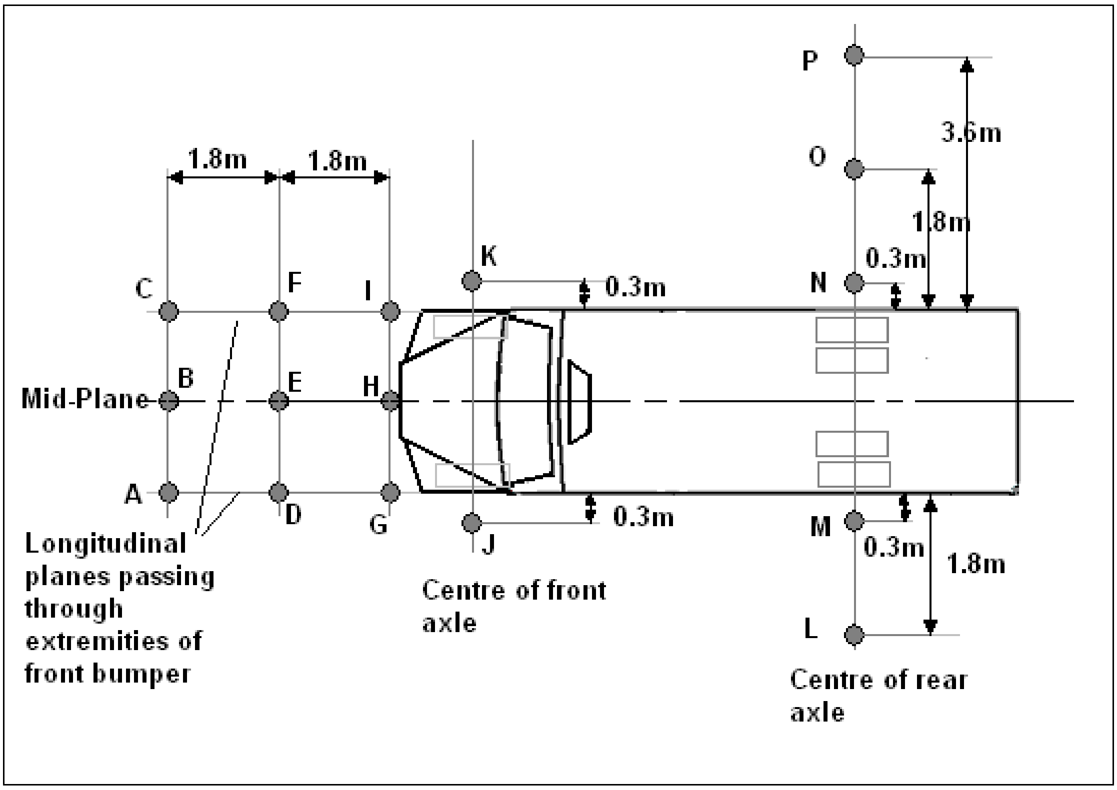


Figure 8: Target positions for FMVSS 111 School Bus Standard
Cylinders A to O are 0.3m tall, while cylinder P is 0.9m tall.

The school bus must have two systems of Mirrors as follows:

- System A comprises the two outside rear-view mirrors. In the driver's side mirror, the view must include the whole of target N and the ground beyond it extending to at least 61m behind the mirror. Similarly for target M on the passenger side.
- System B comprises a wide-angle front mirror or mirrors. The view from this must include the tops of each of the targets A to P that is not directly visible from the driver's seat. The areas of ground visible using System A and System B must overlap

Targets must be visible from a point lying within a zone centred on the ocular point of a 25th percentile adult female in the driver's seat. Zone comprises a semicircle of radius 150mm centred on this point and situated to the front of it.
In addition to the requirement for the driver to have line of sight contact with each target, it also contains provisions to ensure that this is not achieved with an extremely wide field mirror, making the image of a child in it so small that it is difficult to recognise. To achieve this, the reflected image of each target that is not

directly visible must subtend at least 3 minutes of arc in the shortest dimension, and at least 9 minutes of arc in its longest dimension.

3.4.8 Standards for Driver's Direct Vision

European Requirements

European Directive 77/649/EEC (amended to 90/630/EEC) stipulates requirements for direct field of view and is applicable only to M_1 Class vehicles. The standard addresses three different aspects of direct vision, as follows:

- Angle of view through the transparent areas of the windscreen from the driver's seat in the upward, downward and lateral directions;
- Obscuration of the field of view by the windscreen pillars;
- Intrusion of critical objects into the field of view.

View through windscreen

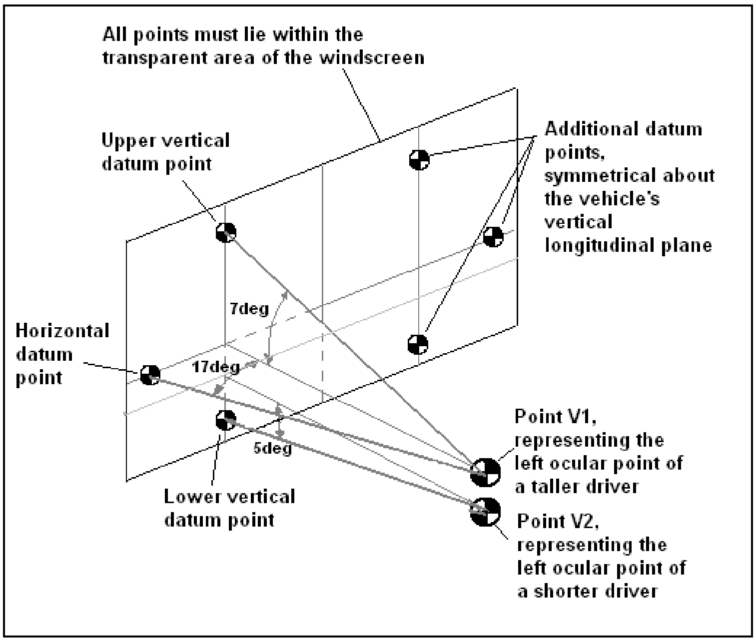


Figure 9: Requirements for Minimum Field of Vision through the Windscreen in 77/649/EEC

Points V1 and V2 are located in relation to the R-Point of the driver's seat as follows:

Point	Longitudinal Direction	Vertical Direction	Lateral Direction
V1	68mm rearward	665mm above	5mm outboard
V2	68mm rearward	589mm above	5mm outboard

Table 7: Location of R-point

Obscuration by the Windscreen Pillar (A-Pillar)

The angle of obscuration of each A-pillar must not exceed 6°, when measured in accordance with the procedure below. The definitions are quite complicated because they consider the driver's binocular vision and measure the external field of view that cannot be seen by either eye.

The procedure can be represented by three steps as follows:

- Step 1: Establish the Pm, P1 and P2 points - The point Pm is located in the same lateral plane as V1 and V2, 43.36mm forward of these two points, and in a horizontal plane mid way between V1 and V2.
- Step 2: Establish an Upper and a Lower section through each A-Pillar - From Point Pm, project an inclined plane forwards at an angle 2° above the horizontal. From the foremost point where this intersects the A-Pillar, draw a horizontal section S1 through the pillar. Project another inclined plane from Pm at an angle of 5° below the horizontal and draw a second horizontal section S2 through the foremost point of intersection between it and the A-pillar in a similar way. For most vehicles, section S2 will lie in front of section S1, due to the natural inclination of the pillars in side elevation.

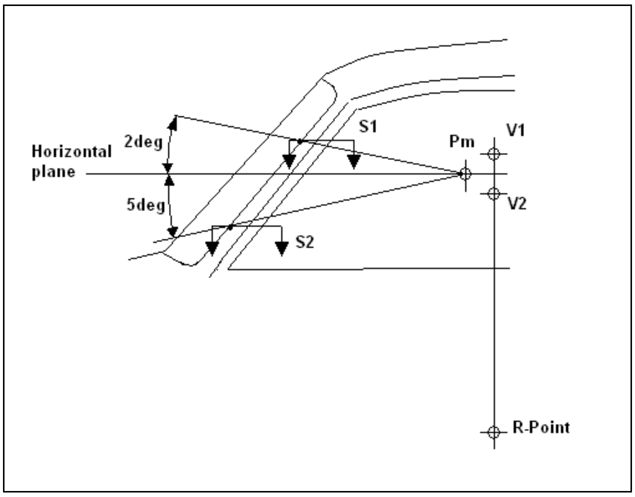


Figure 10: Diagram showing construction of Pm point and S1,S2 sections through pillars

- Step 3: Establish the E1, E2, E3 and E4 points - An array of two E Points is constructed around each P point in accordance with the following procedure:

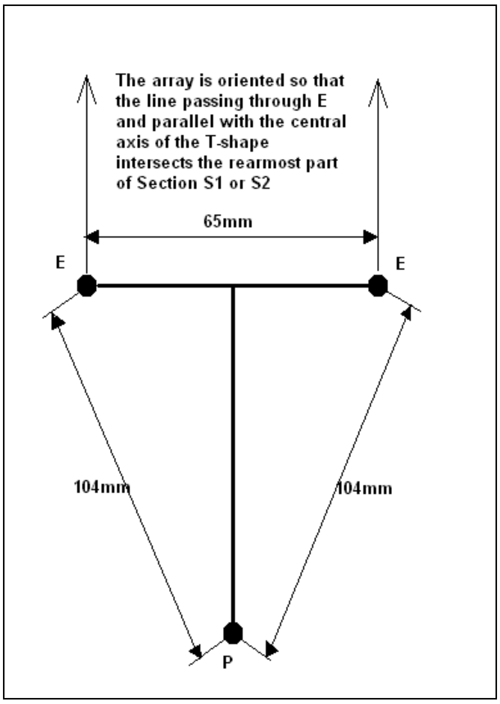


Figure 11: Construction of E points

In the diagram above, Point P represents the neck rotation pivot that allows the observer to rotate the head to face in the required direction, whereas the E Points represent the two eyes in this head orientation

- Step 4: Measure the angle of obscuration - Calculation of the angular width of the zone obscured by the pillar must take account of the overlap in the different views of the two eyes in binocular vision. In this standard, the limits to angular obscuration also take account of the driver's ability to utilise the slope of the pillar in order to view objects to either side, by raising or lowering the viewpoint slightly.

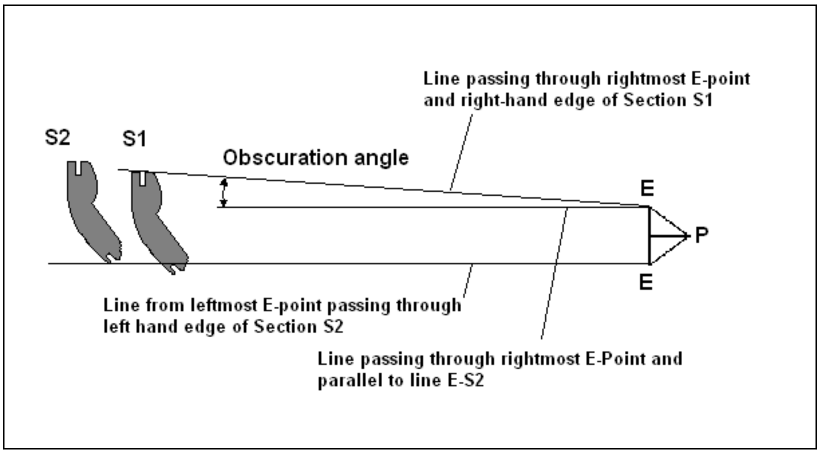


Figure 12: Measurement of A-Pillar Obscuration Angle

Intrusion of Critical Objects into the Field of View

With the exceptions listed below, no internal or external object must intrude into the field of view contained between the horizontal plane passing through V1 and the sloping planes passing through V2, represented by the shaded zone in the diagram below.

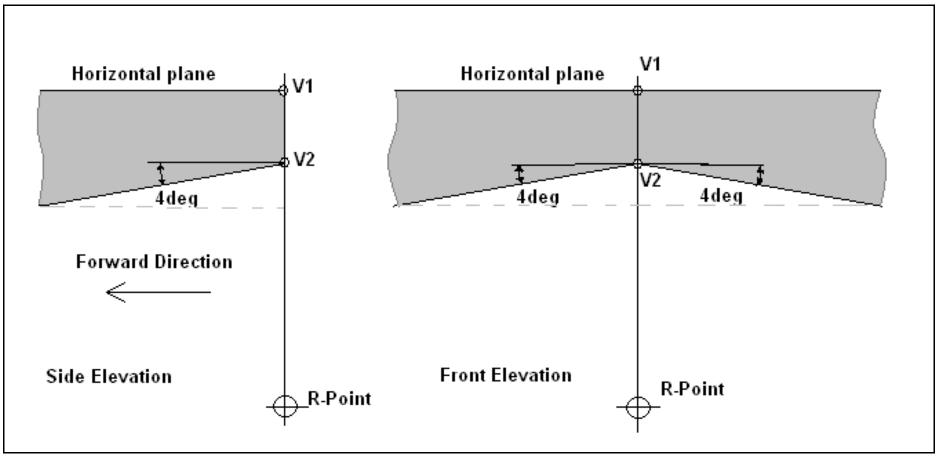


Figure 13: Prohibited Zone for Objects Intruding into Forward Field of View

Objects that are permitted within this zone are as follows:

- A-Pillars
- Fixed or moveable vents
- Side window division bars
- Outside radio aerials
- Rear-view mirrors
- Windscreen wipers
- Embedded conductors (subject to maximum size criteria)

Parts of the steering wheel rim are allowed within the zone, provided they lie below a sloping plane angled downward from V2 at 1° below the horizontal.

Japanese Standard for Forward Field of View

This stipulates that, when a cylindrical target 0.3m diameter and 1.0m tall is placed at any point within a zone in front of the vehicle, at least part of the target shall be visible from the driver's ocular points. However, obscuration of the target by an A-pillar, windscreen wiper, or the steering wheel is permitted.

The driver's ocular reference points used in the test are situated 635mm vertically above the R-Point, and 35mm apart laterally.

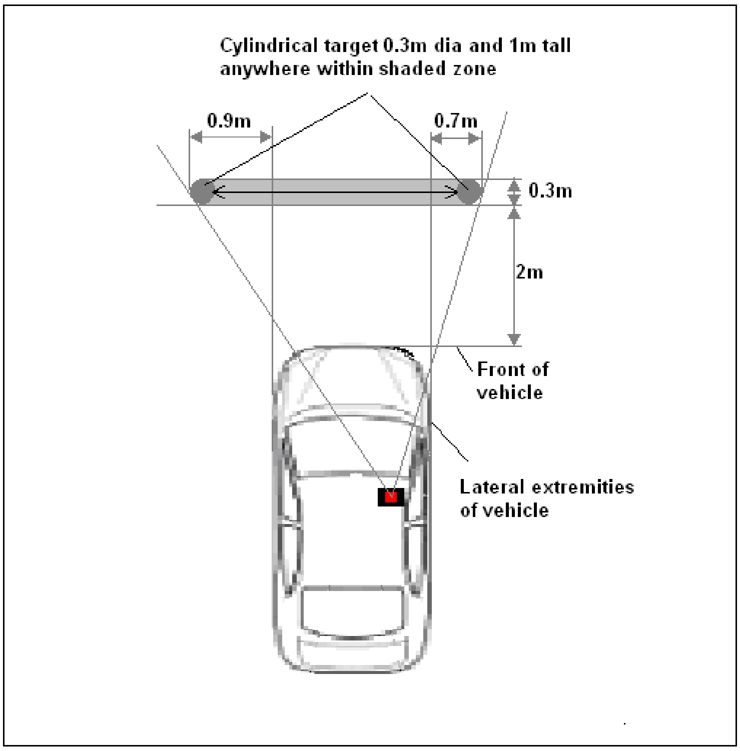


Figure 14: Japanese Standard for Forward Field of View

3.5 Standards for Vehicle Roadworthiness

3.5.1 Cars and Light Commercial Vehicles

In Great Britain, all cars and light commercial vehicles must pass the MoT test inspection no later than 3 years after the date of sale and at yearly intervals thereafter. The inspection includes the windscreen, wash/wipe system and any obligatory mirrors.

Windscreen

The windscreen inspection is a check on damage within Zone A, as shown below. This is 290mm wide and is aligned with the centre of the steering wheel.

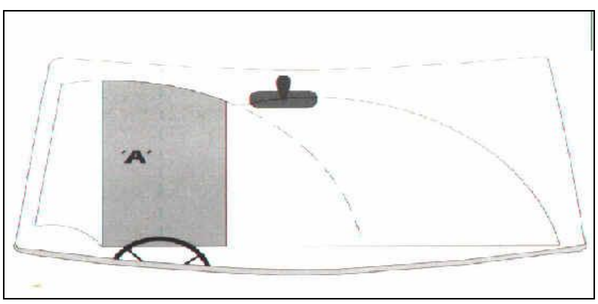


Figure 15: Windscreen damage zone A

A vehicle will fail the test if within Zone A there is any of the following:

- damage not contained within a 10mm diameter circle.
- a windscreen sticker or other obstruction encroaching more than 10mm.
- a combination of minor damage areas which seriously restricts the driver's view.

It will also fail if in the remainder of the swept area there is any of the following:

- damage not contained within a 40mm diameter circle.
- a windscreen sticker or other obstruction encroaching more than 40mm.
- a temporary Windscreen fitted.

Wash-Wipe System

The wipers are examined and the wash-wipe system operated. The vehicle will fail the test if:

- a wiper or washer control is missing or inaccessible to the driver.
- a wiper does not continue to operate automatically when switched on.
- a wiper installed for the use of the driver does not operate over an area of the windscreen large enough to give the driver an adequate view of the road (through the windscreen) to the left and right sides of the vehicle as well as to the front.
- a wiper blade is insecure, missing, or in such a condition that it does not clear the windscreen effectively to give the driver an adequate view of the road (through the windscreen) to the left and right sides of the vehicle as well as to the front.
- the windscreen washers do not provide enough liquid to clear the windscreen in conjunction with the wiper(s).

Obligatory Mirrors

The obligatory mirrors are checked for presence, security, condition and usability. The vehicle will fail the test if any of these mirrors are:

- missing or insecure.
- so damaged or deteriorated that the view to the rear is seriously impaired.
- does not provide a view to the rear of the vehicle.
- not clearly visible from the driver's seat, or incapable of being adjusted to be clearly visible from the driver's seat.

3.5.2 Requirements for Larger Vehicles

In Great Britain, all vehicles over 3.5t Maximum Authorised Mass are subject to a roadworthiness inspection at a VOSA–operated testing station no later than 1 year after the date of sale and at yearly intervals thereafter. The requirements for roadworthiness of mirrors are basically similar to those applied in the MoT test, except for the additional mirrors required to be fitted to larger vehicles at the time of manufacture, or retrofitted afterwards.

3.6 Requirements for visibility of direction indicator lamps

Although the project specification does not call for this aspect of vehicle design to be included in the Phase 1 review, the importance of injuries to vulnerable road users during turning manoeuvres by large vehicles has prompted its inclusion in this report. From a limited review of accidents of this type, it appears that some of these may arise when a cyclist attempt to pass a large vehicle on the nearside, when it is about to turn left. An examination of a sample of large vehicles suggests that on some older trucks and buses a cyclist who is in the gap between the vehicle and the kerb may be unable to see that the vehicle is signalling, because the front indicators are not visible from behind, and the rear indicators are behind the cyclist.

The current legal requirement for direction indicator lamps on vehicles is as follows. Directive 76/765/EEC (amended to 97/28/EC) implements the technical requirements of Regulation ECE48 with regard to installation of lighting and light signalling devices. Paragraph 6.5 in Annex II to the Directive sets out the requirements for direction indicator lamps. Two arrangements of lamps are specified:

- Arrangement B applies to trailers only and consists of two indicator lamps at the rear;
- Arrangement A applies to all other vehicles and consists of the following:
  - Two indicator lamps at the front;

- Two indicator lamps at the rear;
- Two side indicator lamps (repeaters).

The side repeater lamps must be of Category 5 or Category 6, according to the vehicle type.

- Category 5 is required for all M_1 vehicles and N_1, N_2 and M_3 vehicles of less than 6m length;
- Category 6 is required for all N_2 and N_3 vehicles, and of N_1, M_2 and M_3 vehicles of 6m length or more.

All side repeater lamps must be mounted no more than 1800mm behind the front of the vehicle in the longitudinal direction, and between 500mm and 1500mm above the ground in the vertical direction.

The horizontal angles of visibility are the same for Category 5 and Category 6. The lamp must be visible from the rear, between 5° and 60° from the longitudinal plane.

The vertical angles of visibility are different for Category 5 and Category 6:

- Category 5 lamps must be visible between 15° above and 15° below the horizontal, except where the lamp is mounted less than 750mm above the ground, in which case they do not need to be visible from more than 5 ° below the horizontal;
- Category 6 lamps must be visible between 30° above the horizontal and 5° below the horizontal.

<u>Implications for the Visibility of a Turn Signal by a Passing Cyclist</u>

It is assumed that the cyclist passing the vehicle would do so with a minimum lateral spacing between the centre of the head and the side of the vehicle of at least 400mm. Ignoring binocular vision effects, if the side repeater of the vehicle was just visible from the 5° angle specified in the Directive, it would be visible to the cyclist at a distance of D mm, as shown in Figure 1 where
D = 400 / tan 5° = 4573mm behind the lamp. In the worst case, the side repeater could be level with the front of the vehicle, so the lamp might not be visible at more than 4573mm behind the front of the vehicle. Thus, in the case of a long rigid

vehicle there could be a zone between this point and the rear of the vehicle, within which the cyclist might not be aware that the vehicle is signalling a turn, because of the limits on the horizontal visibility angle. In the case of an articulated combination, the cyclist is likely to be able to see the indicator lamps on the tractor unit, even if the repeater lamps are not visible.

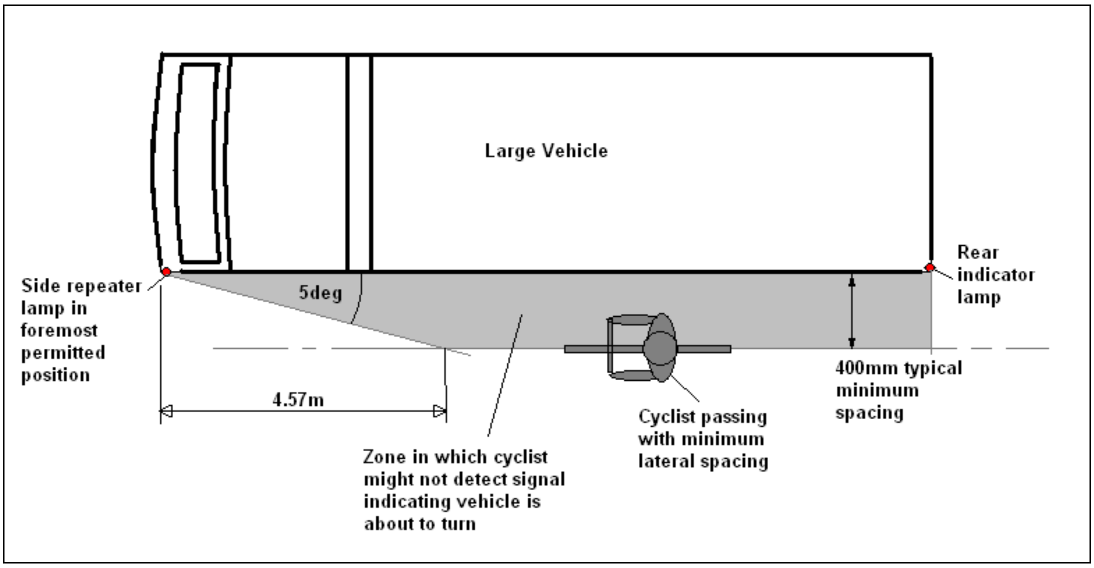


Figure 16: Possible failure to detect side repeater due to horizontal visibility limits

Furthermore the limits on installation height and vertical angle of visibility do not ensure that a cyclist passing this close would be able to see the side repeater lamp at any longitudinal position.

For a Category 6 repeater installed in the lowest permitted height of 500mm and having the minimum upward visibility angle of 30°, the light would be visible to an observer at a lateral distance of 400mm at a maximum height of h mm above the ground, where: $h = 500 + 400 * \tan 30° = 731$mm.

For a Category 5 lamp with a minimum upward angle of visibility of 15°, this would be 607mm above the ground. This compares with an eye height for a typical cyclist of 1600mm. Therefore, some installations that conform fully with the Directive might still not be visible to a passing cyclist, due to the limits on vertical visibility. However, MIRA is not aware of any installations where the upward visibility of repeater lamps is limited in this way. The limits on vertical angle are illustrated in Figure 17 below.

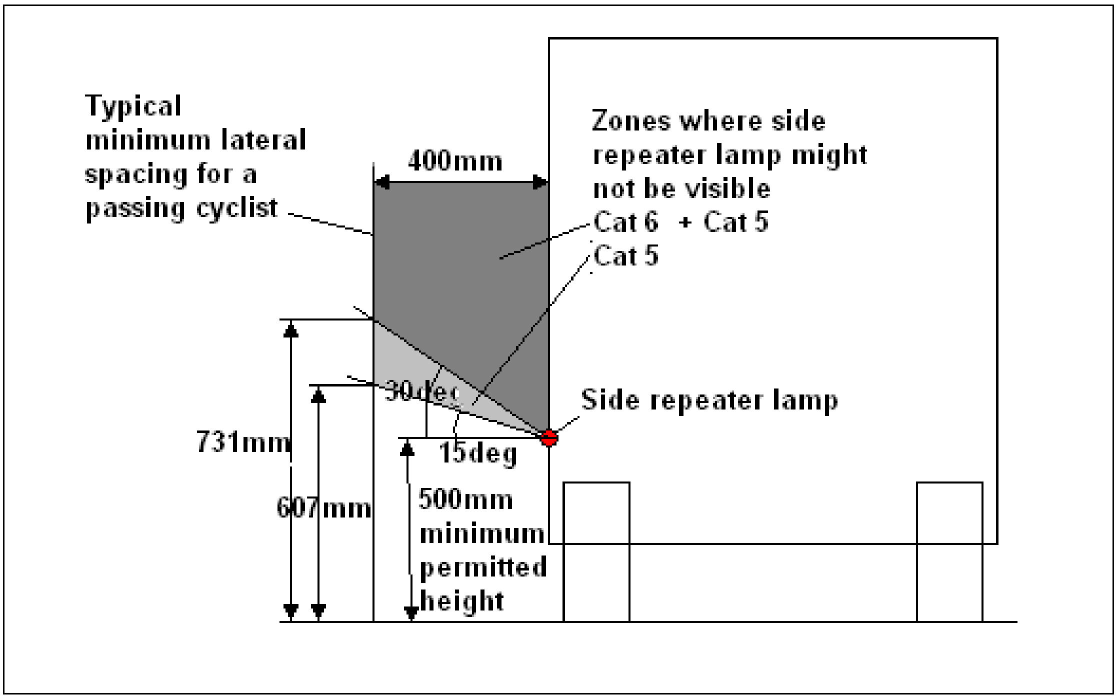


Figure 17: Possible Failure to Detect Side Repeater Due to Vertical Visibility Limits

In conclusion, it is possible that the current standards for installation of direction indicator lamps may allow vehicles on which a turn signal is not visible, either by the front, rear or side indicator lamps, to cyclists or other vulnerable road users who are close to the side of the vehicle.

3.7 Standards for Drivers' Eyesight

When applying for a British provisional driving licence, candidates are obliged to notify the DVLA if they have:

- any visual condition which affects both eyes (not including short or long sight or colour blindness).
- any other visual condition which affects sight (not including short or long sight or colour blindness) for example, sight in one eye only.

Any sight correction surgery must also be declared.

Notifiable conditions include severe bilateral glaucoma and severe bilateral retinopathy.

In its more detailed notes, the DVLA classes an acceptable field of vision as being "a field of at least 120° on the horizontal measured using a target equivalent to the white Goldmann III4e settings" along with the presence of "no significant defect in the binocular field which encroaches within 20° of fixation above or below the horizontal meridian".

The DVLA medical notes also state that it is acceptable to have a peripheral defect that is "a cluster of up to three adjoining missing points, unattached to any other area of defect, lying on or across the horizontal meridian" or "a vertical defect of only single point width but of any length, unattached to any other area of defect, which touches or cuts across the horizontal meridian". Any peripheral defect that is considered to be more severe than this is classed as unacceptable for safe driving.

The medical notes further state that central vision defects are considered significant if they constitute "a cluster of four or more adjoining points that are wholly or partly within the central 20° area"; central vision loss as the result of "a single cluster of three adjoining missing points up to and including 20° from fixation", or central vision loss that is "an extension of a hemianopia or quadrantanopia of size greater than three missed points".

3.7.1 Category B Licences

Drivers wishing to operate cars or light commercial vehicles must hold a B-category driving licence. A driver who has obtained a B-category licence after 1/1/1997 is permitted to drive vehicles in the following classes:

- Cars and other passenger vehicles with no more than 8 seats, (excluding the driver's).
- Goods vehicles of less than 3.5 tonnes maximum authorised mass.

They are also allowed to tow a trailer of less than 0.75 tonnes weight with the above vehicles, provided the combined mass of the combination does not exceed the 3.5tonnes limit.

However, drivers who obtained a B-category licence before 1/1/1997 are granted "grandfathers' rights" to drive C and D category vehicles as follows:

- C1: Medium sized goods vehicle: having max authorised mass between 3.5t and 7.5t.
- D1: Minibus: having between 9 and 16 seats, (excluding the driver's).

At the start of their practical test for a B-category licence, drivers must be able to read a vehicle number plate at a specified distance with one or both eyes. For new-style (post-2000) number plates, the distance is 20m. The characters on these plates (with the exception of the "1" and the "I") are 79mm high and 50mm wide.

In broad terms, this means that all successful driving test candidates are able to distinguish an object that subtends an angle of 3.95×10^{-3} radians (13.5 minutes of arc) in the vertical direction, and 2.5×10^{-3} radians (8.6 minutes of arc) in the horizontal direction. By scaling these dimensions up from the 79mm-tall character to a 1.6m-tall pedestrian, we might infer that they would be able to distinguish the pedestrian or cyclist at a distance of 405m. However, this assumes that all the conditions such as lighting, colour, shape and background contrast are the same in both cases.

The fact that these conditions are met at the time a driver passes their driving test does not imply that all drivers on the road meet this standard. For candidates who are only able to read the number plate with corrective lenses, it is obligatory that the equivalent lenses must be worn at all times while driving but this is not something that can easily be enforced. Furthermore, nearly all individuals suffer gradual deterioration in their eyesight as they age, which in time could put them below the minimum standard without necessarily being aware of it. If a qualified driver suspects that they have a problem with their vision, they are obliged to notify the DVLA. They will then be asked to complete and return a questionnaire about their visual abilities, and this will assess whether they are safe to continue driving. In practice it is believed that there are a large number of drivers on the road who are either unaware that their eyesight falls below the minimum requirements, or are unwilling to disclose it. Again, it is difficult to enforce this under the present system.

3.7.2 Group C and D Licences

Drivers wishing to operate passenger vehicles with more than 8 seats (excluding the driver's), commercial vehicles with a maximum authorised mass greater than 3.5 tonnes, or vehicles pulling a trailer of more than 0.75 tonnes are required to pass a special driving test for a Group 2 licence for one of the following categories of vehicle:

- C1 (Medium sized goods vehicle): having max authorised mass between 3.5t and 7.5t.
- C (Large goods vehicle): any goods vehicle over 7.5t max authorised mass.
- D1 (Minibus): having between 9 and 16 seats, (excluding the driver's).
- D (Bus): any passenger vehicle having more than 9 passenger seats (excluding the driver's).

Any of these can be supplemented by a +E amendment, allowing the driver to tow a trailer of more than 0.75tonnes weight with the appropriate category of vehicle.

To qualify for any of these, drivers are subject to a separate and more thorough medical examination, and must demonstrate a higher standard of visual acuity that the basic standard mentioned above. However, there are still many drivers who are permitted to drive these larger vehicles under the "grandfathers' rights" mentioned above, who will have only been tested to the basic "number plate" standards of visual acuity.

The higher acuity standard is checked using the Snellen eyesight chart, at a distance of 3m. The minimum standard required is as follows:

- With corrective lenses worn, at least 6/9 in the better eye and at least 6/12 in the worse eye.
- Without corrective lenses, at least 3/60 in both eyes.
- Normal binocular field of vision. Thus, any area of defect in either eye must be totally compensated by the vision in the other eye.

The character that must be identified with the better eye is 6.7mm tall, and therefore subtends an angle of 2.23×10^{-3} radians in the vertical direction, which is smaller than the angle of 3.95×10^{-3} radians for the number plate which must be read in the basic driving test. The smallest character that must be read with the worse eye is 8.6mm tall and therefore subtends an angle of 2.86×10^{-3} radians in the vertical direction, and the 40mm-tall character that must be read with uncorrected vision (at a distance of 1.5m) subtends 26.8×10^{-3} radians in the vertical. Again, this represents a very crude comparison between the standards, as the width of each character is different, along with the lighting, contrast etc.

3.8 Evaluation of Changes against Technical and Regulatory Background Developments

There are been many technological developments in the field of driver vision during the past 20 years that have prompted parallel developments in the vision standards.

3.8.1 Changes to Light Vehicle Structure and Bodywork

Developments to improve occupant crash protection, aerodynamics and torsional stiffness, have led to major structural changes in cars and light commercial vehicles over the past 20 years. Many of these have resulted in thickening and repositioning of structural elements, with the effect of obscuring different parts of the driver's direct field of view. One of the most important changes has been the move to a shallower angle of the windscreen pillars in plan. This can place the upper part of the pillar closer to the driver's eyes, leading to increased obscuration of the field of view, especially to the offside. In addition, modern designs tend to have wider section windscreen pillars, which can lead to further obscuration in the exterior view. The same changes have prompted a change in windscreen wiper layout on modern vehicles that can sometimes exacerbate the obscuration effect. The shallower pillars tend to be associated with a windscreen that is taller in profile than previously found, and an increasing number of vehicles have changed the wiper pattern from the traditional swept area comprising two semicircular arcs side by side, to two quadrants centred on the bottom corners and overlapping in the centre (see Figures 18(a) and 18(b) below). Some of these layouts park the wiper blades in an upright position, using recesses in the pillars. This is beneficial to the aerodynamics, but can lead to further thickening of the pillar section.

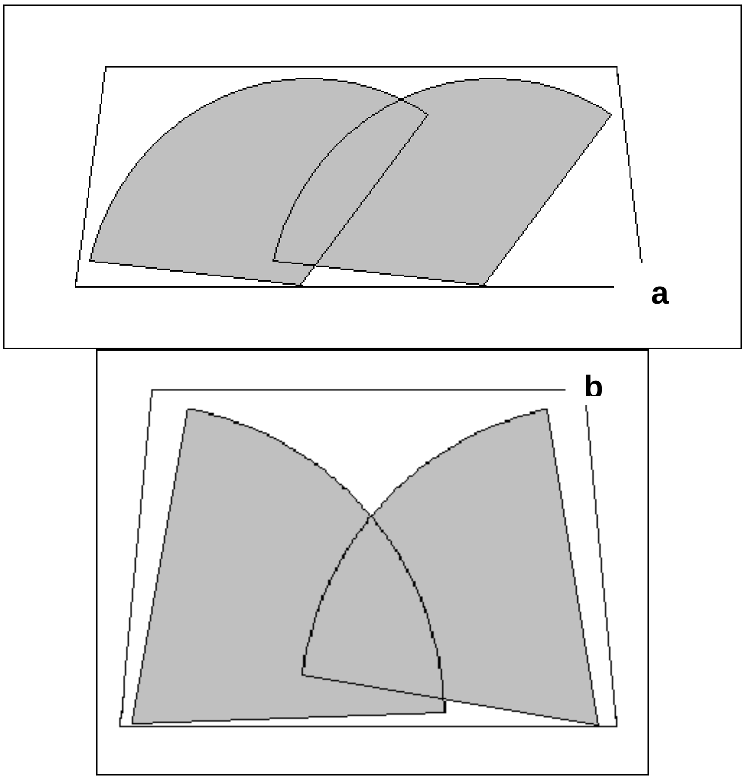


Figure 18: Windscreen wiper patterns
(a) Traditional 'Flat' windscreen shape; (b) Newer 'Tall' windscreen shape

Another change in car bodywork technology that has not been entirely beneficial to driver vision is the reinforcement of the B-pillars to improve occupant protection in side impacts. For most 4-door cars and almost all 2-door cars, the pillar lies well to the rear of the head of an average-sized driver and does not obscure the view to the side. However, in some newer models of car, the B-Pillar could obscure the view to the side for taller drivers and those who choose a reclined seat back position.

3.8.2 Changes in Truck Design

A significant change in truck design has been the move to cabs with a higher drivers' station, such as the Renault Magnum. This can lead to a significant zone of obscuration close to the vehicle at the sides and front. This prompts the question of whether the present standards for direct field of view, which currently only apply to cars and light goods vehicles, should be developed to also apply to the larger vehicle classes.

Another change has been the adoption in many designs of a sloping or curved window line. This helps to drain water that collects on the window glass without penetrating past the window seals into the door; however it is very largely prompted by styling considerations. The need to accommodate the window glass within the lower part of the door when it is fully retracted means that the lower part of the door must be taller than the height of the window glass. Therefore the height of the window line may be dictated by the outline of the wheel arch and other components that lie below it. Designers must arrive at a solution that accommodates these factors alongside an acceptable downward view from the driver's seat. Some trucks have adopted a "stepped" window line with the front (fixed) portion of the glazing extending further downward that the moveable part. This allows the driver a wider view of the zone below the window line on both sides.

3.8.3 Developments in Electronic Imaging Technology

Recent developments in closed-circuit video technology have led to rapid improvements in their performance and package space, but most of all have reduced the cost of installing systems in new areas of application. This has presented an opportunity to use camera / monitor systems for surveillance of zones around vehicles that have previously been invisible to conventional mirror systems. However, there are a significant number of problems that must be overcome before such systems can offer a level of image quality and reliability that would allow them to replace mirrors, for example:

- Ability of cameras to adapt to extremes of ambient light level and contrast in some conditions, such as night-time driving on unlit roads, or images being "burnt-out" when the camera faces a low sun;
- Ability of screens to adapt their brightness between night-time and direct sunlight conditions;
- Obscuration of the view by spray etc, for cameras mounted low on the side of vehicles, and to the rear.

At the present time, only the ECE46-02 regulation includes any provision for electronic systems. These aspects of the standard are addressed in more detail in specialised EN and ISO standards for camera performance.

The principal advantage of camera-based vision systems is that they allow viewpoints that would be impossible to achieve with mirrors alone. However, there may be limitations in the driver's cognitive ability in associating his own frame of reference with that of the camera in some possible viewpoints. One interesting opportunity that video systems present is the possibility of transmitting to the drivers of trailer and semitrailer combinations a view from the trailer unit. This could be used to overcome the limitations of view caused by trailer swing during manoeuvring. At present, driver field of view standards are only applicable to the towing unit and not the combination, even in cases where these are operated as a permanently-coupled unit (for example articulated buses).

An important consideration in adopting electronic imaging is the conditions under which the image is to be viewed, and in particular whether the task requires just one image or a number of images to be viewed. For example, a camera view to the rear can be particularly useful during reversing a larger vehicle, or to replace a front mirror when waiting to move off. In such cases, the display can be automatically switched off when not in use, minimising distraction. On the other hand, current systems are less suited for use alongside the normal mirrors during normal driving, since it can be quite difficult to form a mental image from a mixture of mirror and display screen images.

3.8.4 Developments in Automatic Driver Warning Systems

Recent developments in image-processing software have led to "Blind-Spot Awareness" or "Lane Change Warning" systems becoming available at reasonable cost on a wide range of vehicles. These are capable of detecting the presence of other vehicles in the driver's blind spot, and in some cases measuring the closing speed. The warning given to the driver is normally quite discrete; otherwise it would be irritating and potentially distracting to be constantly alerted due to passing traffic in some circumstances. The normal form of warning is a small but bright light in the exterior mirror, prompting the driver to look in the mirror and see the vehicle.

No standards have yet been developed for such devices, but it is likely that work is in progress to develop them. Since these devices work in conjunction with the mirror system, there may be opportunities for them to be considered as part of the indirect vision system, when future standards are developed

3.8.5 Integration of Component and Installation Requirements

The evolution of mirrors from the status of an add-on component to becoming a fully-integrated system to support the driver's situational awareness has taken place gradually over the past 30 years, and it is possible to trace these changes in the development of the standards that apply to them. The first major development has been the emergence of common standards that allow mirrors to be type approved as components (suitable for installation over a range of vehicles), or as integrated parts of the vehicle. A similar pattern of development is also seen with many other automotive components, such as lamps, reflectors or seat belts. The practical requirements for a single standard to support component and vehicle approval is reflected in the layout of the standards, with separate sections covering the component itself and its installation on a particular vehicle. For example, the ECE46-02 standard has a component section which covers adjustability, minimum dimensions, reflectivity, surface profile, curvature and weather-resistance (along with impact safety requirements). Another section addresses installation requirements, including vibration, field of view, positioning and adjustment. However, such divisions are only found in standards that operate under a regime of formal approval. The FMVSS and CMVSS standards are incorporated into a system of "self-certification", in which the manufacturer or importer bears full responsibility for ensuring that all their vehicles comply with the requirements. In such cases, all the responsibilities for mirrors would fall on the vehicle manufacturer. The only legal responsibilities on the mirror supplier would be in respect of aftermarket components, and this is normally achieved under a different set of standards such as those promulgated by SAE.

3.8.6 Development of a More Functional Approach to Field of View

The included angle of view from a flat or spherical convex mirror is dictated by the size of the reflecting surface, the magnification (radius of curvature) of the glass, and the distance between the mirror and the driver's eyes. Nearly all standards specify requirements for the first two of these parameters, while design convention means that the latter generally falls within a limited range. However, specifying these parameters alone is clearly not sufficient to address all of the factors that could affect the field of view available in a given vehicle installation. Therefore most standards define the field of view available to the driver according to what is visible from the driver's seat.

The indirect vision standards for Europe, Japan and the US represent three very different approaches in how the field of view is defined. The European view (represented by ECE46-02), along with some older parts of FMVSS111 and the Japanese regulations, is to define zones on the road surface that must be visible. On the other hand, later parts of the Japanese standard and the FMVSS111 standard for school buses both define the requirements in terms of upright targets positioned within certain zones on the surface. It can be argued that this is well suited to the school bus standard, since the ability of the driver to detect a child close to the bus is its major priority. However, the adoption of a similar approach in the Japanese regulations shows that it is also of interest to regulators for other vehicle types.

The FMVSS school bus standard is interesting insofar as it includes provisions for the minimum size of the reflected image as it appears in the mirror. The purpose of this is clearly to prevent manufacturers from fitting a small mirror with an extreme curvature, giving a "fish-eye" view covering a wide area, but with individual objects in the view being so small as to be unrecognisable. The stipulation of a minimum size for the wide angle mirrors in the system also serves to encourage mirrors that give easily-recognisable images of any children in the vicinity.

It is debatable whether the US/Japanese or the European approach is better in ensuring an effective field of view; there appear to be advantages and disadvantages with each. However, the less prescriptive terms of the US and Japanese standards are more likely to encourage manufacturers to develop integrated mirror systems that present information on nearby traffic hazards to the driver in a more easily-assimilated way.

The most interesting outcome of further development in this direction is the possibility of an integrated standard covering both direct and indirect field of view. To some extent, the US school bus standard already achieves this.

3.8.7 Development of Separate Standards for Different Vehicle Types

Traditionally, the standards for motorcycle mirrors have been promulgated separately from those for other vehicle types. There are a number of possible reasons for this:

- Motorcyclists use mirrors in conjunction with glancing over the shoulder, so mirrors are seen as an aid to rearward vision and not an essential tool;
- The requirements for motorcycle mirrors are much simpler than those for other vehicle types;
- Some regulatory systems adopt separate approval systems for motorcycles;
- Fitting of replacement aftermarket mirrors is much more common on motorcycles.

The result of this is that the EC, ECE and Japan promulgate different standards for motorcycle mirrors, whereas, the US and Canada incorporate them in separate sections of a combined mirror standard. Another example of separate mirror standards for certain vehicle types is the requirement applied to school buses in the US. To some extent, this reflects the special level of regulatory care applied in the US to several safety aspects of school buses, as well as just mirrors.

4 WHAT DO DRIVERS NEED TO SEE

The aim of this section is to outline what the research indicates that drivers need to be able to see. An ideal field of view requirement would probably be 360° of vision, from the edges of the vehicle's ground plan, for an infinite distance, all around the vehicle. However, as in reality this could prove impracticable, a field of view requirement which enables drivers to detect specified relevant hazards around their vehicle by direct or indirect means may act as an alternative.

4.1 M_1

4.1.1 Early field of view models

Three studies have evaluated overall visibility requirements of motor vehicles by engineering analyses. These were by Barnoski, Maurer and Kugler (1969), Ford Motor Company (1972) and Burger, Smith, Queen and Slack (1976) cited in Shearlaw and Freer (2002). All three studies attempted to derive field of view requirements for passenger cars, based on common driving situations or scenarios. Such situations included manoeuvres (e.g., turning. merging, backing, etc.) various driver/vehicle characteristics (e.g., speeds, reaction times, stopping distances, etc.) and targets of visual importance (e.g., other vehicles, pedestrians, signs, signals, etc.).

The Barnoski, et al., study generated fields of view for targets at various ranges, whereas that of the Ford Motor Company developed field of views for the most demanding range, i.e., the closest targets established the widest field of view requirement. In addition, the former study chose target ranges in terms of radii from the eye point, while the latter study chose ranges that were constant and perpendicular to the longitudinal axes of the driver's vehicle. Figure 19 presents the field of view generated by both studies which were composites of all driving situations evaluated.

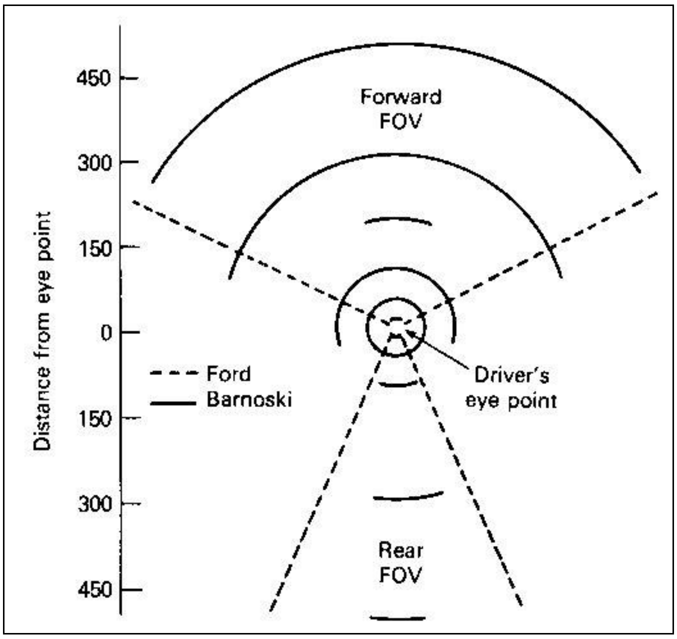


Figure 19: Composite field of view models of Ford (1972) and Barnoski, et al (1969). Note that Ford did not consider side field of view requirements.

Two points of interest should be noted in Figure 19. First, in considering 11 driving situations, Barnoski et al. determined that a 360° field of view was required at a radius (range) of 50 feet. As the range increased, the required field of view decreased, principally to the left and right of the driver. It is widely recognised that the required field of view is task dependant, and as vehicle speeds increase, visual attention becomes more compacted. Second, in developing their composite field of view, the Ford Motor Company did not include required field of view for side targets, hence only forward and rearward required field of views were developed. Moreover, the Ford study did not indicate that there were not any side targets of importance. Rather, they simply indicated that side targets could be seen by direct foveal and peripheral vision and via rear view mirrors. There was the implication, therefore, that a total field of view of 360° was also required.

A more detailed analysis of driving scenarios and visual requirements was undertaken by Burger, et al. (1976). These investigators established visual zones of importance surrounding a driver for various conflict situations similar to the previous investigations. Figure 20 shows a composite of their field of view requirements superimposed on those of the previous studies (note that a log scale was employed in order to present detailed comparisons).

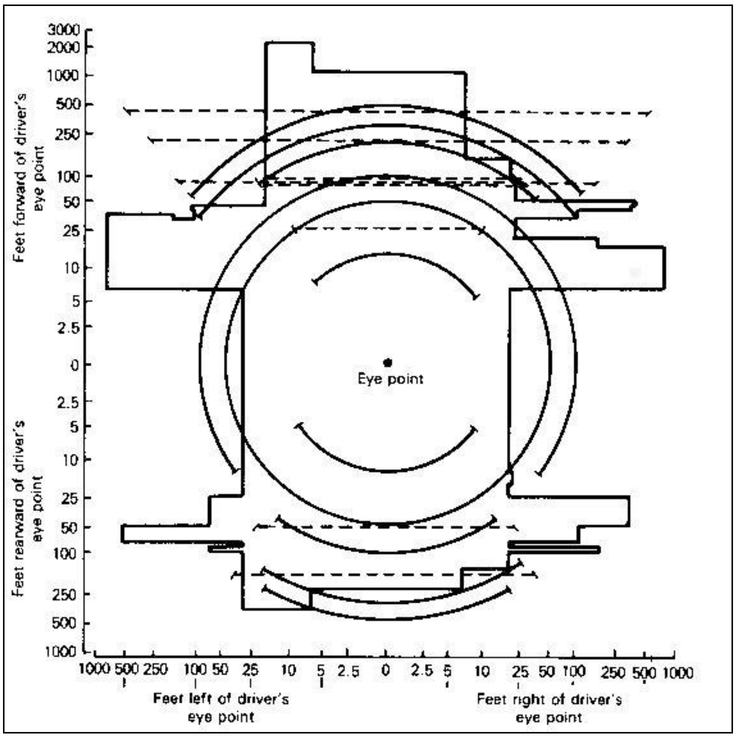


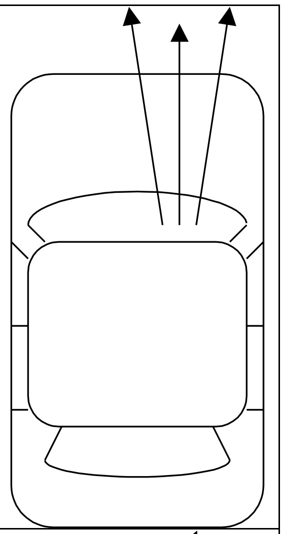
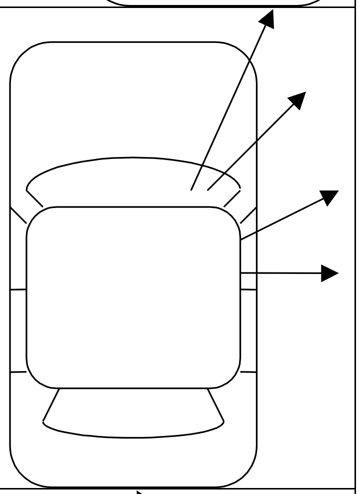
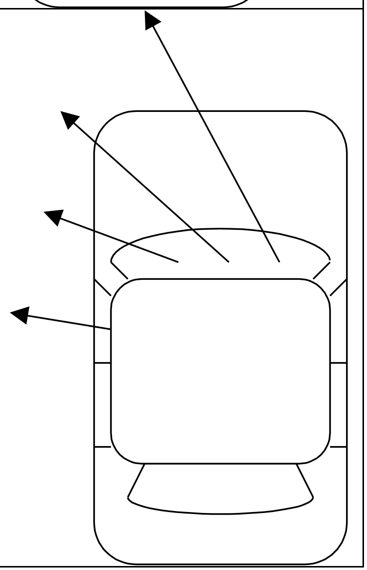
Figure 20: Composite of Ford (1972) [dashed lines], Barnoski et al (1969) [curved lines], and scenario generated requirements of Burger et al., (1976) [irregular outline].

Since the driving environment is highly dynamic and exhibits an almost infinite array of driving situations, only a limited number of specific situations can be selected for evaluation and for defining assumptions regarding vehicle speeds, brake reaction times and so on to be in the analyses. Figure 20, indicates, however, that the detailed analysis of a rather few specific but common driving situations by different techniques yielded field of view requirements encompassing 360°. The inclusion of additional driving situations or variations of the same situations is therefore unnecessary.

4.1.2 PNCAP field of view specification

In 2002 work was conducted to develop 'The Primary New Car Assessment Programme' which aimed to encourage manufacturers to increase the primary safety performance of their cars. As part of this programme, a car's field of view is rated according to how much of the safety critical area is visible.

In order to gain an understanding of which areas of the visual field are important for primary safety, four basic scenarios were studied in order to perform a task analysis and to understand which features most commonly constrain the field of view (Shearlaw and Freer, 2002).

<u>1: Forward vision</u> This is the steady state driving condition. Central vision used to scan the road ahead, most vision through the central area of the windscreen. Vision constrained by windscreen aperture. A-pillars will limit peripheral vision, with the offside pillar obscuring a greater extent than the nearside due to its proximity to the observer's eye.	
<u>2: Manoeuvres involving vision to the right</u> Vision is through offside of windscreen and through side glazing. Vision constrained by top and bottom edges of glazed areas, and most significantly, the offside A-pillar and door mirror. The observer is relatively close to the A-pillar, so it obscures a greater area than the nearside pillar.	
<u>3: Manoeuvres involving vision to the left</u> As with right turns, the A-pillar and door mirror will obscure a proportion of the road scene, although the increased distance between the pillar and observer reduces the amount of obstruction. Also the movement of the body & head is increased relative to the pillar. The vehicle body will limit visibility close to the vehicle.	

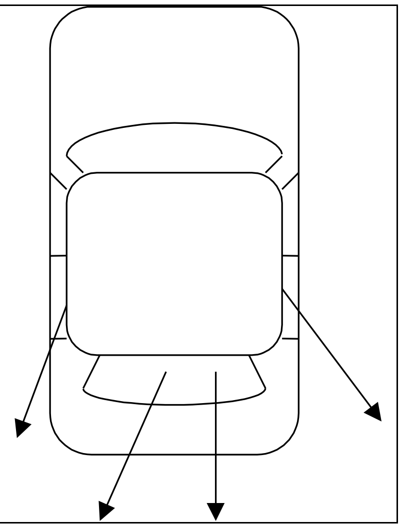
4: Manoeuvres involving direct vision to the rear Vision through the rear window is constrained by the physical size of the aperture, as well as by obstructions such as head restraints and rear bodywork. The rear pillars are usually considerably thicker than the A & B-pillars, resulting in large blind spots. Direct vision through the rear side glazing can be limited by high waistlines, as well as obstructions within the vehicle.	

Figure 21: Constraints to drivers' vision

Based on this information, requirements for the Lateral field of view, Vertical field of view, Side field of view and Rear field of view were developed.

Lateral field of view (Direct)

In 2002 the PNCAP study (Shearlaw and Freer, 2002) concluded that the forward field of view should extend forwards from a line originating at the driver's eye point and extending laterally across the vehicle. The forward field of view extends through 180° forward of this line – Refer to Figure 22.

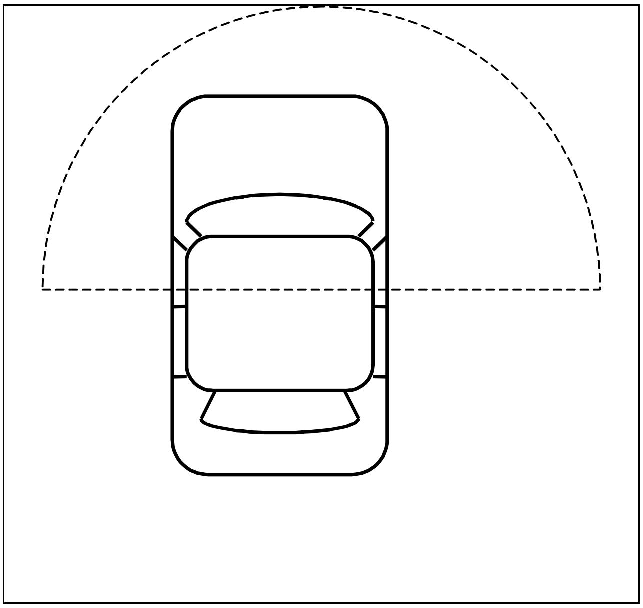


Figure 22: Direct vision – Lateral field of view

In practice there will be many situations where road geometry dictates that the driver needs to see traffic approaching from areas outside the 180° forward field; for instance, on some roundabouts or at 'Y' junctions. These situations rely on the driver's eyepoint moving (dynamic field of view), and instead of the forward 180^{o} being the limit, the B-pillars will now begin to impinge on the field of view.

Vertical field of view (Direct)

PNCAP concludes that it is unlikely that safety critical information will be located more than 10° above the driver's line of sight and so improved vision above this will not significantly contribute to safety. The forward field of view should therefore extend upwards to 10° above the horizontal axis passing through the driver's eyes to account for any high information signs or signals that are not seen until the vehicle is in close proximity.

For maximum visibility the driver ought to be able to see the road directly in front of the vehicle. Even in a flat fronted vehicle this is not possible, so some compromise has to be arrived at. The PNCAP study conducted analysis of road scene data and it was found that 6° down from the driver's eyepoint permits a view of markings on the road surface or objects on the road itself. Therefore the study concludes that the area from 0° to 6° down from the driver's eyepoint should be rated as the second most important area of the forward field of view. It is likely that many vehicles will not afford vision as low as 6° below the horizontal plane, especially for the smaller stature drivers.

Side field of vision (Direct)

The field of view should extend 150° around from the vehicle's longitudinal axis. Taking account of the location of target objects in the real world, most safety critical information is below the horizontal plane passing through the driver's eyes. The PNCAP study concludes that extending this plane upwards by 1° gives the vertical upper limit for the side field of view.

Rear field of vision (Direct)

In the PNCAP study no safety grounds could be identified for a rear view above driver eye height, and conversely no lower limit could be identified. It is preferable that the rearwards field of view reaches to ground level around the edge of the vehicle as a small child could be in this location at the time the vehicle is about to reverse. Shearlaw 2002 states that "This performance requirement will not be met by current vehicles, but is an "ideal", summarising that "The area that should be covered by the rearwards field of view is formed by the swept path of the vehicle as it performs a full-lock reversing manoeuvre. The driver should be able to see a

1 metre target (representing a small child, the most likely vulnerable road user in close proximity to a vehicle) at any point within the swept path of the vehicle as it reverses".

4.2 M2

4.2.1 Field of view specification

The study by Tait and Southall (1999) proposed a new method for defining the minimum field of view requirements for both direct and indirect vision for large vehicles (M_2, M_3, N_2 and N_3).

The benchmark field of view requirement they proposed was based on:

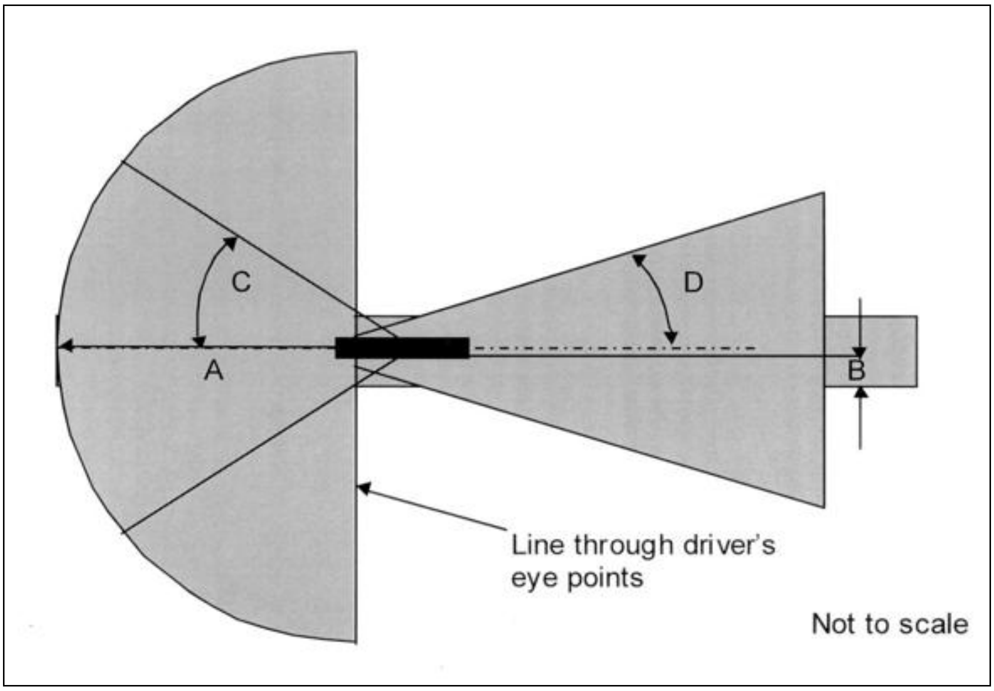


Figure 23: Field of view requirement for large vehicles (Tait and Southall 1999)

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

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

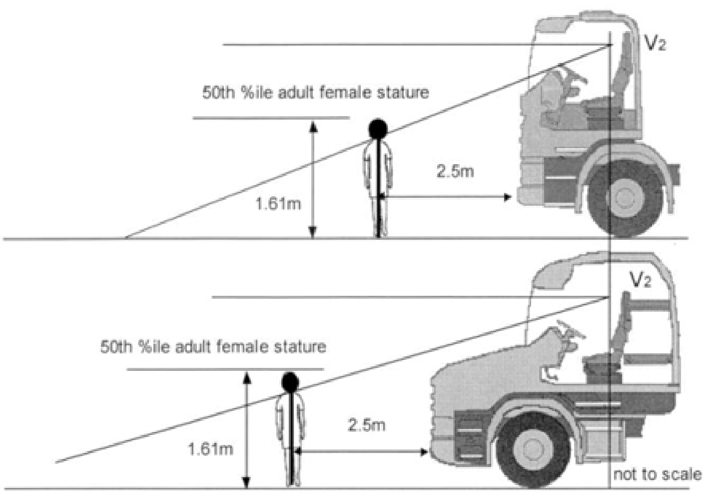
- the angle 'D', emanating from a point at the vehicle's front near-side or off-side corner and extending backwards through a point defined by the vehicle's rear near-side or off-side corner, or the rear near-side or off-side corner of the tractor unit in the case of an articulated vehicle, after a full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

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

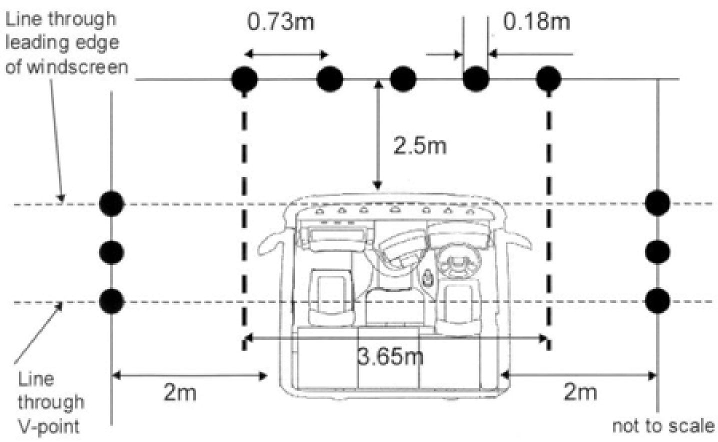
Direct vision

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

THE DIRECT FIELD OF VIEW REQUIREMENT TO THE FRONT OF THE VEHICLE BASED ON THE DETECTION OF A VULNERABLE ROAD USER.



The direct field of view requirements are extended to both the near and off-side of the vehicle.



The requirements are based on:

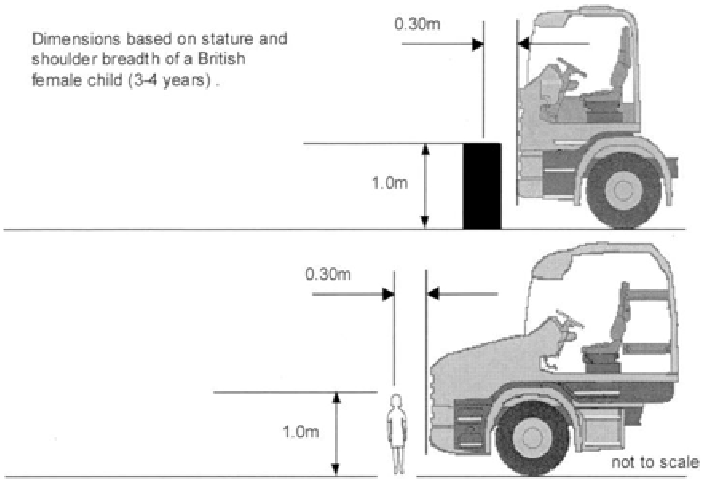
- All of a sphere with a diameter equivalent to that of the head of a 50th %ile adult (19 to 65 years) female - 0.18m,
- the top of which is at a height above the ground equivalent to the 50th %ile adult (19 to 65 years) female's stature - 1.61m,
- must be seen from an eye level corresponding to the height of V2 ,
- at 5 equally spaced points - 0.73m apart,
- which extend across the front of a vehicle which is positioned centrally in a lane with a width equal to that recommended for a district distributor road - 3.65m,
- and running parallel with the vehicle's front at a distance of 2.5m from the most forward point of the vehicle.

Figure 24: Field of view specification – Direct vision

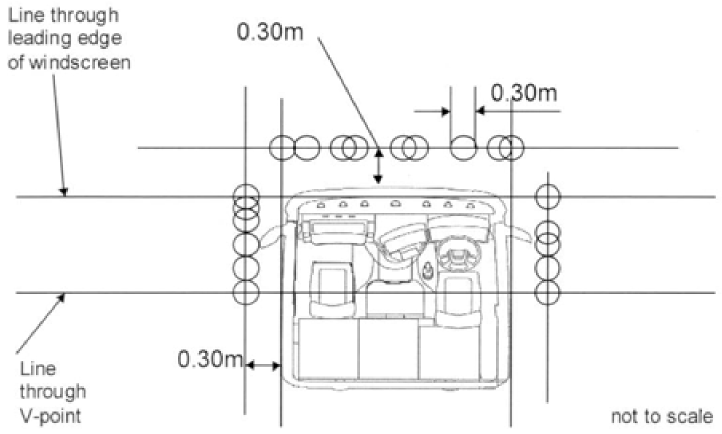
Indirect vision

Tait and Southall (1999) recommend 'A minimum requirement for indirect driver vision in the forward 180° zone, providing that the minimum direct vision requirement has been fulfilled . . .'. This is given as:

THE INDIRECT FIELD OF VIEW REQUIREMENT TO THE FRONT OF THE VEHICLE BASED ON THE DETECTION OF A VULNERABLE ROAD USER.



The indirect field of view requirements are extended to both the near and off-side of the vehicle.



The requirements are based on:

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

Figure 25: Field of view specification – Indirect vision

4.3 M_3

Refer to section 4.2.

Additionally, a review of the relevant literature resulted in limited information concerning what drivers of coaches or buses need to be able to see. Haslegrave (1993) stated that "Buses or coaches need a wide view of the front corners close to the bus where boarding or alighting passengers may be".

4.4 N_1

No specific data was found for this vehicle category.

4.5 N_2

Similar to coaches and buses, a review of the relevant literature resulted in no significant additional information concerning what drivers of HGVs need to be able to see. Information that was found was in the form of comments rather than definitive results/facts. Fenn et al (2005) reported that previous research has shown that HGVs should have a clear view of all adjacent traffic, even when conducting slow speed manoeuvres. Haslegrave (1993) commented that truck drivers may have greater need of views to the rear of the vehicle for reversing or manoeuvring into delivery bays etc. Shiosaka (1995) reported that drivers need to see lower areas more than upper areas outside the HGV. Results from a study looking at industrial vehicles concluded that the visibility from about 10° below the driver's eye level must be kept clear (Schouller and Hella 1998). Literature found relating to accident scenarios (reported in section 7.5) however, does provide insights into the nature of the problem and where critical areas of field of view may be located and currently obscured. Refer also to section 4.2.

4.6 N_3

Refer to section 4.2.

4.7 Consultations

The consultations revealed that ideally drivers need to be able to see as much as possible, a full 360° field of view both in yaw (left / right) and in pitch (up / down) but clearly this is not possible in the categories of vehicle that are the focus of this work. As such the consultations only really highlighted specific areas of view that were required for specific vehicle types in specific manoeuvres or scenarios. The following issues were highlighted by the consultation:

- When changing lane drivers need to be able to see, directly or indirectly, vehicles in lanes to the inside or to the outside depending on the manoeuvre.
- Vehicles approaching a roundabout need to be able to have a clear view of traffic approaching from the right. A particular issue for LHD vehicles.
- Large vehicles with articulated trailers need to be able to have a clear view to the side and rearwards of the vehicle that is not obscured by the articulation of the trailer.
- For cars indirect vision is largely good, legislated for and a key part of training.

5 WHAT CAN DRIVERS ACTUALLY SEE

Whilst the previous section described what drivers of different vehicle categories need to be able to see, this section discusses a number of factors which shape what they can actually see.

The aim of this section is to briefly highlight the complexities of driver vision and the driving task in order to provide a broader context to the field of view issues which are the focus of this project.

5.1 Drivers' visual processing

The functioning of the human eye; the impacts of the ageing process and the limitations imposed by various visual conditions can have the effect that items that are available for view in the driver's visual field may not necessarily be detected.

5.1.1 Foveal and peripheral vision

Binocular human vision covers a field of view of approximately 180°, although according to SAE J985 (SAE 1967) the eyes generally only turn about 30° before the head is moved, which can comfortably give a further 45° view to either side (Haslegrave, 1993).

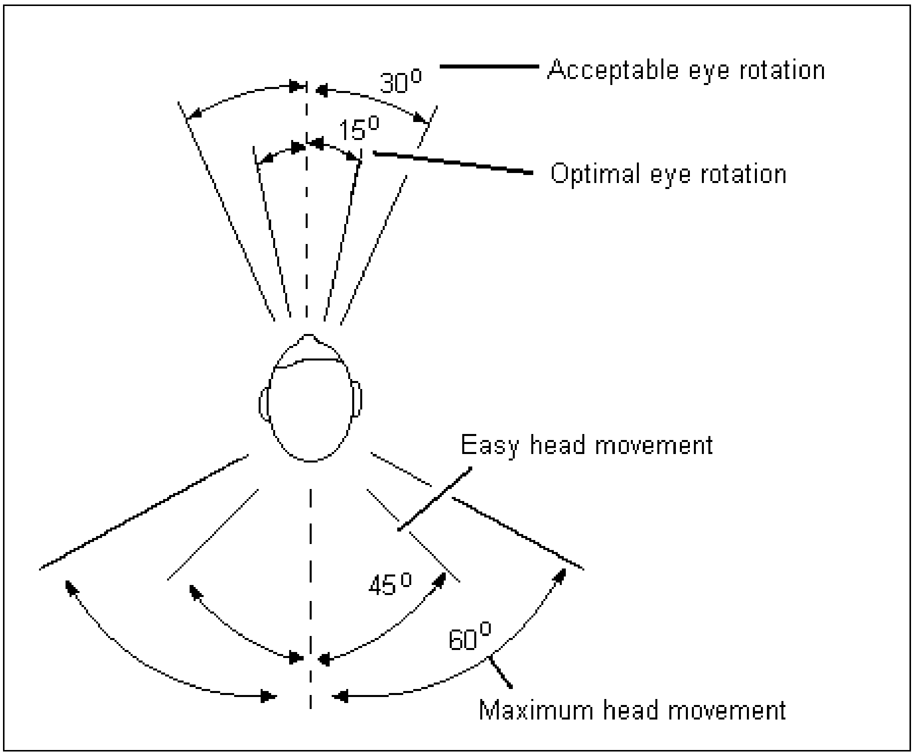


Figure 26: SAE J985 Head rotation angles

In the vertical plane, eye movement is comfortable within 15° above or below the horizontal, although the eyes can be rotated up to 45° upwards or 65° downward. The visual range can be further increased though vertical rotation of the head which can be easily inclined 30° up or down.

Within this visual field, only a small central area of around 2°, which is the focus of our vision (as illustrated by the black dot in Figure 27), enables detailed vision. This central area corresponds to the area of the retina, known as the field of fovea, which is where the light sensitive cones are most concentrated. The cones operate under conditions of high ambient illumination and enable high acuity, colour vision.

Figure 27: Peripheral vision in the driving task (Olson & Farber 2003)

The remainder of the visual field is mediated by peripheral vision which is dominated by rod receptor cells. These offer lower acuity, and no colour, vision, but are highly adapted to detecting changes in state in the surrounding environment e.g. movement, flashing, etc. Within the context of the driving task, peripheral vision is used to detect other vehicles, facilitate lane keeping activities, etc. The function of peripheral vision is therefore a monitoring role whose purpose is to detect objects of significance and re-direct the focus of gaze for central vision towards them.

The image below depicts a view as seen through a computer manikin showing the effects of foveal vision – sharp vision in the centre of the visual field, and peripheral vision – the surrounding blurred vision.

Figure 28: Computer visualisation of foveal and peripheral vision (Rönnäng et al, 2004)

The further the object is from the fovea, the less likely it is to be seen; therefore in order for an object in the periphery to be detected it must have strong attention-getting properties. Factors such a high colour and luminance contrast assist this process and accounts for the use of warning beacons and fluorescent and retro-reflective markings by emergency vehicles. Low contrast objects, such as dully clad pedestrians/cyclists can therefore be more difficult for drivers to detect in the visual field, especially if it is complex with other objects competing for the driver's attention.

In addition, as reported by Shearlaw and Freer (2002), studies of eye scanning behaviour have shown that the driver's use of central (foveal) vision can change with task demands. For example, whilst driving along a straight road on an unfamiliar route, the driver's eyes scan over a wide area searching for route information. With increased familiarity, scanning becomes more compact, with the range of eye fixations moving down towards the road or horizon and slightly to the right of centre. Again, when following another vehicle the pattern of eye movements is compacted, with most attention being used to monitor the vehicle in front.

A study by Swigart (1973) provides some insight into the extent of drivers' field of vision by measuring a driver's ability to see a vehicle that is overtaking them in an adjacent lane by direct peripheral vision. Results from field tests conducted in daylight on overcast days indicate that a vehicle overtaking the driver in an adjacent traffic lane can be recognized with certainty at more than 70° off the driver's direct line of sight. At night, the headlamp of an overtaking vehicle can be seen at 73° off the direct line of sight. This study illustrates how for a given scenario, driver performance can be impacted by a variety of factors such as ambient lighting, vehicle lighting, etc.

5.1.2 Ageing eye

It may be expected that the demographics of an ageing population and increases in the retirement age will be reflected in a greater proportion of older drivers within the driver population. In this case, the reductions in drivers' visual performance resulting from age-related conditions will become more prevalent. Some of these conditions are identified below and their implications for driver vision discussed.

Glare

Light entering the eye is scattered by optic media and this increases by 16-30 fold between ages 40-80 years (Wolf and Gardiner 1965 cited in Cook 2006). For a driver whose vision is adapted to dark driving conditions, this scattered illumination reduces the contrast of an object against its background making it difficult for the driver to detect. This reduction in visibility is called Disability Glare and is generally worse for older, as opposed to younger, drivers. The ability to recover from glare also worsens with age. Burg (1967) in Cook (2006) states a recovery time of 6.8 sec for 75-79 year olds compared to 3.9 sec for 20-24 year olds, which means that older drivers are spending proportionately more time in a non-adapted state for the driving conditions.

Senile myosis

With age, the iris (the ring of muscles which controls the pupil diameter) becomes less flexible and the maximum opening of the pupil is reduced from 7.5mm at 20 years to 4.8mm at 85 years. An implication of this is that, when driving at night, the pupil of the older eye may admit only 10% of the light of that of a younger driver which makes the detection of dim lights at night more difficult.

Accommodation/Presbyopia

As people age, the lens (which refracts light rays and so assists focussing) continues to grow. In time, since it cannot grow larger, it becomes more dense and less flexible. The result is that it is difficult for older people to bring near objects into focus and the near point, the shortest distance at which the eye is able to achieve sharp focus, moves further away. This may be problematic for some drivers who can find difficulty in viewing the dashboard which may be out of focus for both near and far adjustments within their glasses; varifocal lenses however may help.

Speed perception

The perception of angular movement, which is used to estimate aspects such as the relative speed of the driver's own vehicle to the one in front, decreases with age. Hills 1975, in Cook (2006) found that for brief exposures under night-time driving conditions older drivers, aged 70 years, took ½ second longer than younger drivers, aged 20 years, to determine if they were travelling at the same speed or closing on a lead vehicle travelling at 30kph.

Visual field

The driver's visual field declines with age from 175° for 35 year olds to 140° for 80+ year olds in the lateral field and is combined with a reduction in the vertical plane, bringing about an overall restriction of visual field. The implication of this reduction in the drivers' field of vision affects their ability to make accurate detections within the road environment e.g. poor observation of signs; reduced awareness of surrounding vehicles; reduced ability to make accurate observations whilst undertaking manoeuvres (Smith et al 1993).

Older drivers and accidents

Up until the age of 70, older drivers do not have a higher risk than their younger counterparts. However, drivers over 70 and especially over 80 years are more likely to be at fault when they crash (RoSPA, 2010). RoSPA also noted the prevalence for older drivers to be accident involved at junctions citing mis-judgement of the speed/distance of other vehicles or failure to see a hazard as factors thus concluding that visual impairment may be a factor in this type of crash. Similarly Shinar and Scheiber (1991) found that 'improper lookout' as a causal factor in accidents was three times more likely for drivers with reduced vision.

5.1.3 Eye diseases

There are a variety of eye conditions which can negatively impact on drivers' visual abilities thus impacting on what they are able to observe within the driving scene.

Macular degeneration

This condition is particularly common amongst older people (aged-related macular degeneration) and involves both eyes although both may not be affected at the same time. The condition affects central vision and in its initial stages manifests as: blurring; distorting or objects looking unusual in size or shape before progressing to sight loss in the central visual field. In the early stages, sufferers may be unaware they have distorted vision and so may be more vulnerable to driving errors associated with visual processing.

Cataracts

Cataracts generally affect older people and are caused by opacities/clouding in the lens. This causes light rays reaching the retina to be split causing the sufferer's vision to be blurred, fragmented, light dazzled and colour faded. Such distortion and reduced contrast may result in targets in the driver's visual field being overlooked.

Diabetic retinopathy

This condition results from disturbances in the fine network of fragile blood vessels in the retina. These can leak causing localised loss of visual function with vision appearing blurred and patchy. The impact to driving is dependent upon the number of leakages and their location within the visual field – fovea or periphery.

Glaucoma

In this condition increased pressure in the eye damages the optic nerve causing a progressive reduction in peripheral vision. Since there are no symptoms and no pain, the condition can be quite advanced before the sufferer is aware of their visual loss. Sufferers can thus be driving with a significant reduction to their peripheral vision causing lowered spatial awareness which can impede their ability to safely undertake tasks such as lane keeping, etc.

Retinitis pigmentosa

Retinitis pigmentosa relates to an inability of the retina to respond to light causing the sufferer to have difficulty with seeing in poor light and experiencing problems with glare. Sight loss is gradual but progressive causing tunnel vision, although total sight loss is rare. The consequences in the driving context are that sufferers may not be able to focus; may have reduced spatial awareness and will find driving at dusk/night-time particularly challenging.

5.1.4 Corrective Vision

The eyesight test for a B-class licence may be passed with spectacles or contact lenses if necessary, but in such cases the driver must wear them whenever he or she drives. C and D-class licence holders (larger buses and goods vehicles) are required to undergo a more rigorous eyesight test, and this includes minimum requirements for uncorrected vision, as well as when wearing corrective lenses. These drivers undergo further eyesight testing, on a schedule based on their age, so deterioration in eyesight and the need to wear glasses to compensate for this, are likely to be monitored.

There are a number of aspects of the design of spectacles and other vision correction aids that could have a significant effect on driver vision, and could also interact with vehicle design factors. One of these is the effect of widespread use of multiple-focus (bi-focal or vari-focal) lenses. These incorporate regions of different focal length in front of the eyes, allowing a myopic driver to see the instruments more clearly without affecting his or her distance vision, for example. In this type of spectacles, the lenses will be ground so that the myopia is only corrected over a zone in the lower portion of the lens, close to the centre. However, in some layouts this zone could extend sideways so as to affect the driver's view of the exterior mirrors in their peripheral vision. Hence, a driver adapting to new spectacles might find they have to move their head to obtain a clear view in the mirror, where they previously only needed movement of the eye. A further effect of multiple-focus lenses is that they can produce distortion; for example straight lines may appear curved. There appears to have been very little research on the effects of these lenses on driving performance.

Another innovation is the use of variable-tint lenses. In particular, some of these can exhibit a rather slow response to a rapidly-darkening environment, for example when entering a tunnel. As well as the lenses themselves, recent fashions in spectacles have tended to favour thick side frames that could obscure a significant part of the driver's peripheral vision to the side. A further innovation that could have a significant effect on driver vision is the increasingly common use of laser corrective eye surgery. It is a requirement that this must be declared when applying for a provisional driving licence, but there is a possibility that existing licence holders may not divulge to DVLA that this has been carried out. Again, there appears to have been very little research into its effects on driving performance.

5.1.5 Measuring visual performance

The conventional measure of a driver's visual performance is to read the number plate of a stationary vehicle at 20m or 20.5m dependent upon the style of the plate. This is a measure of static acuity, similar in nature to the Snellen chart (the chart of letters) used by opticians, and generally such assessments are undertaken under idealised viewing conditions i.e. reading high contrast text (black on white/yellow) under good ambient lighting conditions. However in the driving context such conditions will not always hold and drivers may have to drive in poor ambient lighting conditions viewing low contrast targets. Hence this measure of drivers' visual performance does not relate well over all aspects of the driving task.

Figure 29 below shows a reduction in contrast sensitivity from 20/20 vision to 20/40 vision – that required for the driving standard. Although there is a loss in clarity to the letters of the Snellen chart (high contrast targets), the reduction in visual loss to photographic depiction of the visual field is greater (low contrast targets). This suggests that drivers' vision can deteriorate significantly yet still be acceptable regarding the driving standard. It is important to note that such deterioration can occur very gradually over time and so drivers may not be aware of the loss to their vision (Allen et al 1996).

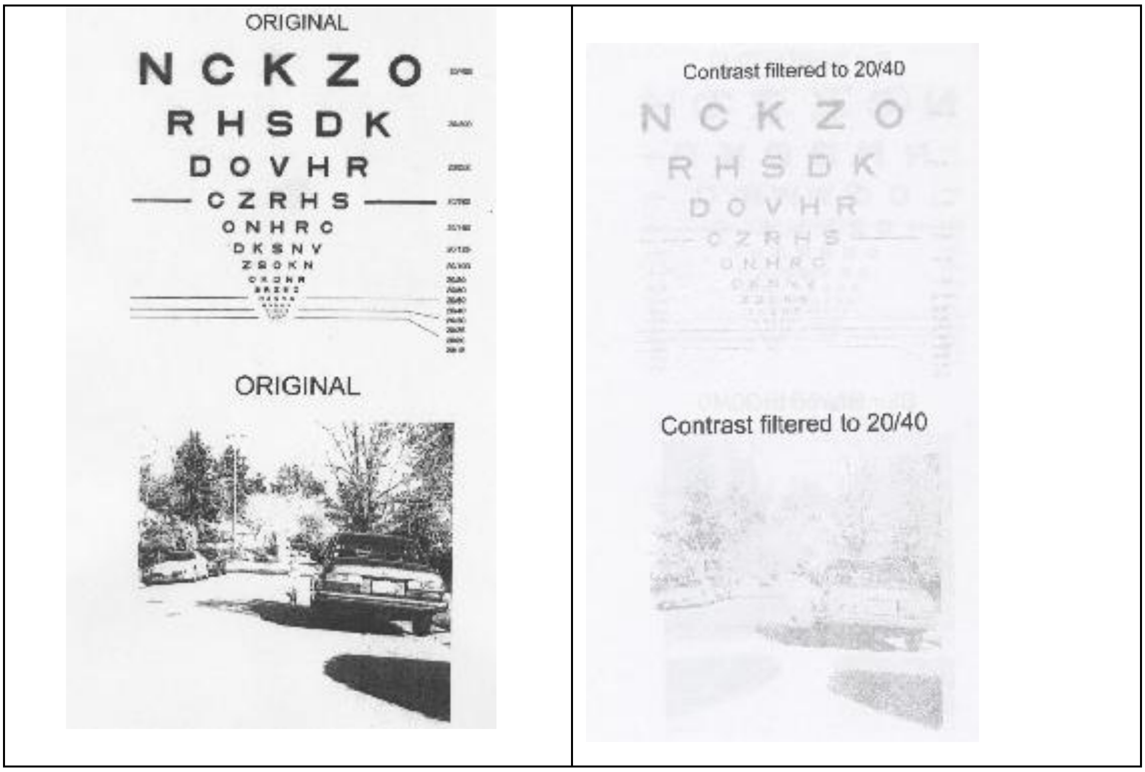


Figure 29: Effect of reduction in contrast sensitivity on high and low contrast targets

Boggess (2008) commented that within accident reconstruction, digital renderings of an accident are often re-created from the vantage point of one or more persons to illustrate what they may have perceived prior to and during an event. However, typically in this process no compensations are made to account for any general and/or individual visual based sensory degradation. The only limits imposed with the renderings are the screen and its subsequent resolution and the camera settings utilized. Boggess (2008) therefore conducted a study where a digital rendering of a driving scenario was used along with several visual based filters to illustrate the difference between general animation renderings and one in which anatomical limitations are accounted. The study considers the physical effects of the following on perception: Refractive Error; luminance; pupil size; effects of age; exposure duration; target and eye movements; accommodation / depth of focus; colour vision and binocular vision. The results of this study found significant differences in image perception when visual acuity impairments were incorporated.

5.2 Quality of vision

In addition to the physiological limitations of the eye, further restrictions are placed on the drivers visual abilities by the vehicle's design. Whilst the field of view offered by the vehicle is an obvious limiting factor (and discussed more fully in section 6), the quality of vision can also influence the driver's ability to detect objects in the visual field.

5.2.1 Variable luminous transmittance (tinting)

The tinting of vehicle glazing is defined in terms of the level of its Variable Light Transmittance (VLT) – the heavier the level of the tint, the lower its level of VLT. Theoretically, whilst an untinted window would have a VLT of 100%,. in practice this is not achievable.   The VLT applied to vehicle glazing is specified in ECE Regulation 43 which states that:

- Windscreens must have a minimum VLT of 75%;
- Glazing other than a windscreen which is located in a position requisite for driving visibility must have a minimum VLT of 70%.

However the VLT of the windscreen is affected by its installation angle; at 90° the installed luminous transmittance is the same at the VLT level of the glass. As the degree of inclination from the vertical increases the level of luminous transmission reduces. Research undertaken by Cook et al (2000) surveyed 27 cars which were up to three years old and found the windscreen installation angle varied from 41-63°. At the extreme, this related to an additional decrease in light transmittance of 10% - Refer to Figure 30.

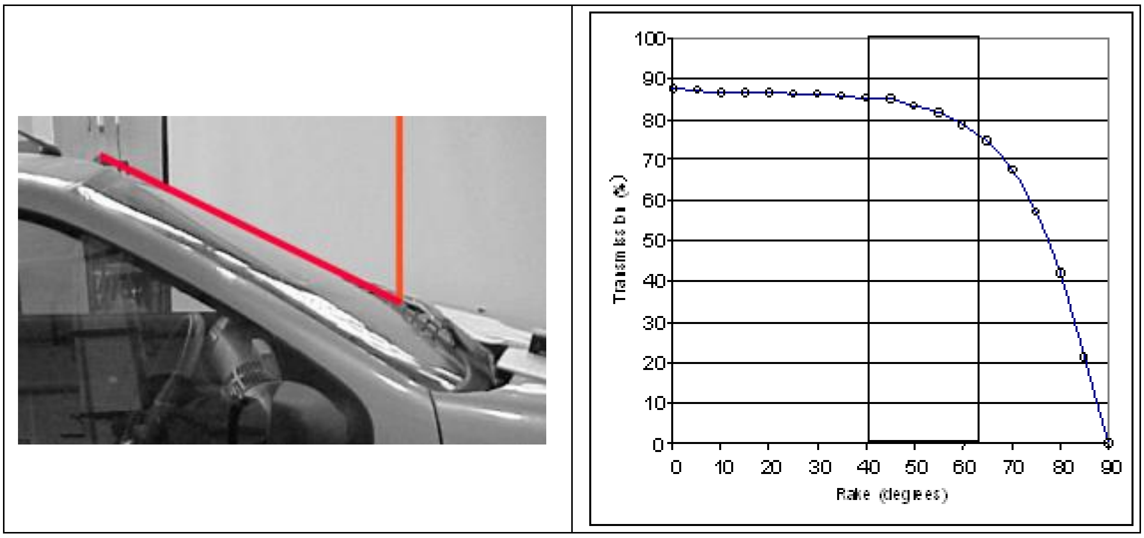


Figure 30: Effect of installation angle on luminous transmission

The importance of VLT to driver vision was further explored within this study which noted from other research that there were claims that a lowered VLT improved driver vision because it reduced the effects of glare on the visual field. However there were counterclaims that a lowered VLT, whilst posing no disbenefits to driving in high ambient lighting conditions, had the potential to reduce driver vision under dusk and night-time conditions making some objects more difficult to see particularly if they have low contrast with the background. Previous research has shown that that tinted windows negatively impact the detection rate, time and distance of objects. It was shown that for transmission values of 65-72%, target size needs to be increased by 10-20%.

5.2.2 Abrasion

Windscreen abrasion is a common feature across vehicles types, with windscreen wiper abrasions being particularly prevalent (Allen 1974 cited in Cook et al 2000)) in Field and Quality of vision work. Other sources of abrasion include: hand cleaning, ice scraping and small particles, such as stones and sand, hitting the windscreen (Allen, 1969, in Helmers and Lundkvist, 1988 in Cook at al 2000). There is a linear relationship between windscreen wear due to small stone impacts and mileage (Timmerman (1986) in Cook et al 2000) and levels of abrasion have been found to be affected by: weather conditions, geographical differences, road conditions, mileage and parking behaviour (garaged or not) (Chmielarz et al (1988) in Cook et al 2000).

The effect of abrasion is to increase the amount of stray light viewed by a driver. Light passing through vehicle glazing is caused to scatter by abrasion of the material's outer surfaces. This results in areas of veiling glare across the road scene and reduces the contrast of objects within the road scene. Research shows that drivers' visual performance is reduced by stray light (Allen 1974 (in Sayer and Traube 1994) and Helmers and Lundkvist 1988 (in Sayer and Traube 1994) in Cook et al 2000) which can take the form of: Reduced detection distances (Rompe and Engel 1984 and 1987 (in Sayer and Traube 1994) in cook at al 2000); increased reaction times (Pfeiffer 1970 (in Allen 1974) in Cook et al 2000) and longer re-adaptation times to abraded screens compared to new screens (Timmerman, 1986 in Cook et al 2000). Objective recommendations, based on

US data for windscreen re-polishing or replacement, vary suggesting 50,000 and 100,000 miles.

5.2.3 Haze

An additional source of visual degradation when driving is a greasy layer/film that builds up on the interior surface of a windscreen. This layer has been attributed to a number of contamination sources including atmospheric pollution drawn in when demisting or ventilating, internal pollution from smoking and food and, in the earlier years of a vehicle's life, from organic solvents given off from interior trim plastics under strong sunlight. The effect of haze is the same as abrasion in that it increases the amount of stray light viewed by a driver which, in the case of haze, is caused by light passing through vehicle glazing being scattered by dirt particles on the interior surface of the windscreen. The resultant veiling glare across the road scene and the reduction of contrast of objects in the road scene significantly increases the risk of accidents for low contrast objects (Rompe and Engel 1974 cited in Cook et al 2000). Olson (1996) cited in Cook et al (2000) noted that haze reduced the probability of detecting targets from 91% with clear windscreen to 73% with moderate level haze.

5.2.4 Reflections

Reflections are always present on windscreens, but are most noticeable when the reflected image is lighter than the scene being viewed through the glass. Although designers generally choose black or grey as the colour of the dashboard top to reduce reflections, mottled patterns on the surface can often cause distraction due to uneven illumination. However, with the trend to shallower windscreen angles on modern cars the most serious distraction can arise from the contrast between the light dashboard top and the dark recesses associated with demisting vents. It is not known to what extent drivers are able to ignore distracting reflections over time.

5.3 Workload

The figure shown below illustrates a generalised information-processing model of driving which shows that in order to maintain safe control, the driver has to respond appropriately to any given hazard. To do this the driver must first 'see' the hazard (detection) and then correctly interpret what they are seeing (identification). The driver must then weigh up the significance of the hazard and then assess and select an appropriate course of action (decision-making) which they then enact using the appropriate vehicle controls (execution). Failure in any of these processes can result in an accident.

However to more accurately represent the driving task, such a model needs to be overlaid on real driving scenarios which need to consider the interactions of factors such as:

- Driving manoeuvre;
- Speed restrictions;
- Weather conditions;
- Road type;
- Road congestion;
- Route familiarity;
- Task familiarity e.g. driver may be less practiced at emergency procedures;
- Vehicle type;
- Physical and psychological state of the driver;
- Time pressures on driver;
- etc.

It can be appreciated that increased realism brings increased complexity which helps to account for the difficulty in modelling the driving task. Research in this area has been ongoing for a number of decades and the level of understanding is still evolving. Work such as that by Walker et al (2001) and Fastenmeier and Gstalter (2007) are amongst a variety of newer approaches proposed although, as yet, a single unified model has yet to be defined.

The Danish proposal for direct vision in heavy goods vehicles N_2/N_3' (Road Safety and Transport Agency undated) notes a range of factors which may distract the driver and impair performance including: reading maps; road works; defective traffic signals and tiredness. The report proposes that the multitasking that is required in driving a HGV is beyond human perceptual abilities. Similarly, White Willow Transport Intelligence (2006) notes that driver performance suffers with workload, e.g. concentrating on congestion while lane changing and checking in many mirrors. It also reports that US accident data suggests that between 60% and 80% of side swipe accidents are caused by vision-related factors and, of these, 20% are caused by drivers being overloaded by the number of mirrors and places to watch. Keigan (2009), in a study which analysed 92 police files relating to fatal pedal cycle accidents that occurred in London from 2001 to 2002, cautioned that there is no research evidence that close proximity sensors work or would help to prevent collisions in London, noting that they could overload the driver with information and make the driving task too complex.

In terms of the processing which has to be conducted at such times, Crundall et al (1999) report that theory suggests that as the level of demand increases at the fovea, more processing is required. Miura (1990) cited in Crundall et al (1999) concluded not only that perceptual narrowing was occurring (from an increase in reaction times to targets in high demand situations), but also that the subjects were searching toward the extremes of their usable fields of view on complex roads, possibly to compensate for a narrowing of the visual field. In this study, reactions time to peripheral targets were found to be significantly slower in the high demand windows. The report by Tijerina (1996) summarised research for the National Highway Traffic Safety Administration to develop methods, data and guidelines regarding heavy vehicle driver-oriented workload assessments of new, high technology in-cab devices. As part of this research, the use of junctions was investigated by analysing the various driving scenarios which could be undertaken: turn left on green; turn left on yellow; drive straight on yellow; turn right on green; turn right on red and stop on red. Information processing bottlenecks across these scenarios were identified and it was concluded that time constraints and the forced-pacing of tasks seem to be recurrent contributory factors with the general problem being that there is only a limited amount of time to perform a variety of different yet necessary tasks. Further complications occur because many of these tasks need to be supported by the same perceptual and cognitive resources. Examples of their findings which have relevance to this study are shown below.

'Prepare for turn' information processing bottlenecks
Difficult, forced-paced gap-judgement task;
Complicated by having to quickly cycle amongst other tasks involving checking for hazards e.g. in the turn path;
High-stress situation due to collision implications resulting from error.
'Execute turn' information processing bottlenecks
Initial part of turn process linked to higher workload levels;
Cognitive elements are particularly affected by need to oversee precise manoeuvres and assess for hazards;
Forced-paced tasks;
Potential high-stress situation due to possible direct conflict with other vehicles and collision implications resulting from error.

Table 8: Examples of the information processing bottlenecks identified by Tijerina (1996)

Brown (2005) found that important causal contributors to 'Looked but failed to see' (LBFTS) are shown to be informational overload, imperfect selectivity of object features demanding attention and incoherent integration of those features which distinguish a hazard from a non-hazard in the visual scene. The data reviewed in Brown's study suggests that LBFTS errors are made more frequently by female drivers than by males and by older drivers rather than younger. Brown reports that LBFTS errors occur mainly at road junctions, but suggests that further research is needed, recommending that detailed analyses of the specific relationships between; the attentional demands imposed on drivers by different types of journey, different types of junction and the different manoeuvres required to negotiate them, is required.

5.4 Attitudes

In a study by Basford (2002), respondents expressed their views that the respect that drivers of larger vehicles demonstrate towards other vehicles diminishes in proportion to the other vehicles' size – i.e., the smaller the other vehicle, the less their respect. However, it should be clarified that this did not necessarily mean that they would behave discourteously towards these smaller road users. Size was also reported as having other implications: such as, the fact that cycles are smaller meaning that they are harder to see. Drivers accused cyclists of not being aware of this and respondents who were drivers of larger vehicles reported that this tended to infuriate them (particularly HGV and bus drivers). Those respondents who were cyclists (and the drivers of other smaller vehicles) said they were unaware that the size of the larger vehicles impacted on their ability to see other vehicles beside and behind them. It was stated that the mass of larger vehicles results in many blind spots, of which other motorists and road users seemed to be unaware.

When prompted, all the professional drivers, regardless of whether they were carrying goods or passengers, tended to be less accepting of cyclists' presence on the roads they were using. They felt their livelihood was being interfered with – particularly if they were held up by a cycle, which was obviously slower than other vehicles, within their lane. It was reported that being caught behind a cyclist added further to the pressure on their work schedules.

5.5 Consultations

The consultations highlighted the following areas that were indicative of a mismatch between the requirements for vision and reality that drivers considered problematic for various categories of vehicles:

- Mirrors can often provide the necessary view but may be significantly handicapped if not properly aligned by the driver. Workload, changing over of drivers, mirror adjustment often being a two person job, lack of training, lack of awareness of issues such as cyclists, all contribute to the improper use of mirrors. Some companies such as TESCO have systems in place to help, e.g. a mirror adjustment, or Royal Mail and their 'check time' bay but there is no guarantee that a driver will use them.
- Some drivers may deliberately mis-adjust their mirrors to provide a non standard view.
- There is considered to be a loophole in the licensing rules, which allow N_2 vehicles of less than 7.5 tonnes maximum authorised mass to be driven on a B-class (cars and light goods vehicles) licence, provided the driver passed the driving test before 1/1/1997. This means that they may not have received training on the mirror systems that are fitted to these vehicles. (Type II plus

Type IV on both sides, plus Type V on the nearside), or have been briefed on the importance of diligent use of the mirrors when manoeuvring such a large vehicle.

- Even if mirrors are fitted and properly adjusted, visual overload is becoming a concern. Knowing where to look and understand what is being seen is an issue with such a large number of mirrors available. This may be exacerbated by the addition of display screens and other items to monitor.
- Driver overload, with respect to the ability to effectively use mirrors in busy urban areas, was noted by one distributor.
- The RHA stated that feedback from members highlights concerns regarding mirror overload.
- Retro-fit mirrors for towing were generally very poor, suffering from vibration and wind deflection. There is a potential additional problem with legislation changing to allow wider caravans to be used, requiring even longer mirror arms to be fitted.
- A further issue highlighted was by drivers who own a RHD vehicle with a LHD wiper swept area that was perceived not to clear the primary visual area adequately.

5.6 Conclusion

This section has briefly reviewed a number of factors which may limit what drivers' can actually see. A key factor with respect to this project relates to the demands on the driver's attention of the driving task and the potential for the driver to be cognitively pressured or overloaded. This suggests that any solutions to improve the driver's visual abilities should be properly supportive of the driver and not add to their task demands. Training is a further area which is related to drivers' visual performance in the sense that appropriate training can support drivers in identifying hazardous situations and negotiating their way through them through correct use and maintenance of equipment and mirrors. Drivers' physiological vision is a factor overlying field of view considerations. The function of the eye. the general deterioration of vision with advancing age, eye diseases and the use of corrective aids to vision, may mean that detecting targets in the driving environment is compromised for a significant portion of the driving population. Field of view issues resulting from poor vehicle design may further compound such problems. The impact of quality of vision issues on driving performance is difficult to quantify. Variable light transmission is regulated at an appropriate level, although lower transmission levels in glazed areas rear of the B-pillar could potentially be an area for concern.

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6 BLIND SPOTS

This section discusses the impediments to the driver's field of view – blind spots, caused by vehicle and equipment design.

6.1 M_1

6.1.1 Overview

For Category M_1 vehicles the literature shows that the main areas investigated regarding impediment to field of vision include:

- The A-pillars.
- The B-pillars.

Burger, Smith, Queen and Slack (1977) attempted to identify the relationship between poor visibility resulting from a variety of vehicle design characteristics and critical incidents. A survey of 10,000 drivers was conducted using a highly structured questionnaire technique involving critical incidents or accidents that respondents had actually experienced and that were associated with 52 possible vehicle design characteristics. The 3,500 respondents in the survey cited whether a particular characteristic had caused them 1) no problems, 2) annoyance, 3) potential danger, 4) a near accident or 5) an accident.

Table 9 below summarises the percent of respondents citing an experience involving a near accident or accident where the occurrence of poor visibility had been a contributing causal factor.

Relevant vehicle design characteristics	**Percent of respondents**
Vision limited because:	
Of rain, snow or fog on side windows	2.51
Of rain, snow or fog on rear windows	3.33
Wipers didn't clear front window quickly or completely	1.43
Defogging didn't clear front window quickly or completely	1.46
Vision blocked by:	
One of the front, side or rear posts	4.13
The roofline, hood or trunk	0.33
Inside left or right mirrors	0.99
Passengers in front or rear seats	0.63
Front seat or front seat headrests	0.50
Limited direct visibility subtotal:	15.31
Vision limited because:	
Inside mirror did not give needed information	3.22
Left mirror did not give needed information	3.35
Right mirror did not give needed information	4.55
Using mirrors distracted my forward attention	1.05
Limited Indirect visibility subtotal:	12.17
Total respondents	**27.48**

Table 9: Percentage of respondents reporting a close call or accident due to various vehicle visibility design characteristics.

When respondents were asked to suggest vehicle design improvements, which would reduce their involvement in such near and actual accidents, better visibility was a dominant recommendation. Better rear view mirror gained highest percentage of respondents, followed by defog other window, reduce windshield glare and better vision from vehicle.

6.1.2 A-pillars

Peripheral vision is a vital function for the driving task, and obstructions in the periphery could have safety implications. EEC directives 77/649 and 81/643, covering the windscreen aperture and A-pillars, are directed at minimising the obstructions in the direct and peripheral view. However, the 6° limit for pillar width set out in EEC directives 77/649 and 81/643 is sufficiently generous to conceal a car at only 15 metres distance.

The positioning and thickness of the A-pillars is essential to the mechanical strength of the vehicle as they form part of the structure that protects the vehicle occupants in the event of impact or rollover (PNCAP 2002). More demanding crash testing of vehicles is pushing manufacturers to increase the strength of pillars, leading to pillars of greater dimensions on today's vehicles compared with vehicles designed in the 1980's.

Allen et al (1996) found that along with the rear view mirror, the bonnet and the wings, the A-pillars have been identified as the main obstructers of the visual field from the driver's seat. An object on collision course with the vehicle may be obstructed by the A-pillars, causing the object to be overlooked until it is too late to avoid it.

Results from a study by Millington et al (2006) found that smaller road users such as motorcycles, cyclists and pedestrians can be obscured by A-pillars. They also reported that failing to see another road user may be related to driver attention, behavioural factors and road side features. The study also found that the forward field of view of smaller stature drivers was shown to be adversely compromised by A-pillar obscuration, because their driving position brings them closer to the windscreen and often the lower parts of the A-pillar are more bulky than the central section on many cars. Also from a 3D simulation it was shown that 95th males may also find the field of view obscured by the flared top portion of the A-pillar.

The study by Quigley et al (2001), which investigated A-pillar geometry and field of vision, surveyed a sample of new model vehicles to determine A-pillar widths, eye-to-A-pillar geometries and the resultant degree of obscuration imposed. A total of twenty-seven vehicles between 0 and 3 years old were surveyed. They were the most current models from a representative range of classes and makes, many of which had been included in the Euro NCAP crash test programme. In addition, a further survey of 11 cars between 5 and 17 years old (i.e. pre Euro NCAP crash test programme) was undertaken for A-pillar obscuration only.

A statistical comparison of measurements from older cars with new models found that compared to the old cars, newer cars had:

- Significantly longer A-pillars;
- Significantly greater internal horizontal obscuration angles (near and off-side);
- Significantly greater A-pillar and windscreen inclination from vertical;

- Significantly closer A-pillar to eye-point in rear most position (off-side only, direct, longitudinal and lateral).

From the information collected, obscuration angles resulting from both the off-side and near-side A-pillars were calculated. The mean obscuration angle of both off-side and near-side A-pillars was less in older cars than newer cars. This difference was found to be statistically significant, i.e. A-pillar obscuration angles have become significantly worse in newer cars than in older cars. However, it must be noted that comparisons were not with identical cars, i.e. many of the older cars were not old versions of the new cars.

Within the same study a series of trials were conducted by ICE Ergonomics to determine the extent to which different angles of A-pillar obscuration affect the detection of targets in the visual field in a number of different driving scenarios. A full-scale, 180° wrap around, panoramic road scene was developed which consisted of enlarged (8' x 4') photographic images of a real road scene (i.e. a busy road junction). Thirty Light Emitting Diodes, which were identical in terms of colour and intensity, were used as the targets for the participants to detect. The targets were positioned around the areas in which the A-pillars could have caused an obstruction in all three chosen vehicles and a number were positioned either side of these areas. This also took into account seat positioning. The targets were positioned between 25° and 65° to the left of the driver's line of sight and between 15° and 47° to the right of the driver's line of sight. The conclusion to both the literature review and driver survey, that A-pillars impede the forward field of view, was verified by the trials that were conducted by ICE Ergonomics. In addition to confirming the detriment to forward vision, the trials also enabled the following quantitative evaluations to be made:

- <u>Changes in A-pillar design</u> - Obscuration angles were simulated, but no evidence was found to suggest that vehicles included in the survey exceeded the regulations. The survey confirmed significant differences in A-pillar design between older and newer cars, namely that newer cars had: longer A-pillars; greater internal horizontal obscuration angles; greater A-pillar and windscreen inclination from vertical and closer A-pillar to eye-point distances.

- Extent of obstruction to forward visibility - Approximately one third of all the targets presented in the vicinity of the A-pillar were not detected. (This varied from 27% to 37% dependent upon the type of car and the near-side/off-side location).
- Comparative performance of older and newer vehicles - Significantly more targets were seen in the vicinity of the off-side A-pillar for the older car (74%) compared to the two newer cars (64% and 66%). The same effect was noted for the near-side A-pillar although this was not statistically significant. It was suggested that these results imply that older vehicle designs are less likely to be involved in accidents where A-pillar obscuration is a contributory factor.
- Compensation of A-pillar obscuration by driver behaviour - The likelihood of seeing a target in the vicinity of both the near-side and off-side A-pillars was significantly improved when drivers made the effort to look around them.

The effect of A-pillars on a driver's field of view is not limited to direct obscuration. Chong and Triggs (1989) investigated the effects of detecting targets when in the vicinity of a window post, such as an A-pillar. It was concluded that visual performance can be influenced in two ways. Firstly, inappropriate visual accommodation towards the post can occur (i.e. vision will be accommodated at the distance of the post rather than the distance of the targets beyond), although this effect can be reduced when the line of gaze is greater than 1° from the post. Secondly, the presence of a target up to 1-2° from the edge of the post, results in them being detected less easily.

A study by Picker (2004) measured the obstruction to drivers' vision caused by the A-pillar in 15 passenger cars manufactured from 1986 to 2003. The measurements are taken at three different eye positions to simulate 95th-, 50th- and 5th-percentile drivers and at three different angles (horizontal, 2° up, 5° down). The degree of obstruction was calculated using both single-eye (monocular) and two-eye (binocular) methods. For the 50th-percentile, horizontal measurement, the results range from 8.5° to 15.31° for the monocular view and from 1.7° to 9.4° for the binocular view.

[1] Combined value for vehicle with divided A-pillar (8.8 and 6.5 degrees).

6.1.3 B-pillars

In practice there will be many situations where road geometry dictates that the driver needs to see traffic approaching from areas outside the 180° forward field; for instance, on some roundabouts or at 'Y' junctions. These situations rely on the driver's eyepoint moving (dynamic field of view), and instead of the forward 180° being the limit, the B-pillars will now begin to impinge on the field of view (Shearlaw and Freer 2002).

Sivak et al (2005) noted that B-pillars on four-door models are farther forward, and nearer the fore-aft position of the driver, than B-pillars of two door models. Furthermore, the B-pillars on two-door models can be narrower, and some two-door models have no B-pillars at all. Sivak et al (2005) looked at the differences in lane-change crashes of four-door and two-door body styles of the same vehicle models. They analysed 2000-2003 North Carolina crash data, and considered the crash experience of four-door and two-door body styles for the same 10 vehicles for model years 1995 and newer. The main findings were that four-door body styles are more likely to be involved in lane change crashes than are two-door body styles of the same vehicle models. Sivak et al suggest that lateral visibility out of the vehicle cabin affects safety.

In the US it is recommended that roadways intersect at 90° as far as is possible, with a minimum of 60°. Research was undertaken by Gattis and Low (1998) to investigate the effect of vehicle design on the driver's line of sight at such junctions since it was considered that aspects such as a car roof post, the door frame or a panel aft of the door may impede safe use. Whilst the findings indicate a revised minimum intersection angle, they also suggest that there should be regulation to mandate 'that the body and glass area be built to provide a minimum line of sight to the right'.

6.2 M_2

6.2.1 Overview

Research by Southall et al (1998) investigated the causes of an insufficient or ineffective field of view for drivers of large vehicles. The findings of surveys with M_2 and M_3 drivers, operators and manufacturers are given below.

Drivers
• Issues regarding mirrors, reversing and near-side vision which are similar to those affecting truck drivers; • The width of the rubber safety seals on the closing edges of bi-fold passenger entry doors; • Screens and body work behind bus and coach entry doors which obscure passengers and two-wheelers at the kerb side; • Bus number and destination information boards, in the near-side window behind the passenger door, obscuring driver vision to the rear/left; • Mirrors, especially on the off-side, can obscure forward vision; • Offside windows with horizontal division bars at eye level; • Security screens with horizontal cross bars at eye level; • Transfers on entrance doors; • Coaches with low position driver's seats have poor vision to the near-side; • High seat coaches have poor immediate forward vision. • Mirrors can be located so they are viewed through the side windows or windscreen with no standardisation.
Operators
Additional problems noted were: • Blind spots caused by 'A' and other pillars; • Wide door pillars; • High dashboards (binnacles). • Metal bars on near-side front window adjacent to the luggage rack;. • Night-time reflections from security screens etc.; • Poor rear vision making drivers very reliant on exterior mirrors.
Manufacturers
Additional problems noted were: • Central safety rubbers on double opening doors; • Near-side pillar; • Wide 'A' pillars; • High line coaches with no rear window.

Table 10: Impediments to driver vision in buses and coaches

In a later study by Tait and Southall (1998), CAD analysis cited the following problems:

<u>All large vehicles</u>

- On all large vehicles (categories M_2, M_3, N_2, N_3) an off-side, wide angle (Class IV) mirror is not a requirement.

- On all large vehicles (with the exclusion of N_3 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.

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 passengers' 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 passengers' 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.

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.

It must be remembered that this study was conducted in the late 1990s and intervening legislation may negate some of these findings.

6.2.2 High seating position

Haslegrave (1993) reports that blind spots occur as drivers are higher above ground, making it difficult to see areas close to the vehicle without using larger mirrors. Jacobs Consultancy (2004) reports that for Buses and Coaches (M_2 and M_3) Class II (rear view) mirrors are the only compulsory mirrors and there is a significant blind spot between the driver's field of direct vision and that through their Class II (rear view) mirrors. Vincent and Lemay (1997) looked at school buses and concluded that the low visibility from the driver's viewing position of children in front of and along the sides of a bus was a contributory factor for children being involved in accidents with school buses.

6.2.3 Long passenger compartment

Haslegrave (1993) states that the rear view is blocked by the long passenger compartment in a bus.

6.2.4 Interior binnacle

All three coaches and one of the buses studied in an assessment of field of vision conducted by ICE Ergonomics were found to have limited fields of view to the area immediately in front of the vehicle (Tait and Southall 1998). This is an 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 31 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.

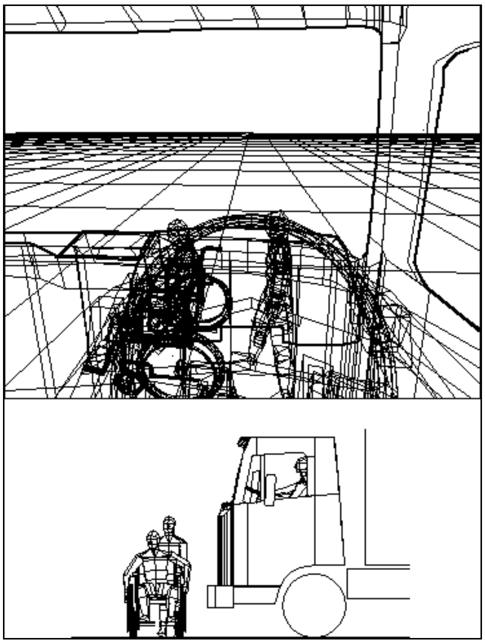

Figure 31. Blind zone to the immediate front of HGVs

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.

6.3 M_3

Refer to M_2.

6.4 N_1

No specific data was found for this vehicle category.

6.5 N_2

6.5.1 Overview

Research by Southall et al (1998) investigated the causes of an insufficient or ineffective field of view for drivers of large vehicles. The findings of surveys with N_2 and N_3 drivers, operators and manufacturers are given below.

Drivers
• A near-side blind spot next to the trailer. Some of the driver's who reported this did not have a cantrail mounted, close proximity, mirror to show this area. Those that did said that near-side vision was not a problem; • Traffic obscured by A-pillars and mirrors when trying to view oncoming traffic to the right (off-side) at roundabouts. It is difficult to see motorcycles approaching at speed. Some criticised mirror size and position; • Traffic coming from the left at Y-junctions is impossible to see when joining main roads at an angle. Some stated that a wide angle mirror might help in some situations; • Turning left at junctions was a problem when cyclists try to undertake on the near-side and the driver is unable to see them; • Driver's need to stop a few feet before pedestrian crossings so that they can see pedestrians crossing in front of the cab; • When reversing left with an articulated vehicle, normal mirrors only show the side of the trailer and not the rear end; • Drivers cannot see anything directly behind at all; • Some articulated vehicles have few windows to the sides and rear of the cab and this makes direct viewing very difficult.
Operators
• A near-side blind spot next to the trailer; • The height of the lower, and sometimes upper, edge of the windscreen on larger HGVs restricting the view to the front; • A restricted view along the near-side; • A restricted view to the rear when reversing; • 'Driver' issues such as not adjusting mirrors appropriately and installing mascots etc. in the window area.
Manufacturers
Additional problems noted were: • The height of the H-point. When the driver's seat is raised to maximum extent, sideways vision for some drivers can be obstructed by the door cantrail; • Drivers use mirrors that are incorrectly set for the width of the vehicle and it's body. Manufacturers claim this is a common occurrence, reflecting poor operator practices.

Table 11: Impediments to driver vision in trucks

In a later study by Tait and Southall (1998), CAD analysis cited the following problems:

<u>All large vehicles</u>

- On all large vehicles (categories M_2, M_3, N_2, N_3) an off-side, wide angle (Class IV) mirror is not a requirement.

- On all large vehicles (with the exclusion of N_3 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.

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.

It must be remembered that this study was conducted in the late 1990s and intervening legislation may negate some of these findings.

6.5.2 A-pillars

Dodd et al (2009) assessed three HGVs (comprising Category N_2 and N_3 vehicles) measuring direct and indirect field of view. The indirect field of view was mapped and measured with mandatory mirrors adjusted to ensure they provided the correct view for ocular points for 5th and 95th percentile drivers and for only one of the test vehicles 50th percentile drivers. Mirrors were masked to provide at least the minimum field of view required first by Directive 71/127/EEC and then Directive 2003/97/EC. The study then assessed the number of blind points of four different types of passing road user; large passenger car, small passenger car, pedal cyclist and pedestrian. Each of these road users was assessed individually for each test vehicle at three lateral distances away from the side of the test vehicle – refer to Figure 32. The study also investigated the use of supplementary devices; Fresnel lens and a Dobli mirror which are discussed in section 9.5.

- The first position was with the right side of the road user in line with the closest edge of the adjacent lane (a lateral distance of 0.5m from the side of the test vehicle);
- The second position was with the centreline of the road user in the middle of the adjacent lane (a lateral distance of 2.4m from the side of the test vehicle); and
- The third lateral position was with the left side of the road user in line with the far side of the adjacent lane (a lateral distance of 4.2m from the side of the test vehicle).

For each of these lateral positions eleven longitudinal positions, spanning an area from 5m behind to 5m in front of the driver's eye-line at 1m intervals, were considered. For the passenger cars, the front of the vehicle was used as the reference point and for the pedal cycle the middle of the front wheel was used.

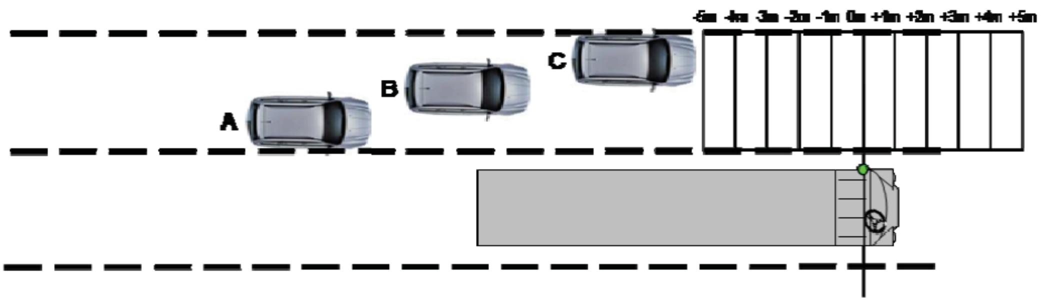

Figure 32: Lateral vehicle positioning in the Study by Dodd et al 2009.

A subjective analysis of the visibility of passing road users showed that from the 1,584 measurements taken, from the ocular view points of a 5th and 95th percentile driver, there were a total of 471 potential blind spots as identified when only the direct field of vision through the window and the indirect field of vision through the mandatory mirrors were considered.

It was found that there were more potential blind spots when the passing road user was positioned in the centre or far side of the adjacent lane. Specifically it was found that about 14% of all potential blind spots were recorded when the passing road user was at the nearside of the adjacent lane compared to 37% and 49% of all potential blind spots when the passing road user was in the centre and far side of the adjacent lane respectively. The majority of the blind spots 72% were recorded from one metre behind the driver's eye-line to three metres in front of it. The position of two metres in front of the driver's eye line had the largest number of potential blind spots. It was reported that this arose from the passing road user being hidden by the A-pillar on the passenger side when the road user was ahead of the front of the test vehicle, and was not visible in the rearward facing mirrors.

A similar area prone to blind spot was identified by Jacobs Consultancy (2004) which reported that the most severe problem is the nearside of the vehicle, in an arc from slightly forward of the drivers cab, to where Class V (rear view) mirrors are effective. This study stated that the problem can be addressed by a combination of Class II, Class V (close proximity) and Class IV (wide angle) mirrors, or using a camera system.

6.5.3 High level side windows

In a report entitled the 'Danish proposal for direct vision in heavy good vehicles N_2/N_3' (Road Safety and Transport Agency undated) the results of the Danish Road Accident Investigation Board (HVU) in-depth analysis of collisions involving HGVs turning right and a cyclist travelling straight on are presented. It noted that high level side windows in trucks are common - in 2/3 of the trucks the lower edge of the window was between 2.1 and 2.2 metres above the ground. The head height of cyclist is 1.5m and in this situation the driver cannot see the cyclist at a distance of less than 3m away from the driver's cab. In a study by Dodd et al (2009), which investigated the number of blind spots for three different HGVs (Category N_2 and N_3), it was found that a frequent cause for the blind spot was when the passing road user was below the lower edge of the passenger side window.

In a study by Couper (2006) a Ford Fiesta was used as a passing vehicle to assess its visibility and when it was obscured in a blind spot. The car was selected because it was a supermini class vehicle which was deemed to be the worst case, that is, the type most easily 'lost' in the blind spot. The supermini class car was positioned in the adjacent lane to determine whether it would be possible for the car to always be seen via either direct or indirect vision. The bottom edge of the test vehicle window frame was 1.8m above ground level, which is lower than many other HGVs resulting in better direct vision of the adjacent lane. A further assessment was conducted by raising the height of the window frame to determine at what point the car could no longer be visible. The driver's eye point was kept in the same location relative to the window frame. It was found that in this particular model that raising the height of the window edge to 2m above ground was sufficient to prevent direct vision of the car at the far side of the adjacent lane. It was also noted in a photographic analysis part of the study that for a tractor unit that had a window base height of 2.35m, the edge of the roof of the car was visible to the 50th and 95th percentile drivers. However, it was unlikely that the amount visible would be sufficient to determine what was in the adjacent lane. For the 5th percentile in the same cab the car was completely obscured.

6.5.4 Shape of window

Dodd et al (2009) showed that the shape of the window can have an effect on the extent of the ground plane visible to the driver. Highlighting the effect of the grab handle in an Iveco HGV and the slope of the lower edge of the window in a DAF HGV both aspects were found to reduce the field of view.

6.5.5 Passenger door

A study by Fenn et al (2005) concluded that a 7.5 tonne vehicle without a Class V mirror will have a blind spot by the passenger door. A cyclist would have to be at least a 50th percentile adult male, seated reasonably upright, to be seen by direct vision.

6.5.6 High seating position

HGV drivers have a high seating position compared to other vehicles' users, which results in drivers having limited low level visibility and not being able to see certain angles properly from the seat (Road Safety and Transport Agency, undated).

6.5.7 Incorrect adjustment / mounting or poor maintenance of mirrors

Within the research reported within the 'Danish proposal for direct vision in heavy good vehicles N_2/N_3' (Road Safety and Transport Agency undated), data were collected over an eight month period in 2005 and during this period 25 HGV and cyclist accidents were recorded and investigated in detail. In 21 HGVs out of the 25, mirrors were adjusted incorrectly. In 7 of the accidents this had been a contributory factor. The report also stated that it was found that 8 of the 18 blind spot mirrors of the 25 HGV accidents investigated were found to be mounted incorrectly on the outside of the lorry, and in 6 of these cases the blind spot mirror was positioned so that the back of the other right side mirrors were over shadowed and obscured.

Dodd et al (2009) consider the effects of using poorly-adjusted close proximity mirrors. Their study found that a close proximity mirror meeting the requirement of directive 2003/97/EC, when adjusted correctly, only just enabled a passing road user at the closest edge of the adjacent lane to be visible, and so commented that "poorly adjusting the mirror could mean that a vehicle in the centre of the adjacent lane might not be visible to the driver of the HGV".

Studies have considered two different scenarios of misadjustment of mirrors:

- Correctly adjusted mirrors for one driver that are not then readjusted by a different driver of the same cab.
- Mirrors are incorrectly adjusted such that other aspects as well as the ground plane are visible.

For scenario 1, a study by (Fenn et al, 2005) found that the lack of corrective mirror adjustment from a position suitable for 50th percentile male, when viewed from a 5th percentile female or 95th percentile male's ocular position, the effect was noted to be small. Fenn et al report that generally the change in visible area is calculated as less than a 7% change for Class IV and 9% for Class V.

Fenn et al, however, do state that the greater concern is scenario 2, where a mirror has been badly adjusted such that other aspects as well as the ground plane are visible. However results, from a driver survey conducted as part of the same study, indicated that 88% (N=311) did not adjust their mirrors in this fashion with 88% of respondents agreeing that the purpose of the Class V mirror was to check for cyclists or pedestrians by the passenger door, or a car, and the majority of drivers claimed to always check the positioning of the mirrors in accordance with this good practice (scenario 1 rather than scenario 2). The report does add a note of caution, acknowledging that drivers who responded to the survey may be more likely to be safety conscious and have greater appreciation for the use of safety related features and therefore may not be entirely representative.

In a report by the White Willow Transport Intelligence (Department for Transport, 2006) it was commented that dirt on mirrors, badly adjusted or even missing mirrors will increase further blind spots.

6.5.8 Mirror housing

Mirror housing and position in itself can act as obstacle to field of view, HVU found this contributory factor in 6 out of 25 accidents (Road Safety and Transport Agency undated). Internet discussion groups have raised the issue of the mirror housing further adding to the problem of obscuration of the field of vision. Below is an extract from http://www.roadtransport.com/cgi-bin/mt/mt-search.cgi?search=blindspot&IncludeBlogs=22

"I have to say I concur 100% with what The Boss says. Indeed, I can't help feeling that the latest generation of 'Big Mirror Clusters' on either side of a truck required by the latest EU regs now seem to create as many problems as they solve... In particular adding an extra wide-angle mirror to the driver's side means that you can barely see around all those mirrors as you enter a roundabout or junction - surely that was not what was intended?"

http://www.roadtransport.com/cgi-bin/mt/mt-search.cgi?search=blindspot&IncludeBlogs=22

Figure 33: Example of concerns regarding blind spots caused by

mirrors and their housings

6.5.9 Interior binnacle and other internal objects

Refer to section 6.2.4.

In 2 out of 25 collisions involving HGVs turning right and a cyclist travelling straight on investigated by Danish Road Accident Investigation Board (HVU) it was found that the positioning of objects within the cab (such as shelves and monitors) also decreased the field of view and were a contributory factor to the accidents (Road Safety and Transport Agency undated).

6.6 N_3

Refer to N_2.

6.7 Compounding factors

6.7.1 Ocular point of driver

The degree of obstruction created by each object/structure is dependent on the ocular point of the driver. The literature review and the consultations indicated that this is affected by factors such as the height of vehicle above the ground; the position of the driver relative to the cab interior and driver anthropometry.

6.7.2 Relative location of passing road users

Literature sources also commented on the effects of the position of the object being viewed, with objects (i.e. passing road users) being more likely to be obscured in certain locations relative to the HGV. Several studies highlighted the same particular areas/locations. These include:

- <u>Far side of the adjacent lane</u> - When positioned at the far side of the adjacent lane the car could not been seen in any of the Class V mirrors considered. However, in some cases the car could be seen directly through the side window. The ability to see the car directly was dependent on the height of the cab and the stature of the occupant (Couper 2006). Similarly, Dodd et al (2009) found that there were more potential blind spots when the passing road user was positioned in the centre or far side of the adjacent lane.

- Motorways - Fenn et al (2005) conducted a CAD analysis to investigate the blind spot from N_2 and N_3 category vehicles. Findings showed that if mirrors are correctly adjusted then other vehicles should be visible in urban traffic and close to the HGV. However, they state that on wider carriage ways, such as motorways, it is possible that passenger cars may be located in a blind spot.

6.8 All vehicle types

6.8.1 A-pillars

Chong and Triggs (1989), cited in Southall et al (1999), concluded that visual performance can be influenced in two ways. Firstly, inappropriate visual accommodation towards the post can occur, although this effect can be reduced when the line of gaze is greater than 1° from the post. Secondly, the presence of the target up to 1-2° from the edge of the post results in them being detected less easily (therefore does not need to be totally obscured to have an effect on the efficiency of object detection).

The study by Chong and Triggs (1989) cited Roscoe and Hull (1982), who found that targets were poorly detected when positioned close to the edges of an intervening post and that the detection of distant targets was affected by posts with widths greater than the observers intraocular distance.

6.8.2 Left hand drive vehicles

Road safety information provided by The Royal Society for the Prevention of Accidents states that 'LHD vehicles are not designed for use on Britain's roads. As a result blind spots can be larger than with British vehicles. This is most pronounced when the vehicle has other road users coming up the far side or when turning right. The danger of blind spots is highlighted by the 2005 DfT figures; in 32% of the collisions involving LHD HGV's, "vehicle blind spot" was found to be a contributory factor' (ROSPA, 2007).

6.9 Consultations

The consultations highlighted the following blind spots that were considered problematic for various categories of vehicles:

- The general view was that whilst mirrors had improved significantly there was still an issue with blind spots. Mirrors could be improved further but care should be taken to avoid additional blocking of direct vision. The lack of compulsory fitting of Class VI mirrors to large tall vehicles in urban areas was seen as a significant omission.
- For HGVs, directly in front of the cab when no Class VI mirror fitted.
- For HGVs, the front quarters of the cab near to the vehicle that falls in front of the field of view of the Class V mirror which is important for changing lanes and close manoeuvring in urban areas.
- For HGVs, the area from the nearside front wheel outwards and rearwards. Even with Class V mirrors there are a number of cyclists fatalities every year many caused by large vehicles turning left. The perception is that mirrors alone are not an answer.
- Areas obscured by aftermarket technology and other ancillaries such as satellite navigation systems and other screen based technology, stickers, tax disk holders, parking permits, driver possessions on the dashboard etc.
- The 'blind spots' of the left and right side mirrors that cover the area rearward of the driver but in front of the field of view of the mirror.
- The view of left or right side mirrors in articulated vehicles that become obscured when turning and the articulation of the trailer fills the field of view of the mirror.
- Many Category N_1 vehicles have poor mirrors for the nature of the vehicle with wide and tall rear boxes.
- Visibility of the nearside rear wheel of N_1 vehicles was considered to be poor.
- Small window apertures in vans, delivery vehicles and the like all contributed to blind spots.
- There was a perception that A-pillar sizes had increased, likely due to increased crash protection requirements and additional safety systems from

structural members and secondary protection such as air bags. Some larger passenger cars (M_1) had two A-pillars with the second one for mirror mounting.

- An observation is that there is a recent trend for the design of cars where the lines tend to drop much more towards the rear of the vehicle. This can impact on vision and whilst such cars meet required standards, this makes them unsuitable for some purposes e.g. driving test vehicles.
- Left hand drive vehicles in particular were perceived to be problematic and their blind spot a particular issue for overtaking vehicles. The Highways Agency are currently providing free Fresnel lenses to LHD vehicles.
- Grab handles can obscure mirrors.

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7 ACCIDENT SCENARIOS

This section describes the findings of existing reviews of accident data.

7.1 M_1

7.1.1 A-pillars

A study by Millington et al (2006) used real world crash data to construct 3-D visualisations to provide a graphical illustration of the obscuration caused by the car 'A' pillar. The real world crash data used in the study was obtained from the On The Spot (OTS) crash study. Out of 10 of the reconstructed accidents, 6 were found to involve varying degrees of A-pillar obscuration as a crash contributory factor. In four of these accidents, A-pillar obscuration was a causative factor. For these four accidents, the obscuration was equally attributed to the nearside and offside pillars i.e. two cases for each; all drivers were female (two were 95th percentile UK stature and one was 50th percentile UK stature) and the struck vehicles were cars (two cases) and motorcycles (two cases). It was found that A-pillar obscuration was significantly more likely to occur at T junctions and accidents where A-pillar obscuration was a factor were more likely to involve car drivers failing to see vulnerable road users such as motorcyclists, pedal cyclists and pedestrians. The project highlights that car A-pillar obscuration could be a contributory factor in some road traffic crashes.

7.1.2 B-pillars

Using North Carolina, USA, crash data for 2000–2003, Sivak (2005) compared the ratio of lane-change crashes to going-straight-ahead crashes for 10 vehicle models that have four-door and two-door variants. The ratio for four-door models (2,126:38,911) is 17% higher than the ratio for two-door models (740:15,898), a statistically significant result. This supports the hypothesis that lateral visibility related to the location of the B-pillar has an effect on safety, and specifically that four-door vehicles, which have the B-pillar located in a more forward position, tend to be over-involved in lane-change crashes.

7.1.3 Intersections

In a study by Cairney (1996) 30% of casualty accidents in Melbourne, Australia, were found to occur at arterial/local intersections. Cairney found that this was more than occurred at arterial mid-block locations and arterial/arterial intersections or on the entire local street system. Not seeing the other road user in time to avoid the collision was the most frequent failure identified. Of drivers, 69%-80% failed to see the other vehicle and 33% failed to see the object that they collided with. In most of these cases the driver looked in the appropriate direction but failed to see the other vehicle. In other cases, the view of the approaching vehicle was obscured by other traffic.

7.2 M_2

Refer to section 7.7 Composite vehicle categories.

7.3 M_3

Refer to section 7.7 Composite vehicle categories.

In addition, as part of a scoping report by White Willow Transport Intelligence (2006), STATS19 data for 2005 was analysed as part of a review to investigate side swipe accidents. It was found that there was only one accident involving a foreign coach side swipe. Whilst traffic flows are far less than for HGVs, coaches often have a courier who acts as a "spotter" for lane change manoeuvres. Due to the low volume of accidents, coaches were not considered further in this study.

7.4 N_1

No specific data was found for this vehicle category.

7.5 N_2

7.5.1 Overview

In a report by Jacobs Consultancy (2004) it was stated that HGVs were the main concern above LGV (light goods vehicles) and Buses and Coaches, due to HGV accident victims typically being dragged under the vehicle, increasing the severity of the accident. This is further exacerbated when the driver cannot see the victim at all. Conversely, the side of a bus is solid and victims are rarely dragged underneath.

APROSYS (2005) presents the development of an Aggressivity Index. The aim of the index is to be used as a computerised system for evaluating trucks and the level of potential danger they posed towards vulnerable road users. As part of the development of the Aggressivity Index, the authors had to determine a set of typical / representative accident scenarios under which to test and evaluate the trucks. The selection of the accident scenarios were based on Austrian in-depth cases, expert knowledge and results of publications and existing accident statistics. Eight key accident scenarios for HGVs were identified and are quoted below. (It should be noted that these scenarios reflect the practice of driving on the right and so need to be transposed to reflect UK practice).

- "HGV is moving towards crossing, adapts speed to cornering manoeuvre, and turns to the right. Bicyclist is moving in same direction like the HGV.
- HGV stopped due to certain reasons (traffic light, traffic jam etc.) starts moving turns to the right. Bicyclist is moving in same direction like the HGV.
- HGV is going straight at high speed. HGV starts overtaking manoeuvre, however maintains no sufficient distance to the pedestrian or bicyclist. Bicyclist/pedestrian is moving in same direction like the HGV.
- HGV is already overtaking, swings to the right (left respectively) due to oncoming traffic. Bicyclist is grabbed by the side guard (for example the handle bar). Can be caused by inexperienced bicyclist as well. Bicyclist is moving in same direction as the HGV.
- HGV stopped due to certain reason (i.e. traffic light/jam) and then pulls away. Pedestrian is crossing the road directly in front of stationary HGV.

- HGV is going straight at high speed. Pedestrian is attempting to cross the street, not seeing the oncoming HGV or misinterprets the situation.
- HGV is going straight at high speed on a highway and is passing a broken vehicle. For a certain reason (vehicle driving at the right side or pedestrian is standing on the right side of the lane) the pedestrian is grabbed by the HGV.
- HGV is moving backwards. Pedestrian attempts to cross stationary HGV at rear."

Research by Southall et al (1998) investigated the scope, causes and possible solutions to the problem of an insufficient or ineffective field of view for drivers of large vehicles in the context of accidents where heavy goods vehicles, buses and coaches collide with pedestrians, pedal cycles, motorcycles or other powered two-wheelers. The study obtained reports of 78 relevant truck accidents and 64 bus or coach accidents; of these 30 of the truck cases and 5 of the bus/coach cases appeared to involved driver vision. Explicit reference was made to blind spots in 6 truck cases, 3 of which were foreign, left-hand drive vehicles. The manoeuvres undertaken by the large vehicles at the time of the accident where field of view may have been relevant included reversing, turning (left), changing lane, negotiating roundabout, and moving straight ahead. The authors note that "deciding whether the accident was likely to have involved a driver vision element is somewhat subjective" based on the limited information in the accident reports. Surveys were conducted to fill the knowledge gap left by the accident data on the scope and detailed nature of the problem. This comprised a postal questionnaire of drivers, operators and manufacturers (61 returned of 258 sent) and interviews with drivers (34). This revealed problems of obscuration in all directions: immediately in front of the cab; direct vision to the left and right obstructed by mirrors, A-pillar(s) and other vehicle bodywork and interior fittings; indirect vision to the left or right due to wrong type, positioning, size or number of mirrors; and no direct rear view due to vehicle design or load. This affects a variety of manoeuvres, including turning, changing lanes, merging, roundabouts, pulling away for stationary position and reversing (Refer to Table 12). The surveys revealed relatively little information about attempts to rectify the problems.

Manoeuvre	Obscuration	Problem	Main causes
Turning right at T-junction.	N/S direct visibility.	Viewing traffic approaching from the left.	Transfers, notices and destination boards in driver's front 180° field of vision. Rubber safety strips on closing edges of bi-fold doors. N/S mirrors positioned at driver's eye level causing obscuration to direct vision.
Pulling in to lay-bys. Returning to left lane after overtaking.	N/S indirect rear visibility	Viewing traffic and other vulnerable road users on N/S.	Wrong type, positioning, size of rear-view mirror. Insufficient mirrors.
Joining a roundabout. Turning right at a junction.	O/S direct visibility	Viewing traffic approaching from the right	Large arrays of forward mounted, O/S, rear-view mirrors. A-pillars and side window division bars too wide.
Joining main road at Y-junction	N/S direct and indirect visibility	Viewing traffic approaching from left-rear of vehicle	Vehicle body work and/or passenger seating obscures vision over driver's left shoulder. Driver's low floor seating position in coaches.
Pulling away from stationary position i.e. traffic lights and give-way signs.	Immediate area forward of cab	Viewing pedestrians walking directly in front of vehicle.	High, rearward driver's seating position. High lower edge to windscreen. Steering wheel and dashboard facias protruding into cab front glazed area.

Table 12: Summary of field of view issues arising from drivers' survey

With effect from 17 July 2008, Rule 43 of the Coroners' Rules 1984 was amended to permit, amongst others, that:

- Coroners have a wider remit to make reports to prevent future deaths. It does not have to be a similar death;
- A person who receives a report must send the coroner a written response within 56 days;
- The Lord Chancellor may publish the report and response to any other person or organisation with an interest.

Under this last provision, a report covering Rule 43 reports issued by coroners between July 2008 and March 2009 was published (Ministry of Justice, 2009). Within this period, there were 207 inquests where Rule 43 reports were issued and of these six pertained to the category 'Road deaths – Vehicle safety'. Of these six reports: three concerned driver vision; one concerned driver education; one concerned vehicle stability and one concerned under run bars. The details of the three vision-related cases are summarised in the table below.

Coroner district	Report number	Details	Report sent to
Blackburn, Hyndburn and the Ribble Valley	47	To consider that all large goods vehicles and not just those registered since January 2007 should be fitted with a wide-angle front mirror to improve visibility.	Department for Transport
Avon	63	To consider providing a device on double decker buses to alert the driver of passengers stood on stairs.	First Bus, Bristol
London: Western	119	To consider that all large goods vehicles and not just those registered since January 2007 should be fitted with a wide-angle front mirror to improve visibility.	Department for Transport

Table 13: Rule 43 reports issued with respect to vision-related incidents

The Ministry of Justice report states that the majority of the 207 inquest reports that were issued were very specific relating to a local situation or organisations. It did however recognise that a few of the reports had wider implications and cited an illustrative case highlighting the issues relating to report numbers 47 and 119. The text is reproduced in the figure below.

Rule 43 report – Road deaths – Vehicle safety
Case details
An elderly pedestrian was killed by a tipper lorry when the driver drove over her at traffic lights as the lights changed to green. The design of the lorry meant the driver was unable to see if a pedestrian crossed immediately below its front.
Summary of correspondence sent to the Department for Transport
There was a blind spot if a pedestrian crossed within one metre of the cab. A front windscreen mirror had subsequently been fitted to the lorry but it was not compulsory if the lorry was manufactured earlier than January 2007. Legislation should be amended to make such mirrors compulsory whatever the date of manufacture of such lorries.
Summary of Department for Transport response
They agreed that the new European legislation was not retrospective. A new European directive was being introduced by end of March 2009 to install new mirrors on all large vehicles first registered from 1 January 2000. The benefits are much greater from side mirrors than front mirrors. The industry advises that front mirrors are often problematic to install on older vehicles due to vibration and cab damage. They will encourage installation of front mirrors wherever feasible, but are unable to change national legislation to require the fitting of front mirrors because of the constraints of European law in relation to vehicle construction.

Figure 34: Rule 43 summary report relating to field of vision inquest

7.5.2 Involvement with cyclist – UK overview

In 2009 Keigan reported on the analysis of 92 police files relating to fatal pedal cycle accidents that occurred in London from 2001 to 2006 with a view to identifying primary (pre-impact), secondary (impact) or tertiary (post-impact) interventions that could prevent these accidents or injuries. Improving the field of vision for drivers of heavy goods vehicles using mirrors was considered relevant in 15 accidents and improving the field of vision for drivers of heavy goods vehicles using sensors and camera/monitor systems was considered relevant in 25 accidents. These two groups do not necessarily total to 40 because a single accident may have several relevant interventions. The single most frequent collision type was a heavy goods vehicle, bus or coach turning or changing lane to the left and striking the pedal cyclist. Improvement of the field of view using mirrors or close proximity sensors was considered relevant in 9 and 20 of these 23 collisions respectively. The report recommends the retrospective fitting of Class V (close proximity) mirrors on heavy goods vehicles and the use of proximity sensors and camera/monitor systems to cover blind spots. The authors, however, caution that there is no research evidence that close proximity sensors work or would help to prevent collisions in London, noting that they could overload the driver with information and make the driving task too complex.

Fenn et al (2005) noted that there are, on average, in the UK 9 fatalities, 14 serious injuries and 33 slight injuries caused to pedal cyclists per annum, by an HGV of greater than 7.5 tonnes turning left.

The Metropolitan Police in supporting Transport for London produced a PowerPoint presentation entitled 'Cycling – The Fatal statistics 1999-2008' which noted that:

- 39% of cyclist fatalities in London involved a vehicle over 7.5 tonnes.
- Large vehicles accounted for 90 of 153 fatalities – refer to table below.

Vehicle involved	Number of fatalities
Motorcycle	3
Car or taxi	60
Light Goods vehicle	12
Heavy Goods Vehicle	9
Heavy Goods Vehicle >7.5 t	60
Bus or coach	9
Total	153

Table 14: Metropolitan Police Fatal statistics data 1999-2008 – Cyclist fatality by vehicle category

- From April 2006 to March 2007 there were 429 cyclists seriously injured in Greater London with around 15% being very serious i.e. life changing.
- There is a high percentage of female cyclist fatalities involving HGVs (52%), however there is a higher male percentage in fatalities involving cars.
- 27 out of 31 fatal collisions involving female cyclists and HGVs were at junctions (22 with HGV turning).
- The number of cyclists on the Capital's streets has almost doubled since 1999.
- In peak hours cyclists can account for up to 40% of traffic.
- March appears to be the worst month statistically (possibly down to the increase in the number of cyclists as weather improves but is still dark in late morning and early evening).
- Weekdays, between 0800 – 0900 hrs, are peak times for cyclist fatalities.

The data also indicate that the top causes of injury to cyclists as those resulting from:

- Going down the nearside of large vehicles may result in fatal or life changing injuries.
- Vehicles changing direction - turning right, left and changing lane.
- Opening doors of vehicle into the path of a cyclist.
- Cyclists failing to conform to traffic lights.
- Cyclists on the nearside of HGV at junctions when the vehicle turns left.
- Cyclists entering road from pavement, including cycling across pedestrian crossings.

The 'Cyclist and lorries' fact sheet produced jointly by RoSPA and Cemex (RoSPA 2006) noted that in 2004, '367 collisions between HGVs and cyclists resulted in 22 riders being killed, 79 seriously injured and a further 262 injured. Although only 2% of cyclists' casualties occurred in collisions with HGVs, this resulted in 22% of cyclist deaths. The vast majority of these collisions occur in built-up areas, even though 75% of HGV mileage is on non built-up roads. There is a particular concentration in London; about one fifth of the fatal HGV/Cyclist crashes in Great Britain occur in the capital. Almost one third of the cyclists killed in London, die in a collision with a HGV. The problem is especially acute in inner London'. The three main types of collision between pedal cyclists and HGV's, accounting for about three-quarters of the pedal cyclists killed in these crashes, are:

- HGV Turning Left across path of Cyclist.
- HGV and Cyclist Turning Left.
- HGV Overtaking Cyclist.

7.5.3 HGV turning left cyclist travelling straight on

In 2005 a total of 41 cyclists were killed and 1,287 were injured on Danish roads. Of these, 11 and 27 respectively resulted from HGVs turning right (equivalent to left in the UK) and cyclist travelling straight on. About a quarter of all cyclists' accidents occur in this type of scenario (Road Safety and Transport Agency undated). The Danish Road Accident Investigation Board (HVU) conducted an in-depth analysis of these types of accidents. Data was collected over an eight month period in 2005. During this period 25 HGV and cyclist accidents in this type of scenario were recorded and investigated in detail. The Danish report gives a summary of the key findings relating to these types of collisions. It was reported that probable causes include:

- Lack of awareness of presence of cyclist - inattentiveness,
- Not using mirrors and windows effectively or looking at these at the wrong time, or
- Had checked mirrors but not typically the close proximity of blind spot mirrors.

The report proposes that the multitasking that is required in driving an HGV is beyond human perceptual abilities. Additional contributory factors noted included:

- Distractive tasks e.g. Reading maps,
- Road works,
- Defective traffic signals,
- Tiredness.

Fenn et al (2005) reviewed STATS19 data for accidents involving HGVs and cycles/motorcycles from 1994 to 1998 and 1999 to 2001. Data showed that the risks to cyclists in this type of accident, (HGV turning left), is high. Data showed that vehicles greater than 7.5 tonnes form 64.9% of the goods vehicle fleet but are involved in 82.3% of the injury accidents to pedal cyclists when the HGV is turning left. On average in the UK 9 fatalities, 14 serious injuries and 33 slight injuries are caused to pedal cyclists per annum, by an HGV of greater than 7.5 tonnes turning left. Over 1994 – 2001 the fatality rate was 12% and the killed or seriously injured (KSI) rate was 36.5%. This is high when compared with the 17.6% for all HGV accidents, and is even higher than that of a car to HGV frontal collision which has a KSI rate of 28.6%. The analysis of the accident data also showed that when an HGV is turning left it is more likely to be involved in an accident with a pedal cycle than a motorbike. This follows the pattern that a pedal cycle is more likely to undertake the HGV if the HGV is slow moving or stationary before turning left. The majority of accidents involved a pedal cyclist older than 16. Fenn et al (2005) suggest that the cyclist would therefore have been aware of the dangers presented by everyday traffic and of the possibility of HGVs turning left at junctions.

7.5.4 Turning left at a junction

Fenn et al (2005) reviewed 'Heavy Vehicle Crash Injury Study' (HVCIS) data from 1994 to 1996. Analysis was conducted on fatal accidents and involved at least one HGV. Accidents were then identified where it was thought that poor visibility along the nearside may have contributed to the accident. Included in HVCIS data is an assessment of potential safety improvements to the vehicles involved in the accidents and their effectiveness. The assessment is partially subjective, based on available data and a comprehensive set of guidelines. For this analysis the safety improvement that was considered was "improve side vision". Improve side vision could either apply to improving the Class IV or V mirror (and presumably other technologies also). The analysis found that for vulnerable road users, there were 95 cyclist or motorcyclist fatalities and 101 pedestrian fatalities. When a subset of these accidents where the HGV was turning left or changing lane to the left were considered, it showed that there were 29 fatalities (17 pedal cyclists or motorcyclists and 12 pedestrian fatalities). Sixteen of these 29 accidents (55.2%) involving vulnerable road users were considered to have been preventable by improved side vision. Additionally it was noted that none of these cases involved an HGV with a gross weight of between 7.5 and 12 tonnes. The cases involved N_1 vehicles and only N_2 vehicle that were less than 7.5 tonnes.

Southall et al (1998) showed that two thirds of accidents occur when an HGV is turning left at a junction, highlighting the blind spot immediately to the nearside of the vehicle.

7.5.5 HGV turning right, motorcycle overtaking

Fenn et el (2005) reviewed STATS19 data for accidents involving HGVs and cycles/motorcycles from 1994 to 1998 and 1999 to 2001. Data showed that when an HGV is turning left it is more likely to be involved in an accident with a pedal cycle than a motorcycle. However when turning right, the vehicle most commonly involved is a motorcycle greater than 125cc. This follows the pattern that a pedal cycle is more likely to undertake the HGV if the HGV is slow moving or stationary before turning left, whereas a motorcycle is more likely to be overtaking the traffic when the HGV is turning right.

7.5.6 HGV overtaking another road user travelling straight on

Fenn et el (2005) reviewed STATS19 data for accidents involving HGVs and cycles/motorcycles from 1994 to 1998 and 1999 to 2001. One of the findings was that when overtaking, the HGV strikes the cycle, most probably with the latter section of the HGV. Fenn et al report that this may be because the driver may have been using their Class IV (Wide angle) mirror but misjudged the length of HGV when compared with the location of the other road user, or that the HGV overtook in a hurried manner, misjudging the speed of on-coming traffic and then pulled in too quickly causing a collision with the cyclist.

7.5.7 HGV failing to see a cyclist as the HGV enters a major road or roundabout

Analysis by Fenn et al (2005) showed that one common accident was the HGV failing to see a cyclist as the HGV enters a major road or roundabout. For two thirds of accidents the cyclist struck the side of the HGV. In most of these cases it was suspected that the driver of HGV caused the accident by not using their mirrors correctly.

7.5.8 Changing lane – Side swiping

"Side swipe" accidents, are where a HGV collides (or has a near miss) with another vehicle, often a private car, as it changes lane. As part of a scoping report to examine this problem White Willow Transport Intelligence (2006) analysed and reviewed STATS19 data for 2005. It was reported that there were 5439 side swiping accidents involving all vehicle types and nationalities. Truck side swipes accounted for only around 20% of all side swipe accidents. In the same review it was found that 300 accidents were caused by a vehicle moving to the left and 325 by vehicles moving to the right, with 74 through overtaking. This suggests that accidents may also occur on the left side for UK LGVs – for example, when a LGV goes through a junction where a lane is added. It may also occur in areas where congestion – or motorway lane control signing - causes all lanes to move at the same speed and hence the blind spot become occupied for a UK vehicle.

In the same report, US accident data was also reviewed and found that there was little evidence of the proportion of side swipes caused by vision problems but US data suggests that between 60% and 80% are vision related. Of these, perhaps 60% are caused by true blind spots; 20% are caused by drivers being overloaded by the number of mirrors and places to watch and the final 20% are perhaps caused by unplanned lane changes, due to fatigue, etc.

The report states that previous US and UK work has highlighted that accidents may occur during:
1) A deliberate and planned lane change manoeuvre, where the vehicle swiped was not seen due to a blind spot, even though the driver actively looked for vehicles;
2) A deliberate lane change but where the driver did not look properly (for reasons of tiredness etc) but there was no blind spot; or
3) An unplanned lane change due to high winds, other vehicle actions, narrow road geometry or fatigue.

This report cites findings from studies by Kent police that supports the theory that fatigue might be a contributory factor in side swipes and that there are other factors involved. This report concludes that reducing the blind spot may not fully remove the side swipe problem.

Blower (2007) defines accident scenarios in the USA in which a truck driver is likely to need mirrors to manoeuvre safely and examines their frequency in the UMTRI 'Trucks Involved in Fatal Accidents' file (TIFA) and in the National Automotive Sampling System (NASS) General Estimates System file (GES) for the years 1994–2000. The relevant crash types include merging, changing lane, turning, backing (reversing) and starting up. These constitute 19.7% (75,102) of all truck crashes (381,675) on the TIFA-GES databases with backing (26,621, 7.0%) and changing lane or merging to the right (25,828, 6.8%) the most frequent individual mirror-relevant types. Changing lane or merging to the left (5,867, 1.5%) was significantly less frequent than to the right and the same applies to turns, indicating that drivers have trouble in manoeuvres to the passenger-side. The Federal Motor Vehicle Safety Standard FMVSS 111 requires only that there be a planar mirror on each side of the cab with an area of at least 323cm^2. In practice many truck operators supplement these with convex mirrors on the doors and on the fender or hood (bonnet) to fill in front blind zones. The field of view for a particular truck is measured, revealing a blind zone beside the cab on the passenger-side large enough to obscure a car if no convex mirror is mounted to the hood or fender. In conjunction with the accident data, this suggests a safety problem that could be addressed by improved mirrors.

7.5.9 Left hand drive HGVs

It is argued that left hand drive (LHD) vehicles are not designed for use on Britain's roads and as a result blind spots can be larger than with British vehicles. ROSPA (2007) report that this factor is most pronounced when the vehicle has other road users coming up the off-side or when turning right. The danger of blind spots is highlighted by the 2005 DfT figures which showed that in 32% of the collisions involving LHD HGV's, "vehicle blind spot" was found to be a contributory factor.

Fenn et el (2005) reviewed accidents involving left hand drive vehicles by analysing accident data from Kent police for the periods: 1997-1998 (12 month data collection); 2000 (6 month data collection) and 2003-2004 (6 months data collection). They found:

<u>All data – 1997-1998; 2000 and 2003-2004.</u>

- Side swiping / lane changing accidents (damage only and injury) occur: 1 every 2.44 days in 1997-1998, 1 in every 1.82 days in 2000 and 1 every 1.57 days in 2003-2004.
- Virtually all of the HGVs involved in side swiping accidents in the Kent police jurisdiction involve foreign registered, left hand drive vehicles. These vehicles are likely to have a higher accident risk due to the difficulties with viewing surrounding traffic at an appropriate time before and during any lane change manoeuvre.
- It is likely that the number of side swiping accident will increase following the trend of increasing numbers of foreign registered goods vehicles visiting the U.K Non-UK registered powered good vehicles visiting the UK were: 730,200 in 1998; 1,060,600 in 2000 and 1,340,700 in 2003. This equates to an increase of over 83% in 6 years. (Taken from a Department for Transport report in 2004 entitled Road goods vehicles travelling to mainland Europe: Q3).

<u>Data for 2003-2004.</u>

- 117 accidents reported as side swiping / lane changing. Of these, 30 were injury accidents including a total of 42 causalities.
- The majority of accidents occurred on the main motorway network which is perhaps unsurprising as this carries the highest density of HGV traffic.
- Of the 117 accidents it was found that 31 occurred within 300 metres of a junction and that the majority of these (19) occurred at the 'on slip road'.
- The report proposes that this may be due to the foreign registered vehicles having to change lanes at short notice, either as they approach a junction, or as the other vehicles join the motorway from the slip road forcing them into the next lane. Alternatively the foreign registered HGV may be attempting to overtake vehicles that have not yet reached motorway speeds.
- Analysis of the time of day shows that accidents were more frequent during the rush hours.
- In the majority of accidents, 79% of HGVs were fitted with a Class V mirror which suggests either the passenger vehicle struck was genuinely in a blind

spot or that the HGV driver was not using their mirror appropriately, if at all. It was not recorded if the mirror was correctly adjusted.

- It is possible that the drive type of the vehicle combined with the driver's potential unfamiliarity with the road network may be a more important contributory factor to accidents than Class V mirror fitment. Fatigue may also be a factor.

Fitch (2007) conducted a study to measure accident data before and after the issue of free Frensel lens to LHD HGVs . Prior to the distribution of the lenses a total of 401 incidents were reported over the 13 week data collection period which equates to 31 incidents per week. An analysis of the data showed the following:

- LHD HGV incidents accounted for 92% of the total (368 incidents);
- 341 of these (85% of all incidents) were attributed to side swipes (all HGVs were moving from left to right);
- There was an average of 26 LHD side swipes per week;
- RHD HGV incidents accounted for 8% of the total (33 incidents).

The findings of the White Willow Transport Intelligence study (2006) which reviewed UK STATS19 data for 2005 are shown in the table below.

There were 1163 injury side swipe accidents . . .	
. . .of these 464 involved foreign registered trucks (40%).	. . . of these 699 involved UK vehicles (60%).
Foreign registered vehicles were not involved in any accidents resulting in a fatal injury.	UK vehicles were involved in 6 accidents resulting in a fatal injury.
Foreign registered vehicles were involved in 20 accidents (1%) resulting in a serious injury.	UK vehicles were involved in 39 accidents resulting in a serious injury.
Foreign registered vehicles were involved in 434 accidents (20%) resulting in a slight injury.	UK vehicles were involved in 654 accidents resulting in a slight injury.
Total accident costs amounted to £15 million.	Total accident costs amounted to £33 million.

Table 15: Comparison of foreign and UK registered vehicles involved in injury related side swipe accidents

The study calculates that side swipe accidents accounted for around £48m of the total UK accident cost of around £18b in 2004 (less than 0.3%), with foreign vehicles accounting for about 0.1%, thus implying that these accidents are not as significant a risk to UK road safety as might be believed from media coverage.

However, given the exposure of foreign vehicles on UK roads (4%), the higher relative proportion of side swipe accidents (40%) for LHD LGVs suggests that side swiping accidents require further examination. The authors note that there were 14 injury accidents involving a LHD truck moving to the left but 392 when the LHD truck moved right where there is known to be a blind spot, in spite of new mirror provision to meet the EU Directive.

The study also confirms that side swiping is not purely a UK phenomenon.

- Blind spot problems in urban areas within mainland Europe has led to the introduction of Class V mirrors;
- US data – where overtaking is allowed on both sides – suggests a significant side swipe problem with 826,000 incidents per year involving all types of vehicle and around 1% fatalities. The US DoT estimates that 35% of truck related accidents occur in blind spots and, in conjunction with the US trucking industry, have started a high profile driver education campaign.

The study by Anslow (2004) sought to identify the characteristics of heavy goods vehicles and their involvement in accidents using the national accident database STATS19 (1997–2001) and by detailed analysis of selected site locations. The contribution to the overall level of personal injury accidents from foreign heavy goods vehicles is reported as both limited and variable by route. 'Blind spot' is a contributory factor for these HGV drivers but "reporting tends to be variable". The contributory factors system, however, was only recorded by some police forces during the years covered. In the absence of sufficient data, the report suggests that ineffective fields of view from large vehicles (front, side and rear) are "likely to play a part in lane changing incidents, especially on motorways and dual carriageways and those involving left-hand drive vehicles". A survey of 83 accidents, over a seven-month period in 2003 in the Cheshire area, that involved a left-hand drive heavy goods vehicle concluded that many drivers experience difficulties manoeuvring their vehicles in UK driving conditions, particularly changing lanes, despite a high incidence of various supplementary mirrors.

The report by Danton et al (2008) into left-hand drive HGVs and foreign truck drivers used UK national accident data and in-depth accident data (On the Spot crash data (OTS)) to investigate the causes of accidents involving heavy goods vehicles with a special focus on foreign, left-hand drive vehicles. It found:

- The national accident data STATS19 (2006) highlights 'vehicle blind spot' as a contributory factor in 36% of 722 foreign-registered, left-hand drive HGVs for whom at least one contributory factor was attributed. This compares with 7–8% of 4,914 other HGV drivers and about 1% of car drivers.
- The in-depth accident database, On-the-Spot (OTS, 2000–2008) identifies 65 left-hand drive HGVs and 250 right-hand drive HGV accidents. Differences are noted in the:
  - collision classification code - 'Overtaking and lane change' (67% for left-hand drive, 20% for right-hand drive),
  - precipitation factor - 'Poor turn or manoeuvre' (49% for left-hand drive, 16% for right-hand drive),
  - contributory factor - 'Vehicle blind spot' (76% for left-hand drive, 6–7% for right-hand drive),
  - interaction code - 'Looked but did not see, due to vehicle geometry' (80% for left-hand drive, 9% for right-hand drive).
- These results are associated with a large blind spot on the passenger side on HGVs which, in the case of left-hand drive vehicles, restricts the truck driver's view of typically faster moving vehicles in right-hand lanes.
- Several potential confounding factors are mentioned: left-hand drive HGVs in the in-depth accident sample were about twice as likely as right-hand drive HGVS to be on a motorway (59% v 25%), in a 70 mph zone (64% v 34%), and to be articulated (89% v 43%).[2] The report does not contain detailed descriptions of the mirrors fitted to the HGVs or specific measurements of the field of view.

7.6 N_3

Refer to N_2.

[2] Some of the percentages in this summary are estimated from graphical figures presented in the report.

7.7 Composite categories

A paper by Mosedale (2003) reports on a trial of the contributory factors system by fifteen police forces in Great Britain from 1999 to 2002. The system allowed for coding of one precipitating factor that led directly to the accident and up to four contributory factors that record reasons why the accident happened. None of the 15 precipitating factors can be related directly to vehicle blind spots; however 'Failed to see pedestrian or Vehicle in blind spot' was registered as a contributory factor in 2% of all accidents.

In a study by Brown (2005), one aim was to evaluate whether the reported problem of 'Looked but failed to see' represents a genuine psychological phenomenon of attention, perception and cognition. The error committed by drivers who look in the right direction but fail to see a vehicle or other road user who is temporarily obscured is more accurately classed as a "failure to appreciate obscuration of potential hazards". This falls outside of the criteria for 'Looked but failed to see' errors used in the report because the obscured road user was not in the driver's visual field. Data from a trial of the contributory factors system by 13 police forces in England and Scotland in 1999 revealed that factors related to obscuration constituted 4.6% (5,043) of the total 110,362 contributory factors registered. Among the obscuration factors, 'Blind spot' (980, 19.4%) was the third most frequent factor after 'Parked vehicle' (2,190, 43.4%) and 'Sun glare' (1,045, 20.7%).

7.8 Consultations

The consultations highlighted the following scenarios that were considered problematic for various categories of vehicles:

- HGVs manoeuvring in urban areas, in particular turning left from stationary or whilst moving along, turning right across a junction, or proceeding straight on at a junction. All of these have visibility issues around the cab; particular concerns are the area immediately in front of the HGV and the front quarters.
- HGVs in particular, but not restricted to those vehicles, changing lane.
- Articulated HGVs on roundabouts.

- Reversing.
- Any situation where vulnerable people are around the vehicle ranging from reversing on driveways to turning left at an urban junction.
- Left hand drive vehicles in the UK at roundabouts that have to orientate themselves facing right to essentially begin a manoeuvre turning left.
- Vehicles towing that then require additional mirrors to be fitted.
- Field of vision was considered still to be an issue for large vehicles and particularly left hand drive (LHD).
- It was noted that on-site driver vision was much better controlled. Whilst driver vision was still an issue the control of the environment played a big part in safety and the avoidance of accidents, so one way systems, high visibility clothing, segregation of vehicles and pedestrians, were all useful measures.

Intentionally Blank

8 SOLUTIONS – VEHICLE DESIGN

8.1 M_1

8.1.1 A-Pillar assessment methods

The study by Millington et al (2006) noted that the EC directive assesses A-pillar obscuration in a new vehicle using 50th percentile driver data. It suggests that consideration should be given to the use of greater and lesser percentile values to better represent both larger and smaller drivers.

8.1.2 A-pillar design

In a study by Kinoshita (2007) elimination of a blind spot due to the front pillar (A-pillar) was studied. It was considered that the front pillars may be made to appear transparent by making the width of the structures less than the driver's intra-ocular distance (the distance between the driver's right and left pupils). A substantial reduction of the cross section of front pillar could be achieved without degrading the cabin strength by changing the material and plate thickness of the pillar and employing a new method of fastening the front windshield.

8.2 M_2

8.2.1 Maximise glazing

Research by Tait and Southall (1998) investigated the possible solutions to the problem of an insufficient or ineffective field of view for drivers of M_2 and M_3 vehicles. Manufacturers' suggested engineering solutions included extending the windscreen and glass panelling of the doors downwards to give a better close proximity view of the immediate outside area of vehicles.

8.2.2 Binnacle intrusion

In the same study by Tait and Southall (1998), three coaches and one bus were found to have limited fields of view to the area immediately in front of the vehicle giving rise to the potential for accidents with crossing pedestrians. It was proposed that 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 binnacle (display unit). The CAD investigation of improvements to direct frontal fields of view demonstrated that without the binnacle being present the immediate frontal field of view was improved – refer to Figure 35.

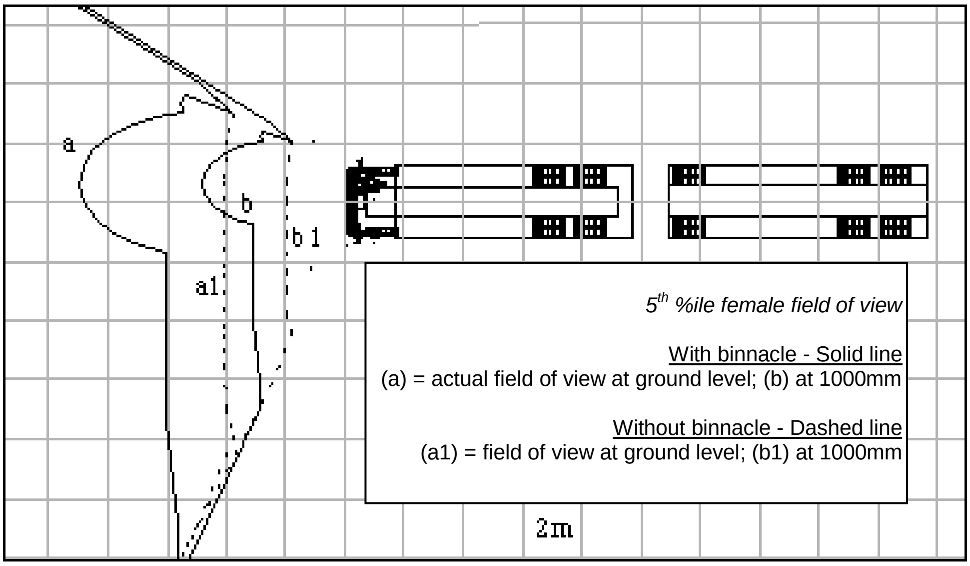

Figure 35: Improvements to the drivers forward field of view when the binnacle is removed

8.3 M_3

Refer to M_2.

8.4 N_1

No specific data was found for this vehicle category.

8.5 N_2

Refer to M_2.

The Danish proposal for direct vision in Heavy Goods Vehicles N_2/N_3 (Road Safety and Transport Agency undated) proposed a set of recommendations for design changes which included: a low-level window to the right (near-side); a low level window screen and, for those large vehicles with high driver's cabs, there should be restricted access to urban areas. It also suggested that low forward mounting of the cabin would be beneficial to increase visibility from the vehicle but noted that this would typically result in longer HGVs to maintain the same volume as previously without a lower cabin. Lowering the cabin can also have an effect on the driver; in a study by Yamanaka it was noted that drivers became fearful when driving on expressways if the lower part of their field of view was increased too much (Cited in Shiosaka 1995).

Daigo (1982) evaluated two different design improvements with 19 vehicles:

1. Supplementary windows.
2. Low-floored cab which improves field of view by lowering eye height.

Static and dynamic visibility tests were conducted and found that both types of improvements significantly improved field of view in empirical and subjective tests.

8.6 N_3

Refer to N_2.

9 SOLUTIONS – EQUIPMENT/HARDWARE AIDS

9.1 M_1

eSafety is the term used to define all vehicle-based electronic safety systems which aim to improve road safety through risk exposure reduction, crash avoidance and injury and death reduction. It utilises crash avoidance technologies that protect car occupants by informing, advising and alerting the driver with regard to hazardous situations and assisting them in their avoidance (eSafetyAware! Undated). The paper recognises that a multitude of eSafety technologies are available but that market penetration needs to be encouraged if the full safety benefits are to be obtained.

9.1.1 Blind spot monitoring system / Lane change assistant

The eSafety background paper produced by eSafetyAware (undated) aims to promote a wider understanding of five safety systems that offer significant potential benefits and that are at an advanced stage of development; amongst those reported is a blind spot monitoring system. The purpose of this system is to reduce the potential for collision with a vehicle in an adjacent lane by continuous monitoring of the blind spots to the vehicle's side and so support drivers in lane changing activities. The system uses radar, camera or ultrasonic technologies to monitor its vehicle's blind spot areas and issues a warning if an object is detected in close proximity to the vehicle. Systems vary in terms of the size of vehicles they can detect, the ambient lighting conditions which they can detect them under, the vehicle speeds they need to respond to and the form of warning given to the driver. At the European level, the eIPACT project analysed the Lane Change Assist system and estimated that 975 fatalities and 2,100 injuries could be saved annually if all cars within Europe were fitted with the system (eSafety undated).

The Audi 'Side Assist' system uses a radar based detection system to analyse the blind spot region on both sides of the vehicle. The driver, when they have specified an intention to change lane through activation of their indicator, is informed of any intrusion into it via a flashing LED light in the exterior mirror – Refer to Figure 36 (Cook et al, 2007).

Figure 36: Audi side assist system – external mirror with LED warning
http://www.autoblog.com/2006/03/21/video-animation-of-audi-s-trick-side-assist/

9.1.2 Lane departure warning systems

These warning systems are used to alert the driver if their vehicle is unintentionally leaving its lane. The system monitors the lane markings and if these are crossed and the driver has not signalled an intention to change lanes, a warning is given (eSafety undated). Whilst such systems do not address driver vision issues, they may help to reduce the number of accident attributed to blind spots since they result in the same scenario for the overtaking driver i.e. that of the driver they are overtaking inappropriately pulling out in front of them.

9.1.3 Cooperative communication systems

Inter-vehicle communication systems enable vehicles within sufficient proximity to exchange information about their speed, positioning, heading and vehicle type. This information is conveyed to the driver who is then alerted if a collision is predicted (Bayly et al 2006 cited in Cook et al, 2007). Application areas include:

- Junction negotiation - Honda's third-generation ASV system exchanges positional data (GPS) and dynamic data (speed, acceleration, yaw rate) between vehicles in order to prevent detection failures with its principal focus on avoiding intersection accidents. When the vehicle has come to a stop the system detects the position of the approaching vehicles, assisting the driver and motorcyclist in determining whether it is safe or not to proceed through the intersection – Refer to figure below (Cook et al, 2007).

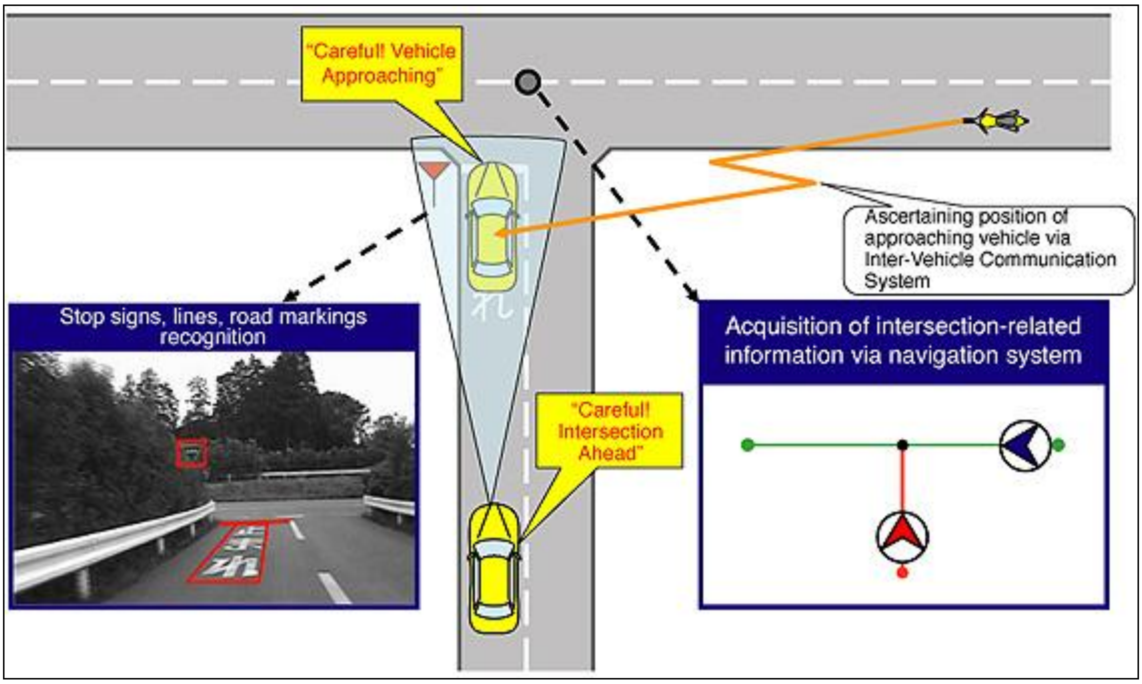

Figure 37: Motorcycle and automobile communication at T-junction
http://world.honda.com/news/2005/c050902.html

- Merging traffic – CarTALK 2000 started in August 2001 as a three-year European research project focussing on new driver assistance systems which are based upon inter-vehicle communication. The main objectives were the development of co-operative driver assistance systems on the one hand and the development of a mobile ad-hoc radio network as a communication platform with the aim of preparing a future standard on the other hand. One of the application clusters of CarTALK 2000 relates to 'Co-operative Assistance Systems' - a typical scenario for which is the highway entry and merging scenario. By exchanging information relating to simple trajectory plans, critical situations can be foreseen and solved by the vehicles themselves (Cook et al, 2007).

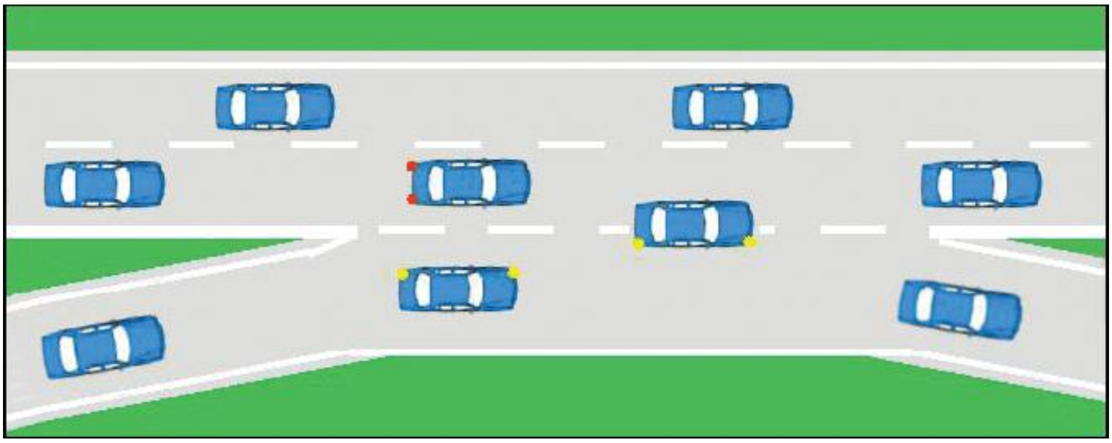

Figure 38: Illustration of CarTALK co-operative assistance system scenario

9.1.4 Adaptive lighting

The aim of adaptive lighting is to provide greater illumination of the road ahead in the dark through automatic adjustments to accommodate speed, gradient, curves, intersections, high/low beam settings, etc. There are different forms of adaptive lighting including:

- Dynamic curve illumination - Based on factors such as vehicle speed, steering angle and yaw rate, the changes needed to provide improved illumination of the road ahead are calculated and adjustments made by electronically pivoting the headlight module. In this way the system is able to anticipate bends in the road ahead and alter the vehicle's light distribution to accommodate them.

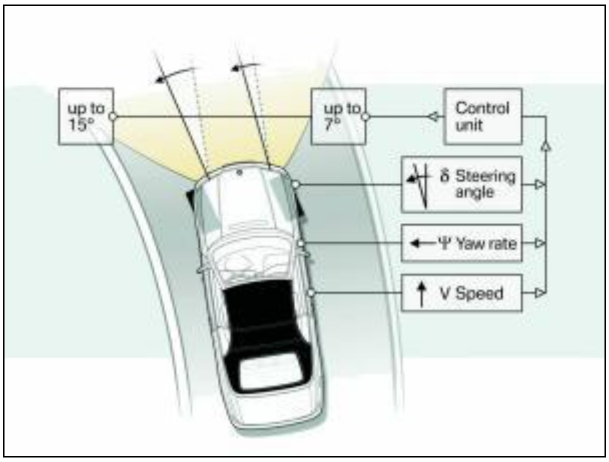

Figure 39: BMW adaptive front lighting
http://www.bmwworld.com/technology/lighting.htm

- Turning light – In a system developed by Audi, an additional headlight is located in the headlamp unit between the dipped and main beam lights. When the dipped beam is on and the vehicle speed is less than 40mph, the turning light is activated when the indicator is used or there is a significant change in steering angle. The light emitted assists the driver by placing more light in the area of the turn.

9.1.5 Vision Enhancement Systems

Whilst such systems use different forms of sensors and different display technologies, their shared aim is to enhance the drivers' night-time vision and so improve the safety of night driving. Some systems can extend vision up to five times thereby giving the driver increased time to react and some can be used to initiate automatic action by the vehicle (Gregoriades 2006 in Cook et al, 2007). The first Night Vision system introduced in the US market in year 2000 on the Cadillac DeVille is based on an infrared camera and head-up display which depicts a thermal image of the front scene in front of the driver (Saroldi and Bianco 2003 in Cook et al, 2007) – Refer to Figure 40.

Figure 40: Night Vision system on Cadillac Deville
source: www.cadillac.com

9.2 M_2

9.2.1 General

Research by Tait and Southall (1999) investigated the possible solutions to the problem of an insufficient or ineffective field of view for drivers of M_2 and M_3 vehicles. Operators commented on systems used to try and overcome vision problems which included: additional mirrors, remotely operated mirrors, obstacle detectors and camera/monitor systems; however drivers believe that increased mirror size would be more of a hindrance than benefit by causing direct visual obscuration.

At the end of the study, the following recommendations were made for bus and coach vehicles:

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

For buses only:

- Fit a two-camera/monitor systems with one camera to monitor directly behind the vehicle and one to monitor the near-side of the vehicle. The monitor should be mounted in the cab so that the driver's line of sight to it is close to that of the off-side mirrors.
- If the structure of the bodywork permits, fit Class IV wide-angle mirrors below the near-side and off-side rear-view mirror such that the minimum mounted height is 2m.

For coaches only:

- Fit Class IV, wide-angle mirrors below the near-side and off-side rear-view mirrors such that the minimum mounted height is 2m.
- Mount all near-side mirrors forward of the A-pillar so that they can be viewed through an area of the windscreen swept by the windscreen wipers.

9.2.2 Crossview mirrors

A study by Lemay et al (1998) assessed a driver's field of view and the performance of six crossview and two sideview mirror systems on a conventional long-nosed school bus. (A crossview mirror was defined as 'a convex mirror installed on one or both front corners of a bus to provide a seated driver with a view to the front and side'). It also conducted an evaluation of the image quality of the crossview mirrors in terms of the angular length and width of their reflected images. The results demonstrated that none of the crossview mirrors on the conventional long-nosed bus performed adequately in that they did not eliminate the blind spots nor provide good quality images to the front and sides of the bus. Furthermore, no crossview mirror reflected all the visual targets along the rear axle, and where they were viewed, the image quality was not always acceptable. The Double Nickel sideview mirror system, which is composed of one pair of flat and one pair of convex mirrors, had a narrower field of view than the mirrors installed by the bus manufacturer. Although the image quality of the sideview mirror systems was not formally evaluated, the Double Nickel had better image quality.

To help drivers detect children in front of and along the sides of the bus, the Federal Motor Vehicle Safety Standard (FMVSS) 111 of the National Highway Traffic Safety Administration (NHTSA) established two requirements for object visibility and discrimination within crossview mirrors (Cited in Vincent 1997). The first requirement mandates that the separation between the image's edge and the mirrors edge be at least three minutes of arc (i.e., 3'). The second requirement is that the minimum angular size of a retinal image of an object be at least 9' X 3' minutes of arc.

9.3 M_3

Refer to M_2.

9.4 N_1

No specific data was found for this vehicle category.

9.5 N_2

9.5.1 General

White Willow Transport Intelligence (2006) on behalf of the Department for Transport conducted a review of various accident databases to examine the issue of side swipes. In the final conclusions of this report suggestions for future research are put forward specifically aimed at addressing the side swipe problem. They state that technology is already available in the UK that could address at least some of the side swipe problem. Hence, research is not required to develop this technology but to exploit and foster its safe use, but with an eye to the relatively small scale of the problem. The scoping report recommends that DfT should:

- Look at the wider business case of vehicle blind spots, not just side swipes and for all types of situation, including UK and foreign businesses and society alike;
- Link with other research, notably in the Netherlands, to make the most of experience elsewhere in fitment of technology and in driver education;
- Establish and promote a business case to UK operators for them to invest in such technology;
- Encourage safe fitment of cameras in line with the European Statement of Principles for such technology and review older UK legislation to reduce driver distraction issues; and
- Ensure UK industry considers cameras as a potential solution for mirror retrofitting.

Research by Tait and Southall (1999) investigated the possible solutions to the problem of an insufficient or ineffective field of view for drivers of N_2 and N_3 vehicles. Manufacturers suggested:

- positioning mirrors to the requirements of European Directive 71/127/EEC;
- maximising the glazed area of the cab;
- minimising intrusive items, e.g. sun visor, sun blinds, binnacle profile;
- using remotely operated mirrors and/or heated mirrors;
- using obstacle detectors (close proximity warning beeper, for reversing) and camera/monitor systems.

At the end of the study, the following recommendations were made for both articulated and rigid vehicles:

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

For articulated vehicles only:

- Fit an additional Class IV, wide-angle mirror to the off-side of the vehicle, mounted below the Class II, rear-view mirror (the wide-angle mirror currently fitted to the near-side should also be mounted below the Class II, rear-view mirror) such that the minimum mounted height is 2m.

For rigid vehicles only:

- Fit Class IV, wide-angle mirrors below the near-side and off-side rear-view mirrors such that the minimum mounted height is 2m.
- Fit a Class V, close-proximity mirror to the near-side.

9.5.2 Mirrors - General

Fenn et al (2005) cites Satoh et al (1982) which reports that the introduction of additional mirrors can provide an increase in the field of view but their design can alter the size and level of distortion of visible objects.

The Danish proposal for direct vision in heavy good vehicles N_2/N_3 (Road Safety and Transport Agency undated) reports that new rules introduced in 2004 which included: mounting an extra mirror (a blind spot mirror); using mirrors with greater curvature or mirrors with larger mirror area and mounting a camera, were found not to have affected accident patterns. It proposes that:

- Mirrors should have a position so high up and so far away from the corner of the cab unit that they allow a free field of view below and on both sides of the mirror housing;

- Mirrors need to be simple and easy to adjust;
- Lorry mirrors should comprise a single mirror unit that can be viewed in one glance. A maximum of three lorry mirrors should be allowed and they should be mounted on a single extended arm, which allows the driver to check all at once by looking in one direction. New research should focus on the driver's capabilities to judge the traffic situation by means of windows, mirrors and cameras.

Flannagan et al (1997) discuss the implication for using mirrors with large radii over 2m. They highlight the need to understand the effects of mirror curvature on drivers' perceptions of distance and speed, quoting that previous data offer empirical evidence about the effects of mirror radii up to 2m. The evidence indicates that distances are overestimated, and that overestimation is still substantial at a radius of 2m. They conclude that 'Given the current practical interest in mirrors with radii above 2.0 m, the lack of empirical evidence above 2m, and the theoretical uncertainty caused by the substantial violations of the visual-angle model, it seems worthwhile to conduct further empirical work using mirrors with radii over 2.m'.

Tait and Southall (1998) conducted trials to investigate different aspects of mirror performance as discussed below:

- <u>Effect of mirror radius of curvature on distance estimation</u> - The aim of this test was to establish if the radius of curvature 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. The study found that convex rear-view mirrors with radii of curvature down to 1200mm have no detrimental effect on a driver's ability to make static target distance judgements compared to current mirrors.
- <u>Effect of mirror radius of curvature on reversing accuracy</u> - 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. It was found that 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.

- Effect of mirror radius of curvature on judging lateral displacement - 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. The findings indicated that 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.
- Effect of mirror radius of curvature on judging closing speed - 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. The study indicated that 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.

Couper (TRL Limited) 2006 compared the visibility from two different HGVs with Mirrors compliant with Directives 71/127 and 2003/97. Assessments were made using geometric modelling tools and by conducting a physical assessment on the TRL test track. Findings showed that:

- On the driver's side of the vehicle there appears to be no blind spot issue, as a vehicle in the adjacent lane is always visible in either a well adjusted Class II mirror or direct through the side window;
- Assessment of the visibility of a car as it passes an HGV on the opposite side from the driver found that the car was visible in the Class II and IV mirrors for most of the manoeuvre. However, when alongside the cab the car was only visible via the Class V mirror, until it could be seen through direct vision. When the HGV was fitted with mirrors minimally compliant to 71/127 the car was completely obscured for approximately 2m of forward travel. The car was also obscured for a similar distance if the HGV was fitted with a poorly adjusted 2003/97 compliant mirror. If the HGV was fitted with a well adjusted 2003/97 mirror it was possible to see the car in all positions as it moved along the HGV.

Similarly a study by Dodd (2009) found that overall the mandatory mirrors meeting the requirements of the directive 2003/97/EC did offer an improved field of vision over the mirrors that just met the requirements of the directive 71/127/EEC, eliminating about a third of the potential blind spots identified when the test vehicles were configured to the older directive.

9.5.3 Class V mirrors (close proximity mirrors)

Mounting, use of and adjustment of Class V mirrors

In a report entitled 'Danish proposal for direct vision in heavy good vehicles N_2/N_3' (Road Safety and Transport Agency undated), it was reported that incorrect adjustment or of mounting of mirrors was a contributory factor in a high percentage of the accidents studied.

Within a study by Fenn et al (2005), the use and adjustment of Class V mirrors was investigated. A driver survey, eliciting 311 responses, found that: 63% (181 respondents) claimed to always check the positioning of the close proximity mirror when getting into the cab and 35% (101 respondents) claimed to check the mirrors at least rarely or sometimes.

Whether a driver always drove the same vehicle or shared a vehicle with other drivers had a significant effect on whether mirrors were checked. 70% of respondents who usually drove different cabs reported to check the position of the mirrors every time they got into the cab, whereas just over half (76, 55%) of those respondents that usually drove the same vehicle checked every time.

Of those drivers who always drove vehicles fitted with close proximity mirrors and who checked the positioning of the mirror on at least some occasions, (n=190) 33% had to adjust the mirror every time. Those who usually drove different cabs needed to adjust the positioning of the mirror significantly more than those who drove the same vehicle.

It was found that the majority of respondents used close proximity mirrors in accordance with their primary safety intentions. The most common use of close proximity mirrors was to check for obstacles by the passenger door. Almost 9 out of 10 drivers 88% used the mirrors often or very often for this purpose. Most HGV drivers 'often' or 'very often' used the mirrors to check for cyclists or pedestrians by the passenger door, when manoeuvring (246, 86%).

White Willow Transport Intelligence (2006) on behalf of the Department for Transport conducted a review of various accident databases to examine the issue of side swipes. The report notes that a Class V mirror is positioned well away from the normal forward plane of the drivers' vision and suggests that this could result in the remaining 20% of side swipe accidents, when the vehicle is in the mirror but still not "seen".

Opinions of close proximity mirrors

In the same study (Fenn et al, 2005) results relating to drivers opinions of the Class V mirrors were also collected. It was found that overall those who always drove a vehicle fitted with close proximity mirrors viewed the benefits of the safety features significantly more positively than those who never drove vehicles fitted with close proximity mirrors. Furthermore those drivers who viewed closed proximity mirrors more positively were significantly more likely to check the position of close proximity mirrors on regular basis. 90% of HGV drivers agreed the use of close proximity mirrors generally contributes to the reduction of HGV accidents and collisions whilst 61% of drivers claimed that the use of close proximity mirrors had specifically helped them to avoid a potential accident within the past 12 months.

As a consequence of these findings, Fenn et al (2005) report that public awareness needs to be further increased by publicity and training in order to address the knowledge gaps of HGV drivers who do not currently have close proximity mirrors and that it may be worth targeting these drivers specifically.

Drivers of articulated HGVs reported significantly greater accident savings due to the presence of close proximity mirrors than drivers of rigid vehicles (vehicles in range of 7.5 to 12 tonnes will be rigid).

Most of drivers surveyed agreed that fitting close proximity mirrors to all HGVs in excess of 7.5 tonnes and to coaches would be a good idea. However there is concern that the majority of drivers do not realise the purpose of the close proximity mirrors and are still using them incorrectly.

Potential casualty savings

From an analysis of STATS19 data, HVCIS and Kent police data Fenn et al (2005) provide a best estimate of the potential casualty savings if 7.5 to 12 tonne HGVs are fitted with close proximity mirrors. They estimate that less than one fatality, less than one serious injury, approximately 3 slight injuries and less than one damage only accident may be prevented by fitting the Class V mirror to 7.5 to 12 tonne goods vehicles. They note that whilst these numbers appear small, it is anticipated that the cost of fitment will also be small and that the ratio of cost benefit could be more favourable than first appears. Findings from this report suggest that a limited retro-fit program for recently registered vehicles may be of benefit, because it is considered that a full retro-fit program is unlikely to offer substantial benefits. CAD also showed that Class V mirrors conforming to directive 2003/97 fitted to goods vehicles in excess of 12 tonnes, show a clear benefit for vulnerable road users and would be of benefit if right hand drive vehicles of this size category driving on the left (or vice versa) were fitted with Class V mirrors.

The report also offers a further recommendation that it might be of benefit if left hand drive good vehicles in excess of 12 tonnes driving on the left, which were not fitted with close proximity mirrors, were fitted with Class V mirrors conforming to directive 2003/97. They additionally believe that it would also be of benefit if left hand drive vehicles of 7.5 to 12 tonnes driving on the left (or vice versa) were to be fitted with Class V mirrors to reduce this blind spot.

9.5.4 BDS mirrors

The BDS mirror is designed to fill the gap between the Class IV and V rearward mirror view and the rearward lateral extent of the drivers' direct field of view as shown in Figure 41.

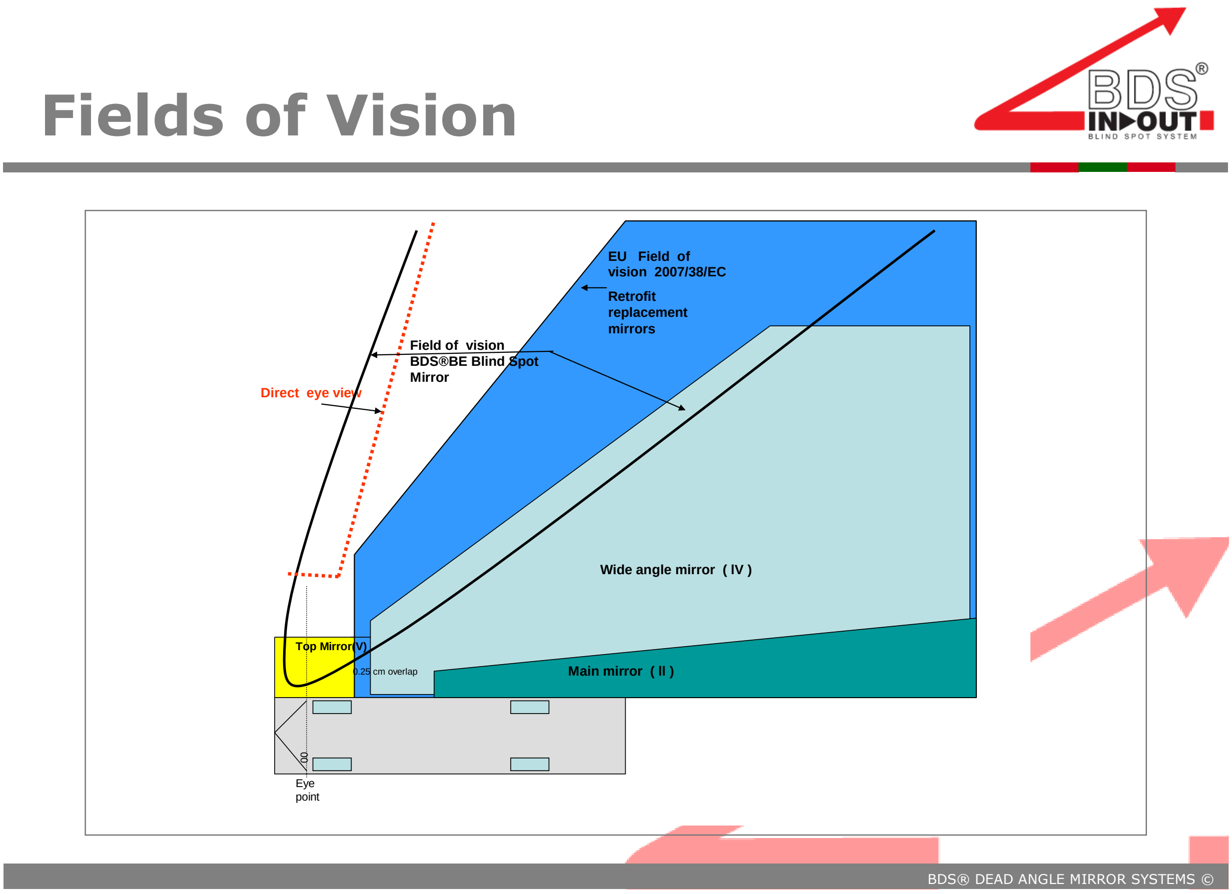

Figure 41: BDS mirror field of view

http://www.bdsmirror.eu/folders/BDS%20Blind%20Spot%20Mirror%20Systems%20UK.ppt

The mirror is designed to be installed inside the vehicle cab, located on the passenger side A-pillar – Refer to Figure 42.

Figure 42: Location of the BDS mirror
http://www.bdsmirror.eu/advantage.htm

A study by Dodd (2009) showed that having the correct adjustment of the BDS mirrors was critical in maximising the field of view they could provide. In some cases the Class IV field of vision from the BDS mirrors was obstructed by the window frame and/or external rear view mirror on the vehicle which reduced the size of the ground plane visible through the mirrors. However, the BDS mirrors still offered additional benefits to the mandatory mirrors and eliminated some of the potential blind spots. It was estimated that for the test vehicles and ocular points used in this study, the BDS mirror could eliminate 37% to 75% of blind spots.

9.5.5 Dobli mirrors

The Dobli website states that the function of the mirror is to add 'an additional field between the area visible directly through the window and the field of vision in the class IV and V mirrors. In this way a near to complete view on the 'blind spot' at the passenger side of the truck is generated . . .'.

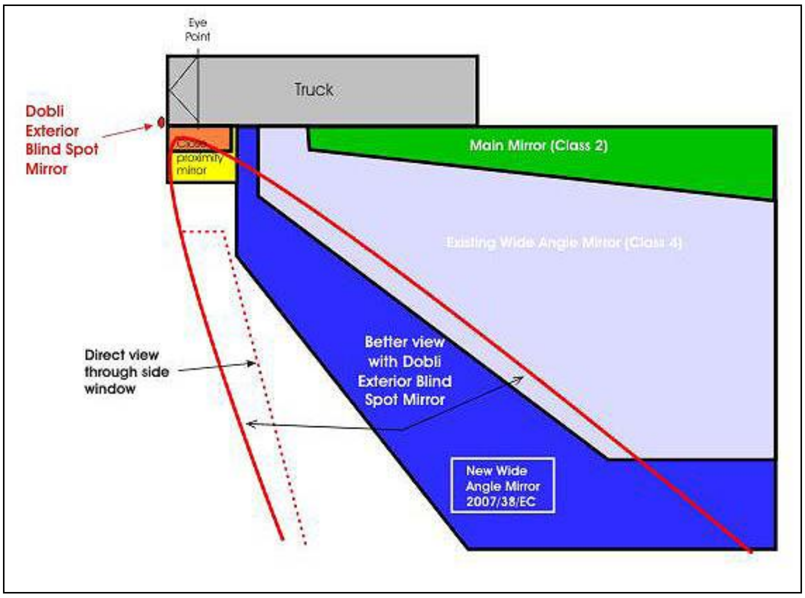

Figure 43: Dobli mirror field of view
http://www.blindspot-mirrors.co.uk/dobli-exterior-mirror-2-c.asp

The mirror is designed to be installed on the exterior of the front quarter of the cab on the passenger side – Refer to Figure 44.

Figure 44: Location of Dobli mirror
http://www.blindspot-solutions.eu/

Test results from a study by Dodd (2009) showed that having the correct adjustment of the Dobli mirrors was critical in maximising the field of view they could provide. In some cases the Class IV field of vision from the Dobli mirrors was obstructed by the window frame and/or external rear view mirror on the vehicle which reduced the size of the ground plane visible through the mirrors. The ground plane field of vision for a Class V mirror meeting the requirements of the directive 2003/97/EC extends 1m ahead of the driver's ocular point. With the Dobli mirror angled to see the Class IV ground plane, it was often not possible to see the foremost edge of the Class V ground plane illustrating that it could not meet the requirements of the directive 2007/38/EC for either test vehicle. The Dobli mirror offered additional benefits to the mandatory mirrors and eliminated some of the potential blind spots. It was estimated that for the test vehicles and ocular points used in this study, the Dobli mirror could eliminate between 43% and 76% of the blind spots.

9.5.6 Fresnel lens

Unlike mirrors which support indirect vision, Fresnel lenses offer a specifically focussed, direct field of view to the driver. By precisely shaping the arrangement of the concentric rings within the lens, the needs of HGV drivers to view downwards into the blind spot at the passenger side of their cabs can be further addressed. Whilst images provided by Fresnel lenses are generally of reduced quality compared to a conventional lens, in many instances this is good enough and is offset by the improved design flexibility and reduced cost.

Figure 45: Fresnel lens (Dodd, 2009)

Location

As part of a study by TRL (Dodd, 2009) the use of Fresnel lenses placed in three positions were studied: the rear most position at the bottom of the window; the foremost position at the bottom of the window and the mid-point at the top of the window. Tests showed that it was preferable to position the lens at the bottom of the passenger window because it was possible to see the ground closer to the vehicle than if the lens was positioned at the top of the window. The fore/aft positioning of the lens showed that there was minimal difference between placing the lens at the front or rear of the window. However it was noted that when the lens was positioned towards the front of the passenger window, the external rear-view mirrors of the vehicle partly obstructed the view (however this is largely dependent upon the vehicle the lens is fitted to). The possibility of etching the lens design into the side glazing was investigated, but considered not to be viable due to manufacturing difficulties and the resultant increase in cost.

As part of a study conducted by Couper (2006) investigating the visibility from two different HGVs using geometric modelling tools and by conducting a physical assessment on the TRL test track, a limited assessment of the practical use of a Fresnel lens was also conducted. Findings indicated that the use of a Fresnel lens would not adversely be affected by window operation, though a second Fresnel lens may be required if the passenger window is frequently left lowered (not relevant if completely lowered).

Effectiveness

The study by Dodd (2009) found that that for the test vehicles and ocular points used, the Fresnel lens could eliminate 78% to 90% of the blind spots. Additionally its performance was not reduced by vibration or dirty windscreens. The investigations by Couper (2006) compared vision though the Fresnel lens with that of direct vision and through a Class V mirror; the findings suggest a superior performance of the Fresnel lens – refer to Table 16.

Occupant percentile	Directive Class V mirror complies to	Mirror position	Car position in lane	Car visible through direct vision	Car visible through indirect vision (Class V mirror)	Car visible through a fresnel lens
5th	2003/97	To meet directive	Middle of lane	X	√	√
50th	2003/97	To meet directive	Middle of lane	X	√	√
95th	2003/97	To meet directive	Middle of lane	X	√	√
5th	2003/97	To meet directive	Far side of lane	X	X	√
50th	2003/97	To meet directive	Far side of lane	√	X	√
95th	2003/97	To meet directive	Far side of lane	√	X	√
5th	2003/97	Towards wheel	Middle of lane	X	√	√
50th	2003/97	Towards wheel	Middle of lane	X	√	√
95th	2003/97	Towards wheel	Middle of lane	X	√	√
5th	71/127	To meet directive	Middle of lane	X	X	√
50th	71/127	To meet directive	Middle of lane	X	X	√
95th	71/127	To meet directive	Middle of lane	X	X	√

Table 16: Direct vision, Class V mirror and Fresnel lens – Comparison of visual performance afforded to driver

However, Dodd (2009) noted that reflections, level of ambient light and angle of the sun have an effect on the visibility through the lens, whilst Couper (2006) observed that glare from direct incident sunlight will adversely affect visibility through a Fresnel lens and that there is potential for a Fresnel lens to focus sufficient sunlight to cause combustion, although this had not been assessed.

Frensel lens and LHD

Fresnel lenses were issued by VOSA, to foreign HGV drivers, as part of study to evaluate their effectiveness in side swipe accidents (Fitch 2007). The evaluation project's methodology was to:

- issue Fresnel Lenses free-of-charge to incoming foreign HGV drivers
- encourage drivers to fit the lenses to their vehicles on a voluntary basis;
- evaluate the effectiveness of the lenses in helping to reduce side swiping incidents by collecting accident data from before the lenses were issued.

The study results are presented below for incident data, fitment, effectiveness, and performance in wet and night conditions.

Incident data

The collected incident data is shown in the table below.

Pre-Lens issue	Post-Lens issue
The following data was collected:	
401 reported side swiping incidents over 13 week period equating to 31 incidents/week.	174 reported side swiping incidents over 13 week period equating 13.4 incidents/week.
The data analysis showed:	
LHD HGV incidents accounted for 92% of the total (368 incidents);	LHD HGV incidents accounted for 92% of the total (160 incidents);
341 of these (85% of all incidents) were attributed to side swipes (all HGVs were moving from left to right);	139 incidents (80% of all) were attributed to LHD side swipes. There were 13 incidents where the vehicle had a lens fitted.
There was an average of 26 LHD side swipes per week.	There was an average 10.7 side swipes per week.
RHD HGV incidents accounted for 8% of the total (33 incidents)	RHD HGV incidents accounted for 8% of the total (14 incidents)

Table 17: Pre- and post-lens issue incident data (Fitch 2007).

Fitment

The study found that overall, the majority of drivers fitted the lens when they received it (86%) and most of these drivers still had it fitted at the time of the interview. Of those who fitted the lens themselves, the majority (87%) said that the lens stayed in place. Of the few (22) cases where the lens did not stay in place, eighteen said that it fell off while winding the window up and down.

Effectiveness

The lens has had a positive effect in reducing blind spots. Three-quarters (77%) of drivers who fitted the lens thought that it either completely eliminated blind spots

(28%) or reduced them to a great extent (49%) - Only one percent of drivers think that the lens has not helped blind spots at all. The majority of drivers also felt that the lens was effective in wet conditions (77%) including 30% who found it very effective. Seven in ten found it effective at night, including 29% who found it very effective.

9.5.7 Sensors

The EU has been investigating sensors and other such devices through its Prevent project and associated sub projects. Vehicle makers such as Volvo and Scania have also identified this blind spot issue and although they have developed technological solutions, none are available as line fit. Technology is focussed on the tractor unit, due to the complexities of coupling trailer units with different systems. The report concludes that there are many off the shelf products that could potentially reduce up to 60-80% of side swipe accidents and much further research and development is underway.

ROSPA (2007) suggest that sensors, similar to those on cars for reversing, could be installed along the side of HGV's to inform drivers when a vehicle, pedestrian or cyclist is along side of them; commenting that "a system of this nature will not only make drivers more aware of their environment but could also encourage better observation. Once hearing the warning drivers will hopefully look in their mirrors to assess the situation".

Tait and Southall (1998) conducted trials to investigate the effectiveness of various types of reversing aids and found that:

- Infra-red – The system was only able to detect a child at 600mm on the vehicle centreline.
- Ultrasonic – Not able to reliably detect the 1m tall child behind the vehicle.
- Radar obstacle detectors – The system could only detect the child at 1600mm and 2700mm distance but failed to detect at 600mm.
- Camera/monitor rear vision system – The system enabled better detection at distances further from the rear of the vehicle (1600mm and 2700mm). In good

lighting conditions, the study participants were failing to detect targets on about one in six occasions which rose to around one in two at night-time.

Within a study by White Willow Transport Intelligence (2006), various technologies to address the issue of side swipe accidents were discussed. It was stated that "radar detectors tend to give an audible alarm when indicators are used, and so have limited ability to distract drivers. There are issues of after fit devices having similar audio warning tones to in vehicle alarms already present, as whilst there are standards for example for the colour and shape of warning lights, there are none for audible alarms".

9.5.8 Camera monitoring systems

Also within the White Willow Transport Intelligence study (2006), as part of its technology review, it was stated that offers the lowest cost and potentially the best safety improvement, as it can also be used in urban situations and gives added value to the operator. However it has potential issues for driver distraction since it is a vision-based system and such problems could be further compounded if these systems are fitted incorrectly. In line with this, the Danish proposal for direct vision in heavy good vehicles N_2/N_3' (Road Safety and Transport Agency undated), stated that for camera systems, the monitor should be positioned in the same visual angles as the mirrors and without impeding the field of view through the windows.

The White Willow Transport Intelligence study (2006) also noted that within The Netherlands cameras are a popular alternative to mirrors since it is considered that simply having additional mirrors may not fully address the side swipe issue as they may only serve to increase the driver's vision workload during lane changes – accidents that already lie in the 20% where drivers are not able to fully use information presented to them. Therefore there is a belief that advanced technology solutions may offer real benefit to addressing side swipe incidents if they not only reduce blind spots but also reduce driver workload from existing mirrors.

In the study by Tait and Southall (1998), trials to investigate the effectiveness of various types of reversing aids found that the rear vision camera system enabled better detection at distances further from the rear of the vehicle (1600mm and 2700mm). In good lighting conditions, the study participants were failing to detect targets on about one in six occasions which rose to around one in two at night-time. A study by Flannagan et al (2005) examined drivers' perceptions of distance to a rearward vehicle while using a camera-based rear vision system in actual driving conditions. Participants drove an instrumented car equipped with conventional rear-view mirrors and with a camera rear vision system. Using various configurations of these rear vision systems, they observed the approach of an overtaking car and indicated the last moment at which it would be safe to initiate a lane-change manoeuvre in front of it. Their judgments were strongly affected by the type of display used to observe the overtaking car. The longest distances were obtained with the camera-based display at unit magnification. Distances were substantially shorter with the conventional mirror and with the camera-based display at 0.5 magnification. These results are consistent with results from an earlier study conducted under static conditions.

9.6 N_3

Refer to M_2.

9.7 Consultations

The consultations highlighted the following hardware solutions that were either perceived to offer a benefit or posed further problems for various categories of vehicles:

- Additional solutions should never be relied upon and should always serve as an addition to mirrors.
- No one solution is perceived to be sufficient, there is a trend to 'double up' on systems.

- A number of companies have mandatory fitment of additional vision aids such as cameras: including Tarmac, BP and Sunlight Laundries. However, many companies will only meet legislative requirements and not go beyond.
- Nearside proximity sensors are being fitted by companies such as Cemex working in London and other urban areas. The view is that they provide a useful warning for obstacles that may not have been seen or looked for.
- Royal Mail are trialling a considerable number of solutions in their new Safety Concept Vehicle developed in collaboration with DAF. These include a blind spot camera that covers the nearside blind spot, rear view cameras, and a range of sensor systems facing to the nearside and rearwards that offer audible warnings as well as brake assist. Early feedback is good.
- Systems activated for specific manoeuvres (activated with turn signals, or engagement of reverse gear) are perceived to be better than 'always on' systems.
- The cost of additional systems can be an issue.
- There is a perception that real world testing of aftermarket solutions were difficult and so testing was essentially done in the field. This may lead to a de-valuing of some of the technologies.
- Information processing by the driver is becoming an issue especially for systems that give unwanted alarms. Systems warning of a driver observed obstacle, or falsely warning when no obstacle is present, can lead to fatigue and a desensitising to the warning such that an undetected obstacle that provides a warning is ignored.
- The Class V mirror does not cover a large enough field of view. In particular when a HGV pulls wide to take a left hand turn, the mirror no longer covers the area where a cyclist may be positioned. In certain cases sensors and audible warnings are being used to warn both other road users and the driver that there may be an unseen obstacle. Initiatives have been put in place in London to ensure all Crossrail HGVs have these sensors fitted.
- Aftermarket – retro-fit mirrors for activities such as towing were considered to be poor. However, small blind spot mirrors for vehicles such as Category N_1 vehicles were considered good and cost effective.
- Fresnel lenses were considered to be useful.

- Trixi mirrors may be a possible useful addition at junctions. These are mirrors attached to traffic lights and provide an additional view of the nearside of the vehicle.

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10 SOLUTIONS – DRIVER BASED

10.1 General

The Danish proposal for direct vision in heavy good vehicles N_2/N_3 (Road Safety and Transport Agency undated) suggested that hauliers, drivers and mechanics are uncertain about the correct mounting, adjustment and use of new blind spot mirrors. The report also provides a set of recommendations, these included the following;

- Clear and easy to follow instructions in how to mount mirrors are required.
- Regular lorry inspections should include checking the mounting and adjustment of mirrors.
- Driver learning courses and tests should include correct adjustment and use of mirrors.
- Police control – road check should focus on driver inattention, field of view from the driver's cab and incorrect mirror adjustment.
- Campaigns should be launched by driver and haulage organisations to focus on this type of accident and raise awareness and responsibility.
- Campaigns to cyclists to make them aware of vulnerability in this scenario.
- Right of way regulations should be amended to force right turning vehicles to stop before crossing the cycle lane.
- New rules should require lorries to make stop and check traffic prior to and during the turning manoeuvre.

10.2 Drivers' use of mirrors

A driver survey conducted as part of a study by Fenn et al (2005) showed that of the 350 respondents:

- 90% agreed that close proximity mirrors generally contribute to a reduction in accidents and collisions;
- 61% of drivers claimed that use of the Class V mirror had specifically helped them to avoid a potential accident within the last 12 months;

- 88% agreed that the purpose of the Class V mirror was to check for cyclists or pedestrians by the passenger door;
- 79% agreed that the purpose of the Class V mirror was to check for cars by the passenger door;
- Many of the drivers also reported the benefit of using the Class V mirror when manoeuvring or reversing;
- Drivers of articulated HGVs reported significantly greater accident savings due to the presence of close proximity mirrors than drivers of rigid vehicles (vehicle in range of 7.5 to 12 tonnes will be rigid);
- Most of the drivers surveyed agreed that fitting close proximity mirrors to all HGVs in excess of 7.5 tonnes and to coaches would be a good idea. However there is concern that the majority of drivers do not realise the purpose of the close proximity mirrors and are still using them incorrectly.
- The majority of drivers claimed to always check the positioning of the mirror in accordance with good practice.

A section in the report on driver opinions of close proximity mirrors found that overall those who always drove vehicles fitted with close proximity mirrors viewed the benefits of the safety features significantly more positively than those who never drove vehicles fitted with close proximity mirrors. Furthermore those drivers who viewed close proximity mirrors more positively were significantly more likely to check the position of close proximity mirrors on a regular basis.

10.3 Importance of mirror adjustment

Dodd (2009) noted that without markings on the ground to define the required field of vision it is possible that it could be quite difficult for a driver, on his own, to ensure that he has correctly adjusted the mirror. The correct adjustment of the mandatory mirror is important in ensuring that the driver has the best possible field of view. In fact, research by Jacobs Consultancy (2004) stated that "a badly adjusted mirror may be worse than no mirror at all".

10.4 Awareness and training

Research by Jacobs Consultancy (2004) did not show universal support for policies which focussed solely on the use of new mirrors. The broad consensus was that associated measures are necessary, particularly publicity and driver education. Similarly a study by Fenn et al (2005) showed that awareness needs to be further increased by publicity and training in order to address the knowledge gaps of HGV drivers who do not currently have close proximity mirrors and it may be worth targeting these drivers specifically.

Fitch (2007) reporting on a trial of Fresnel lenses stated that of those drivers that fitted the lens, 90% were aware of blind spots before fitting the lens and 36% were aware of additional blind spots around their vehicle due to fitting the lens.

RoSPA (2007), in their report on LHD vehicles, stated that one means for improving the safety of LHD heavy goods vehicle drivers is for a requirement by the UK for such drivers to undertake further training before they are eligible to drive in this country.

A study by Larue (1999) investigated the use of a 3D model as an aid in driver's safety training and in gaining a better understanding of visibility problems around heavy goods vehicles.

The consultations identified initiatives by the Metropolitan Police/Transport for London and Cemex/RoSPA which took the form of:

- PowerPoint presentations – Highlighting accident statistics and scenarios;
- Leaflets – Citing accident statistics and scenarios; emphasising the joint responsibility of HGV drivers and cyclists towards each other; advice to cyclists as to how to interact with large vehicles on the road;
- Driver guidance – Advising that mirrors should be clean and properly adjusted to achieve maximum effect and eliminate blind spots along the front and down the side of the cab;
- DVD – Showing the HGV driver's viewpoint of a passing cyclist using Class II, IV, V and VI mirrors and a Fresnel lens.

- Website factsheet – Outlining accident statistics and scenarios; providing guidance to cyclists for safe interaction with trucks.
- Public engagement – A number of initiatives were undertaken in 2009 around the UK inviting cyclists to sit in a truck cab in order to appreciate the driver's field of view limitations.

11 DESIGN AND USE OF ROAD LAYOUT / INFRASTRUCTURE

11.1 Road and junction design

Basford (2002) stated that physical road features which force cyclists and drivers into close proximity should be avoided, or where this is unavoidable, motor vehicle speeds at such locations should be reduced.

The Danish proposal for direct vision in heavy good vehicles N_2/N_3 (Road Safety and Transport Agency undated) concluded that better road designs and/or road markings can help to prevent right turn accidents (for vehicles driving on the right). In addition, all signalled junctions should be designed to improve safety for cyclists; where space allows all junctions should be supplied with a pre-green phase for cyclists, a five metre staggered stop line for motor vehicles or a truncated cycle's track in right turn lanes.

In the US it is recommended that roadways intersect at 90° as far as is possible, with a minimum of 60°. Research was undertaken by Gattis and Low (1998) to investigate the effect of vehicle design on the line of sight of drivers emerging from minor roads at such junctions since it was considered that aspects such as a car roof post, the door frame or a panel aft of the door may impede safe use. The findings of the study recommend that the minimum intersection angle be increased to 70-75° since this will provide sufficient sight-line distance for a vehicle travelling on the through road to stop if a vehicle inappropriately enters the junction from a minor road. However to accommodate a sight-line which enables the minor road vehicle to enter the through roadway and accelerate before the through-road vehicles overtakes them, could necessitate intersection angles nearer 90°.

With respect to LHD vehicles, ROSPA (2007) suggested that the safety of LHD heavy goods vehicle drivers (whose drivers are not required to undertake any training and testing before driving on Britain's roads) could be improved through road engineering.

11.2 Road use

The ROSPA (2007) report on LHD vehicles suggested that the safety of LHD heavy goods vehicle drivers could be improved by prohibiting their road use in suburban areas or segregating HGVS from other traffic flows during different times of the day. This was similarly suggested within the Danish proposal for direct vision in heavy good vehicles N_2/N_3 (Road Safety and Transport Agency undated) which stated that large vehicles with high driver's cabs should have restricted access to urban areas.

12 IDENTIFICATION AND PRIORITISATION OF RISK FACTORS

12.1 M_1 and N_1 - Identification of risk factors

12.1.1 Field of view specification

Based on past research, there is a good foundation for a field of view specification upon which to base any subsequent Phase 2 activities for M_1 and N_1 (M_1 derivative) vehicles.

For non-M_1 derivatives, further research may be required.

12.1.2 Accident data

The review of recent accident data studies indicates that both A-pillar and B-pillar obscuration could be a factor in some road traffic accidents.

12.1.3 Blind spots and other limitations to vision

Key impediments to vision were identified as:

- A-pillars.
- B-pillars could potentially be a factor for specific junction scenarios for drivers with longer body dimensions.
- Dual A-pillars are an emerging design feature whose effects are unknown.
- The upper and lower limits to glazed areas and obscuration due to: equipment; after-market ancillaries and stickers/holders/etc.
- Left hand drive swept areas to windscreens.

For non-M_1 derivatives, specific additional blind spots may be present e.g. smaller window apertures, absence of rear windows, inadequate side mirrors.

12.1.4 Legislation

The legislative review identified the reinforcement of both A- and B-pillars as a factor in their increasing thickness.

Additionally, some windscreen wiper arrangements park the blades in the upright position using recesses in the A-pillar. Such arrangements have the potential to further increase obscuration in the vicinity of the A-pillar.

12.1.5 Solutions

For M_1 vehicles, research by Kinoshita (2007) found that A-pillars of narrower width than an observer's intra-ocular distance can help to eliminate blind spots.

12.1.6 Phase 2 implications

The data above suggests that the following limitations to driver vision may be worth further investigation:

- A-pillars.
- B-pillars.
- Dual A-pillars.
- Benefits of narrower A-pillars.
- The upper and lower limits to glazed areas and obscuration due to: equipment; after-market ancillaries and stickers/holders/etc.
- Left hand drive swept areas to windscreens.
- For non-M_1 derivatives, specific additional blind spots.

12.2 M_2 and M_3 - Identification of risk factors

12.2.1 Field of view specification

Based on past research, there is a good foundation for a field of view specification upon which to base any subsequent Phase 2 activities for M_2 and M_3 vehicles.

12.2.2 Accident data

The review of recent accident data studies indicates a potentially lower level of involvement of M_2 and M_3 vehicles compared to N_2 and N_3 vehicles. The main accident scenarios of relevance to M_2 and M_3 vehicles relate to reversing and left turns at junctions.

12.2.3 Blind spots and other limitations to vision

Key impediments to vision were identified as:

- The A-pillars including dual A-pillars.
- Lack of rear vision.
- The upper and lower limits to glazed areas and obscuration due to: binnacle; equipment; after-market ancillaries and stickers/holders/etc.

12.2.4 Legislation

Unlike N_2 and N_3 vehicles, there are no legislative requirements for Class IV, V or VI mirrors to be fitted.

12.2.5 Solutions

Research by Tait and Southall (1999) suggested improvements to:

- Direct vision by: Extending the windscreen downwards; extending glass panelling in doors downwards and minimising the intrusion of binnacles.
- Indirect vision by: Fitment of Class IV mirrors; fitment of a mirror to provide a view to the immediate front of the vehicle; mounting of all nearside mirrors forward of the A-pillar so that they are viewed through the swept area of the windscreen and the use of reversing aids.

12.2.6 Point to note

The lack of data (accident, literature and consultation) relating specifically to minibuses suggests that these vehicles pose a reduced accident threat compared to other M_2 and M_3 vehicle types.

12.2.7 Phase 2 implications

The data above suggests that the following limitations to driver vision may be worth further investigation:

- The A-pillars including dual A-pillars.
- Lack of rear vision.

- The upper and lower limits to glazed areas and obscuration due to: binnacle; equipment; after-market ancillaries and stickers/holders/etc.

However, the indicated lower level of involvement by M_2 and M_3 vehicles compared to N_2 and N_3 vehicles in accidents suggests that these are lower priority areas for investigation within Phase 2.

12.3 N_2 and N_3 - Identification of risk factors

12.3.1 Field of view specification

Based on past research, there is a good foundation for a field of view specification upon which to base any subsequent Phase 2 activities for N_2 and N_3 vehicles.

12.3.2 Accident data

The review of recent accident data studies indicates the following accident scenarios:

- HGV turning left.
- HGV changing lane to the left.
- HGV overtaking.
- Articulated HGVs on roundabouts.
- Reversing.
- LHD HGV changing lane to the right.
- LHD vehicles on roundabout.

12.3.3 Blind spots and other limitations to vision

Key impediments to vision were identified as:

- A-pillars / front quarters of the cab near to the vehicle that falls in front of the field of view of the Class V mirror.
- Area from the nearside front wheel outwards and rearwards.
- High level side windows and shape of window.
- Passenger door.
- High seating position.

- Incorrect adjustment / mounting or poor maintenance of mirrors.
- Mirror housing.
- Interior binnacle.
- Lack of view to the rear.
- The upper and lower limits to glazed areas and obscuration due to: binnacle: equipment; after-market ancillaries and stickers/holders/etc.
- Obscuration in mirrors by articulated trailers when turning.

Compounding factors

- Seat height relative to ground.
- Seat location relative to cab interior.
- Lateral displacement of passing road user.
- High cognitive workload of driver,
- Environment vehicle being driven in.

12.3.4 Legislation

The legislative review identified the importance of a good field of view to these vehicle categories, particularly N_3, by the additional requirements for Class IV, V and VI mirror fitment over other vehicle categories and the retrofitting of Class V mirrors.

12.3.5 Solutions

Solutions identified within the research included improvements to:

- Direct vision by: Maximising the glazed area of the cab; minimising the intrusion of binnacles
- Indirect vision by: Class V mirrors; BDS mirrors; Dobli mirrors; mounting of all nearside mirrors forward of the A-pillar so that they are viewed through swept area of windscreen; Fresnel lenses; detection technology; camera monitor systems.

12.3.6 Phase 2 implications

The data above suggest that the following limitations to driver vision may be worth further investigation:

- A-pillars / front quarters of the cab near to the vehicle that falls in front of the field of view of the Class V mirror (RHD and cyclists; LHD and side swipes).
- Area from the nearside front wheel outwards and rearwards (Cyclists and turning accidents).
- Lack of view to the rear.
- The upper and lower limits to glazed areas and obscuration due to: binnacle; equipment; after-market ancillaries and stickers/holders/etc.
- High level side windows and shape of window.
- Passenger door.
- Incorrect adjustment / mounting or poor maintenance of mirrors.

The review of accident data analyses supports the statement by Jacobs Consultancy (2004) that HGVs were the main concern above LGV and buses and coaches. For this reason, HGVs should be considered a priority area within Phase 2.

12.4 Prioritisation of risk factors

It can be seen from the data presented thus far that addressing field of view problems across all vehicle categories is a complex task since there are many factors involved, each of which could potentially be addressed within Phase 2. However it is important at this point to clearly identify what these problems are and to aim to prioritise their inclusion within Phase 2.

One approach is to consider that solutions to field of view problems form a hierarchy with each level building upon the next.

1. **Define** what the driver needs to see – Such definition may be provided through legislative requirements and/or field of view specifications e.g. PNCAP.
2. **Enable** the driver to see what is required by identifying and eliminating blind spots e.g. mirror fitment.
3. **Optimise** the quality of vision provided by such solutions e.g. minimise any negative effects of convex mirror distortion.

4. **Support** the driver in appropriate use of the solution; e.g. assist driver in correct mirror set-up; alert driver to use the mirror when a hazard is detected by sensing technology; etc.

Table 18 summarises the findings discussed above against this hierarchy with the grey cells depicting where the need for further research has been identified.

All things being equal, task prioritisation might follow the hierarchical levels; i.e. work first on the 'defining' activities and then on those relating to enabling, optimising and supporting. However, due to other factors, a re-ordering of this prioritisation is proposed as summarised in Table 19.

	Define what the driver needs to see				**Enable** the driver to see what is required by identifying and eliminating blind spots		**Optimise** the quality of vision provided by field of vision solutions	**Support** the driver in appropriate use of the solution
	Direct vision		**Indirect vision**		**Direct vision**	**Indirect vision**		
	Legislative requirement	Field of view specification	Legislative requirement	Field of view specification				
M1	✓	✓ (Shearlaw & Freer, 2002)	✓	✓ (Shearlaw & Freer, 2002*)	**X** A-pillars			
M2	**X**	✓ (Tait & Southall, 1999)	✓	✓ (Tait & Southall, 1999)	**X** A-pillars	**X** view to rear	**X** Compare performance of mirrors; sensors; cameras.	**X** Investigate how designs can be improved to support driver
M3	**X**	✓ (Tait & Southall, 1999)	✓	✓ (Tait & Southall, 1999)	**X** A-pillars	**X** view to rear		
N1	**X**	**X** for non-M1 derivatives	✓	**X** for non-M1 derivatives	**X** A-pillars	**X** view to rear		
N2	**X**	✓ (Tait & Southall, 1999)	✓	✓ (Tait & Southall, 1999)	**X** A-pillars/quarters; view to side	**X** view to front quarters; view to rear		
N3	**X**	✓ (Tait & Southall, 1999)	✓	✓ (Tait & Southall, 1999)	**X** A-pillars/quarters; view to side	**X** view to front quarters; view to rear		

Table 18: Areas for further research (x)

(✓ - data is available; X – knowledge gap)

(* For the purposes of this report, it is assumed that where the requirements for direct vision cannot be met; indirect methods will be used)

Priority	Work package	Rationale
1	N_2 & N_3: Blind spot to front quarters and to side.	Recent accident data and consultations suggest this is problematic area.
2	M_2, M_3, N_1, N_2 & N_3: View to rear.	The regulation review, literature review and consultations indicate that there is no regulated requirement for a view to the rear although the lack of rear vision is problematic for drivers. This is a factor across most of the vehicle categories.
3	M_2, M_3, N_1, N_2 & N_3: Compare and optimise indirect vision systems.	A review of various indirect vision systems were assessed by Tait and Southall (1998). Whilst further investigations of mirror designs have been undertaken since then, an analysis to compare such mirrors against other technologies would be beneficial. Such a work package would link to the review of Regulation 46 by the Informal Group Camera Monitor Systems (IGCMS) and equipment/concept vehicle trials by operators. This is a factor across most of the vehicle categories.
4 =	M_1: A-pillar obscuration.	Accident data suggests that A-pillars could be a factor in vision-related accidents. This package could be extended to consider dual A-pillars as well as B-pillars.
4 =	N_1: Field of view for non-M_1 derivatives	Field of view specifications based on drivers visual requirements have been developed for all classes of vehicles except for N_1 (non-M_1 derivative) vehicles.

Table 19: Prioritisation of risk factors to driver vision

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13 INITIAL IMPACT ASSESSMENT

13.1 Introduction

One of the tasks in Phase 1 of the project is to compile an initial Impact Assessment on possible measures to improve driver vision. Impact Assessment is a technique that is normally employed to present regulators with the information they require to choose the most appropriate response to a specific problem. In doing this, it sets out the range of options available, and assesses the consequences of each of these, in terms of the costs and benefits that are likely to arise. There is a closely-defined procedure for doing this, published by the Department for Business, Innovation and Skills on its website.

However, it is not yet possible to do this for the Driver Vision project. Although there is clearly a need to improve driver vision generally, the problem manifests itself in different ways for different category of vehicle. Each of these represents a specific problem that will probably require a specific solution, although these solutions are likely to be closely linked. Therefore, the formal impact assessment is not appropriate at this stage in the project, but it seems likely that one or more of these will be carried out later on, on more specific solutions identified in Phase 2.

This problem was discussed at an early stage in the project, and it was agreed with the Department that the project team would conduct an initial impact assessment at the end of Phase 1, reviewing the solutions identified at that stage of the project. The partners are not aware of any established procedure for carrying out such an assessment, so an appropriate methodology has been devised, which is described below.

13.2 Methodology for Initial Impact Assessment

The procedure comprises the following steps:

1. Earlier sections within this report have identified the possible measures that have the potential to improve driver vision, along with the vehicle categories to

which they are relevant. They include actions that might be taken by a variety of stakeholders, including vehicle and mirror designers, operators, drivers, maintenance organisations, highway authorities and the Police, as well as the Department for Transport. To make the assessment relevant to the Department, the first part of the procedure is to list each of the solutions in terms of the action that they would undertake in order to promote the measure. These actions include a range of initiatives, including the development of technical standards, creation of training resources, publicity campaigns, and shared initiatives with the Police and highway authorities.

2. Each of the actions is then assessed for its relative importance, using the following technique. Three factors were identified as being relevant to the outcome of the measures in improving driver vision. These are: Readiness, Effectiveness and Acceptability.
    - Readiness is an indicator of to what extent the measure is available for use
    - Effectiveness is an indicator of how cost-effective the measure is likely to prove
    - Acceptability is an indicator of how difficult it might be to promote the measure
3. To conduct the assessment, the measure is judged against each of these factors, and allocated a whole-number score on a scale of 0 to 3. A score of 0 represents a solution that has practically no value, while a score of 3 represents maximum value. The judgement is largely subjective, but certain criteria are provided for guidance and these are explained in more detail below.
4. A combined score is then calculated by multiplying the three individual scores together. Thus, the most attractive measure would receive a combined score of 27 (3x3x3), while one that was judged to be not available, not effective or not acceptable would receive a score of zero. There are two points to note in connection with this technique
    - Not all values of combined score are possible
    - As a consequence of the above, the combined score does not necessarily represent a linear indicator of the value of the measure

5. For each vehicle category, the potential solutions are then listed in ranking order of their combined score. Thus, the highest scoring measures are the ones that are assessed as having the highest value for follow-up in the project.

The relevance of the three factors, and the criteria for awarding a particular score is as follows:

- Readiness - This represents to what extent the solution is available for implementation, and what measures need to be in place before it can be implemented. This factor is more complicated to assess than the other two because many of the measures rely on technological innovations which must be developed and products put on the market before further work to promote it can proceed. Therefore, it combines an assessment of the technological state of the art, as well as the regulatory state of the art. The criteria for scoring are as follows:
    - 0: The necessary technology to support the measure does not yet exist.
    - 1: It is likely that the measure will work given the technology, but that technology is not yet on the market.
    - 2: All of the technology needed to support the measure is on the market, but details of how it should be implemented are not yet clear.
    - 3: The technology is on the market and there is a clear idea of how to implement it.
- Effectiveness - This is a measure of the cost-effectiveness of the measure in improving driver vision.
    - 0: The measure is unlikely to improve safety.
    - 1: The measure is likely to improve safety, but the cost-benefit has not yet been evaluated.
    - 2: The measure will improve safety in a limited number of cases.
    - 3: The measure will improve safety in all cases.
- Acceptability - This is a measure of how easily the measure might be implemented, and the possible conflicts that might arise. It is both a measure of the technological conflicts (for example, a measure that improves driver vision but detracts from some other perceived value) and of the political or commercial conflicts.
    - 0: The measure stands very little chance of ever being accepted.

1: The case for implementing the measure needs to be developed before it could be accepted.

- 2: There is widespread acceptance of the need to implement the measure, but opposition from some quarters can be expected.

3: The need to implement the measure is universally accepted.

13.3 Driver vision problems

Before listing the solutions, the following section revisits the problems highlighted in the earlier sections. These are presented under the following headings:

- Failure to See
- Failure to Understand
- Failure to Act

13.3.1 Failure to see

This may be due to:

Obscuration of direct field of view by:

- Windscreen by stickers, sat-nav etc (all vehicles).
- Windscreen by wipers, steering wheel etc.
- Forward view below the windscreen (large trucks).
- Forward view by A-Pillars (mainly cars and light goods vehicles).
- Side view by B-Pillar (cars, for taller drivers).
- Rear oblique view by bodywork (light and heavy commercial vehicles) or excessive tinting (cars).
- Rear view by bodywork (all vehicles).
- Rear view by head restraints.
- Rear view below the rear window (all vehicles).
- Nearside view below the side window (LHD vehicles used on RHD roads, and vice versa).

Degradation of forward field of view by:

- Dirt, haze, raindrops, ice and misting on windscreen and side windows.
- Low sun.

- Distraction due to reflections of dashboard etc inside windscreen (mainly cars and light goods vehicles).

Degradation of indirect field of view by:

- Insufficiently wide field of view.
- Incorrectly set mirrors.
- Dirt, haze, raindrops, ice or misting on the side glass.
- Dirt, haze, raindrops, ice or misting on the mirror.

Driver's poor eyesight, due to:

- Driver was not tested to a sufficiently high standard.
- Driver has fallen below the required standard due to age-related deterioration.
- Driver not wearing prescribed corrective lenses.
- Inappropriate glasses.
- Glare.

Failure of driver to look in mirrors, due to:

- Driver has not developed the habit of using all the mirrors.
- Driver forgets to look in a mirror.
- Driver overloaded by too many visual tasks.
- Driver overloaded by other visual or cognitive tasks (navigation etc).

13.3.2 Failure of driver to understand the visual information

This may be due to:

- Distraction.
- Cognitive overload.
- Fatigue.
- Inability to "connect" information gained from different mirrors.

13.3.3 Failure to act on the information

This may be due to:

- Distraction.

- Ignoring an alert, due to too many false positive results.
- Misjudgement of likely outcome.
- Misperception of risk.

13.4 Driver vision solutions

Generally speaking, the solutions to these problems can be divided into the following broad categories:

- Vehicle design.
- Vehicle maintenance.
- Roadway design.
- Driver licensing.
- Driver training.
- Driver working practices.

Some of these can be further divided into sub-categories, for example:

Vehicle design:

- Developing new technologies to improve vision, or alert the driver to hazards nearby.
- Developing new tools to help design vehicles with better vision.
- Changing vehicle design to improve vision in conjunction with, or even at the expense of, other design requirements.
- Encouraging or mandating the fitment of existing devices that could improve vision.
- Developing legislation to encourage changes to the design of those vehicles that provide poor driver vision.

Vehicle maintenance

- Encouraging or mandating the retrofitting of additional or improved devices.
- Encouraging or mandating more regular or more effective inspection of mirror condition.
- Developing tools to assist operators or drivers in more effective maintenance and inspection.
- Developing the standards required in regular roadworthiness inspection, or the effectiveness of the inspection system.

- Improving the effectiveness of roadside inspections.

Roadway design

- Encourage the redesign of junction layouts to improve driver vision, or compensate for poor vision.
- Encourage the introduction of facilities to improve vision (for example fixed mirrors) at critical points.
- Introduce more facilities giving drivers the opportunity to rest.
- Install aids for adjusting mirrors at rest stops.

Driver licensing

- Improve driver testing to eliminate potentially dangerous eyesight conditions.
- Improve the detection, treatment or disqualification of drivers with a potentially dangerous eyesight standard.
- Encourage or mandate measures to ensure that drivers do not drive with unsuitable corrective lenses.
- Improve the regulation of driver licensing to eliminate potentially dangerous concessions to drivers with "grandfathers' rights".
- Improve the implementation of legal measures to eliminate unqualified drivers, expired licences etc.

Driver training

- Improve practices in driver training, with increased use of driving simulators etc.
- Improve practices in driver assessment.
- Train drivers in the correct adjustment of the type of mirrors they will be using.
- Train drivers of LHD trucks in driving on UK roads.

Driver working practices

- Improve the regulation of potentially dangerous driving activities (for example, limiting overseas drivers with little experience of left-side driving from driving in London, or prohibiting larger vehicles from driving in city centres at busy times).
- Encourage or mandate operators to improve their working practices to avoid excessive workload on drivers.

- Encourage or mandate measures that could potentially reduce driver fatigue.
- Install aids for adjusting mirrors at depots, especially available when changing drivers.
- Install aids for adjusting mirrors at rest stops.

13.5 Compilation of measures based on identified solutions

13.5.1 Material from literature review

The first part of this section lists the measures identified in the literature review. Each entry includes a brief reference to the paper that highlighted the solution. Some of the measures originate in early papers, where the solutions have since been implemented, or partially implemented. The entry indicates where this is the case. The solutions are listed in the order that they appear in the report text. However, there is some overlap between entries, so it may appear that some solutions appear a number of times.

- Assessment of A-pillar obscuration to include a wider range of driver statures (Millington et al, 2006).
- Reduce the width of car A-pillars (to less than the inter-ocular distance) (Kinoshita, 2007).
- Extend windscreen area on M_2 vehicles (Tait and Southall, 1999).
- Extend side door glazing downwards on M_2 vehicles (Tait and Southall, 1999).
- Reduce forward field of view obscuration by the instrument binnacle on M_2 and M_3 vehicles (Tait and Southall, 1999).
- Lower the base of the windscreen on N_2 and N_3 vehicles (Road Safety and Transport Agency, undated).
- Introduce a lower glazed area on the nearside door of N_2 and N_3 vehicles (Road Safety and Transport Agency, undated).
- Reduce the driver's eye height above the road in HGV's (Road Safety and Transport Agency, undated; Daigo 1982).

- Supplementary windows in cab (Daigo).
- On buses and coaches, (Southall and Tait, 1999)
  - Reduce the Class II, rear-view mirrors minimum convex radius of curvature to 1200mm. (Already in place).
  - Fit a forward-viewing wide-angle mirror, with a 200mm (minimum) radius of curvature, to the near-side such that it provides a view to the immediate front of the vehicle. (Already in place).
  - Provide the means to adjust all mirrors from the driver's seated position.
  - Fit a reversing aid camera monitoring system.
  - Design instrument binnacles to reduce their intrusion into the driver's line of sight to the lower edge of the windscreen.
  - Design internal furniture to the near-side of the driver, such as the entry/exit door, steps and co-driver's seating, to reduce direct vision obscuration of the windscreen and immediate near-side.

- On buses only, (Southall and Tait, 1999)
  - Fit a two-camera camera monitoring system with one camera to monitor directly behind the vehicle and one to monitor the near-side of the vehicle. The monitor to be mounted in the cab so that the driver's line of sight to it is close to that of the off-side mirrors.
  - If the structure of the bodywork permits, fit Class IV wide-angle mirrors below the near-side and off-side rear-view mirror such that the minimum mounted height is 2m.

- On coaches only, (Southall and Tait,1999)
  - Fit Class IV, wide-angle mirrors below the near-side and off-side rear-view mirrors.
  - Mount all near-side mirrors forward of the A-pillar so that they can be viewed through an area of the windscreen swept by the windscreen wipers such that the minimum mounted height is 2m.
- Adopt cross-view mirrors for school buses (Lemay et al, 1998).

- For HGV's, (White Willow, 2006)

- Look at the wider business case of vehicle blind spots, not just side swipes and for all types of situation, including UK and foreign businesses and society alike.
- Link with other research, notably in the Netherlands, to make the most of experience elsewhere in fitment of technology and in driver education.
- Establish and promote a business case to UK operators for them to invest in such technology.
- Encourage safe fitment of cameras in line with the European Statement of Principles for such technology and review older UK legislation to reduce driver distraction issues.
- Ensure UK industry considers cameras as a potential solution for mirror retrofitting.

- On N_2 and N_3 vehicles (Southall and Tait, 1999)
  - Position mirrors to the requirements of European Directive 71/127/EEC;
  - Maximise the glazed area of the cab.
  - Minimise intrusive items, e.g. sun visor, sun blinds, binnacle profile.
  - Use remotely operated mirrors and/or heated mirrors.
  - Use obstacle detectors (close proximity warning beeper, for reversing) and camera monitoring system.

- For articulated and rigid N_2 and N_3 vehicles (Southall and Tait, 1999)
  - Reduce the Class II, rear-view mirrors minimum convex radius of curvature to 1200mm. (Already in place).
  - Fit a forward-viewing mirror with a 200mm (minimum) radius of curvature, to the near-side, such that it provides a view to the immediate front of the vehicle. (Already in place).
  - Mount all near-side mirrors forward of the A-pillar so that they can be viewed through an area of the windscreen swept by the windscreen wipers such that the minimum mounted height is 2m.
  - Provide the means to remotely adjust the near-side mirrors from the driver's seated position.
  - Fit a reversing aid camera monitoring system.

- Design instrument binnacles to reduce their intrusion in to the driver's line of sight to the lower edge of the windscreen.

- For articulated N_2 and N_3 vehicles fit an additional Class IV, wide-angle mirror to the off-side of the vehicle, mounted below the Class II, rear-view mirror (the wide-angle mirror currently fitted to the near-side should also be mounted below the Class II, rear-view mirror) and such that the minimum mounted height is 2m. (Southall and Tait, 1999).
- For rigid N_2 and N_3 vehicles (Southall and Tait, 1999)
  - Fit Class IV, wide-angle mirrors below the near-side and off-side rear-view mirrors such that the minimum mounted height is 2m. (Already in place).
  - Fit a Class V, close-proximity mirror to the near-side. (Already in place).

- For N_2 and N_3 vehicles (Road Safety and Transport Agency, undated)
  - Mirrors should have a position so high up and so far away from the corner of the cab unit that they allow a free field of view below and on both sides of the mirror housing.
  - Mirrors need to be simple and easy to adjust.
  - Lorry mirrors should comprise a single mirror unit that can be viewed in one glance. A maximum of three lorry mirrors should be allowed and they should be mounted on a single extended arm, which allows the driver to check all at once by looking in one direction. New research should focus on the driver's capabilities to judge the traffic situation by means of windows, mirrors and cameras.
  - Improve instructions for mechanics on how to mount mirrors properly.
  - Limit access of high-cab trucks to urban areas.

- More effective training of drivers in the use of close proximity mirrors (Fenn et al, 2005).
- LHD trucks of 7.5 to 12 tonnes driving on UK roads should be fitted with a Class V mirror on the right side (Fenn et al, 2005).
- Further research is needed to understand the effects of mirror curvature on drivers' perceptions of distance and speed (Flannagan et al, 1997).
- Fit BDS Dead Angle mirror systems (Dodd, 2009).

- Fit Dobli mirror systems (Dodd, 2009).
- Fit Fresnel lenses to nearside side windows (Dodd, 2009).
- Fit automatic sensors (similar to parking sensors) or radar devices to the sides of large vehicles to detect pedestrians and cyclists (White Willow, 2006).
- Fit camera monitoring system (White Willow, 2006).
- Redesign roads to eliminate cyclist / truck interaction; where this is not possible speed restrictions should b imposed (Basford et al, 2002).

13.5.2 Material from consultations

- Encourage or mandate fitment of small blind-spot mirrors for M_1 vehicles.
- Blind spot cameras (Royal Mail).
- Rear view cameras (Royal Mail).
- Nearside sensors with audible warning (Royal Mail).
- Reversing sensors with audible warning (Royal Mail).
- Reversing sensors with brake assist (Royal Mail).
- Install fixed mirrors at traffic lights (Trixi mirrors).
- Nearside proximity sensors (Cemex).
- Develop caravan towing mirrors (RAC).
- Encourage or mandate more regular inspections of mirrors to check mounting and adjustment.
- Make mirror adjustment part of the driving test.
- More police checks on mirror adjustment.
- Publicity campaigns by driver and haulage associations to highlight mirror issues.
- Publicity campaigns aimed at cyclists to make them aware of the issues.
- Regulate to make turning vehicles stop before crossing a cycle lane.
- Regulate to make lorry drivers stop and check traffic prior to turning manoeuvre.
- Set up facilities where drivers can check their mirror adjustment.
- Encourage or mandate training for drivers of LHD trucks before they drive on UK roads (RoSPA).
- Public engagement programmes (sit in truck and appreciate the view).
- Measures to revise junction layout for cyclist safety

- Cyclists only pre-green phase.
- 5m staggered stop line.
- Truncated cycle lane.

- Increase intersection angle at skewed junctions.
- Special road engineering measures at roads frequented by newly-arrived LHD trucks.
- Prohibit use of LHD HGV's on suburban roads (RoSPA).
- Segregate HGV's from other traffic flows at busy times of the day (RoSPA).

13.6 Assessment tables

The following tables set out the assessment scores for different groups of vehicles. Similar solutions from the above listing have been combined. The solutions have been listed in terms of the role of the Department for Transport in promoting or implementing them.

Solution	**Rating**			
	Readiness	Effectiveness	Acceptability	Overall
Design and promote facilities where drivers can check their mirror adjustment	2	2	3	12
Encourage or mandate the redesign road junctions to eliminate cyclist / truck interaction	2	2	2	8
Encourage more fixed mirrors at traffic lights	3	1	2	6
Publicity campaign to warn cyclists of danger from turning large vehicles	2	1	3	6
Public engagement programmes (sit in truck and appreciate the view)	2	1	3	6
Develop forward field of view standards to reduce the maximum width of A-pillars to less than the inter-ocular distance	1	2	1	2
Regulate to make turning vehicles stop before crossing a cycle lane	2	1	1	2

Table 20: Solutions applicable to all vehicle categories

Solution	**Rating**			
	Readiness	Effectiveness	Acceptability	Overall
Encourage or mandate fitment of small blind-spot mirrors on M_1 vehicles	3	1	2	6
Develop a standard for caravan towing mirrors to address field of view, stability, ease of adjustment etc	2	1	2	4
Develop A-pillar obscuration standard to address 5%ile driver Inter-Ocular Distance and 95%ile driver Stature, as well as current requirements	1	2	1	2

Table 21: Solutions applicable to M_1 and N_1 vehicle categories

Solution	**Rating**			
	Readiness	Effectiveness	Acceptability	Overall
Publicity campaign to encourage drivers to check mirror adjustment more regularly	3	2	3	18
Encourage or mandate requirement for all exterior mirrors to be remotely adjustable	2	2	3	12
Support or encourage installation of automatic sensors on nearside of large vehicles to detect pedestrians or cyclists	2	2	2	8
Make mirror adjustment part of the driving test for heavy vehicles	3	1	2	6
Publish training resource for large vehicle mechanics to improve mirror installation and checking	3	1	2	6
Support or encourage Police campaign to stop large vehicles and check their mirror adjustment	3	1	1	3
Support or encourage local initiatives to segregate heavy goods vehicles from other traffic flows at busy times of the day	2	1	1	2
Support or encourage local initiatives to limit access of high-cab trucks to urban areas	2	1	1	2

Table 22: Solutions applicable to large vehicles – M_2, M_3, N_2 and N_3 vehicle categories

Solution	**Rating**			
	Readiness	Effectiveness	Acceptability	Overall
Encourage or mandate training for drivers of LHD trucks before they drive on UK roads	2	2	1	4
Support or encourage local initiatives to prohibit use of LHD HGV's on suburban roads	2	1	1	2

Table 23: Solutions applicable to Left Hand Drive heavy vehicles used on UK roads

Solution	**Rating**			
	Readiness	Effectiveness	Acceptability	Overall
Encourage or mandate installation of reversing alerts	2	2	3	12
Mandate forward field of view standard for M_2 vehicles	2	2	1	4
Encourage or mandate fitment of reversing cameras	2	2	1	4
Encourage or mandate a lowered window line or auxiliary door glazing panel	3	1	1	3
Encourage or mandate fitment of Fresnel lenses to nearside window	2	1	1	2

Table 24: Solutions applicable M_2 vehicle categories

Solution	**Rating**			
	Readiness	Effectiveness	Acceptability	Overall
Encourage or mandate installation of reversing alerts	2	2	3	12
Mandate forward field of view standard for M_3 vehicles	2	2	1	4
Encourage or mandate installation of reversing cameras	2	2	1	4
Encourage or mandate fitment of Fresnel lenses to nearside side window	2	2	1	4
Mandate installation of Class IV mirrors on the nearside	3	1	1	3
Mandate installation of Class IV mirrors on both sides	3	1	1	3
Mandate installation of Class II mirrors where they are visible through the swept area of the windscreen	2	1	1	2

Table 25: Solutions applicable M_3 vehicle categories

Solution	**Rating**			
	Readiness	Effectiveness	Acceptability	Overall
Mandate forward field of view standards for N_2 vehicles (downward angle only)	3	2	2	12
Encourage or mandate more rigorous training for drivers in the use of close-proximity mirrors	3	2	2	12
Encourage or mandate fitment of Fresnel lenses to nearside side window	3	2	2	12
Mandate forward field of view standards for N_2 vehicles (similar to M_1 requirements)	3	2	1	6
Publicity campaign to encourage heavy vehicle mechanics to improve mirror installation	3	1	2	6
Encourage or mandate reversing alerts	2	2	1	4
Encourage or mandate reversing cameras	2	2	1	4
Mandate minimum height requirements for exterior mirrors so that driver has a clear forward view underneath	2	1	2	4
Mandate installation of Class II mirrors so that they are visible through the swept area of the windscreen	2	1	1	2
Mandate installation of Class V mirror on nearside (right hand side) of left hand drive trucks being used on UK roads	3	2	0	0

Table 26: Solutions applicable N_2 vehicle categories

Solution	**Rating**			
	Readiness	Effectiveness	Acceptability	Overall
Encourage or mandate more rigorous training for drivers in the use of close-proximity mirrors	3	2	2	12
Encourage or mandate fitment of Fresnel lenses to nearside side window	3	2	2	12
Encourage manufacturers to introduce more low-cab N3 vehicles	2	2	2	8
Mandate forward field of view standards for N_2 vehicles (downward angle only)	3	2	1	6
Mandate forward field of view standards for N_2 vehicles (similar to M_1 requirements)	3	2	1	6
Publicity campaign to encourage heavy vehicle mechanics to improve mirror installation	3	1	2	6
Encourage or mandate reversing alerts	2	2	1	4
Mandate minimum height requirements for exterior mirrors so that driver has a clear forward view underneath	2	1	2	4
Encourage or mandate reversing cameras	2	2	1	4
Mandate installation of Class II mirrors so that they are visible through the swept area of the windscreen	2	1	1	2

Table 27: Solutions applicable N3 vehicle categories

13.7 Conclusions

The assessment has demonstrated the range of actions that are available to the Department for Transport for improving driver vision in various M and N-categories of vehicle, and for alleviating a range of problems that are associated with poor vision on UK roads. The assessment, together with the earlier sections will help to determine the more detailed investigations that are planned to be carried out in Phase 2 of the project.

14 PHASE 2 RESEARCH PLAN

A suggested research plan for Phase 2 is outlined below as a basis for discussion with the Department for Transport. The extent to which this is achievable within Phase 2 is dependent upon the range of sub-tasks within each work package and depth of investigation required for each of them.

14.1 Description of work packages

14.1.1 Work Package 1: N_2 & N_3 – Blind spot to front quarters and to side

Subtasks within this package may include:

• In-depth accident data analysis. • Driver consultations/interviews. • Operator consultations/interviews. • Manufacturer consultations/interviews.	To further define scope and nature of the problem and identify possible solutions.
• Human digital modelling.	To quantify problem and investigate solutions.
• Trials of potential solutions.	To assess performance and usability of solutions.

14.1.2 Work Package 2: M_2, M_3, N_1, N_2 & N_3 - View to rear

Subtasks within this package may include:

• In-depth accident data analysis. • Driver consultations/interviews. • Operator consultations/interviews. • Manufacturer consultations/interviews.	To further define scope and nature of the problem and identify possible solutions.
• Definition of field of view requirement.	To specify drivers' requirements for rear vision.
• Human digital modelling.	To quantify problem and investigate solutions.
• Trials of potential solutions.	To assess performance and usability of solutions.

14.1.3 Work Package 3: M_2, M_3, N_1, N_2 & N_3 - Compare and optimise indirect vision systems

Subtasks within this package may include:

• Driver consultations/interviews.	To further define scope and nature of the problem and identify possible solutions.
• Operator consultations/interviews.	
• Manufacturer consultations/interviews.	
• Human digital modelling.	To quantify problem and investigate solutions.
• Desktop evaluation of relative usability.	Benchmark performance of systems and shortlist those for trialling.
• Trials of potential solutions.	To assess performance and usability of solutions.

14.1.4 Work Package 4: M_1 - A-pillar obscuration

Subtasks within this package may include:

• Confirm work package scope – A-pillar; dual A-pillar, B-pillar.	
• In-depth accident data analysis.	To further define scope and nature of the problem and identify possible solutions.
• Driver consultations/interviews.	
• Manufacturer consultations/interviews.	
• Human digital modelling.	To quantify problem and investigate solutions.
• Propose solutions.	

14.1.5 Work Package 5: N_1 – Field of view for non-M_1 derivative vehicles

Subtasks within this package may include:

• In-depth accident data analysis. • Driver consultations/interviews. • Operator consultations/interviews. • Manufacturer consultations/interviews.	To further define scope and nature of the problem and identify possible solutions.
• Definition of field of view requirement.	To specify drivers' requirements for rear vision.
• Human digital modelling.	To quantify problem and investigate solutions.
• Trials of potential solutions.	To assess performance and usability of solutions.

14.2 Outline description of identified work package sub-tasks

14.2.1 In-depth accident data analysis

While existing studies have been reviewed within Phase 1, the aim of this sub-task is to target and analyse the most recent accident data in support of the specific requirements of the main study and to ask questions that are most relevant.

Sources of Data

On-the-Spot (OTS)

The VSRC carry out in-depth, On The Spot (OTS) accident investigations for the DfT. Consequently the Centre has considerable experience analysing the resulting database containing over 4500 cases gathered in both the Nottinghamshire (by VSRC) and Thames Valley (by TRL Ltd.) regions. The statistical sample plan is designed to ensure a selection of accidents that broadly represents the national population, including all types of collisions and road-user types reported to the police, with both injury and non-injury collisions.

Factors contributing to the causes of accidents, including those relating to: vision issues, relevant vehicle, environmental and road user characteristics, are recorded within the database and so accidents arising from restricted field of view should be readily identifiable e.g. s_9983 Failure to see pedestrian in blind spot; int_0006 Looked but did not see due to vehicle geometry (e.g. blind spot; windows obscured; s_8811 Vision affected by vehicle blind spot. Whilst OTS is ideal for an in-depth investigation of factors relevant to this project, there is a limitation that if the relevant incidents are rare this will reflect in the limited number of cases available for review.

STATS19

Additionally the VSRC holds the national (STATS19) accident data set and has considerable analytical experience in this area. STATS19 includes valuable information for all police reported injury accidents, including accident scenarios, basic road user characteristics and police assigned contributory factors. With permission, the VSRC are able to link STATS19 to the contributory factors and vehicle make and model data for more extended analyses. Whilst this database provides comprehensive cover of all injury accidents in Britain and therefore has a huge number of cases; most of the accidents are not examined in-depth by specialist investigators which may therefore affect the accuracy of any vision-related codings entered; it will also not have the same level of qualitative detail as OTS. STATS19 has contributory factors relating to "vision affected", namely affected by parked vehicle, vegetation, road layout buildings, dazzling headlights, dazzling sun, rain, spray, dirty windscreen, and finally vehicle blind spot. Suitable contributory factors which could be investigated are: 205 'Defective or missing mirrors' and 710 'Vehicle blind spot'. Using these factors typical data which could be investigated include: The types of vehicles associated with the blind spots; the type of road user (collision partner) concealed by the blind spot; vehicle manoeuvres; relative directions of travel; first points of impact; accident severity, road type, junction detail, time of day, weather and light conditions; driver age and gender as well as foreign registration and left-hand drive vehicles. One means for conducting this activity is for the VSRC to work in conjunction with DfT officers in the interrogation of this database.

Co-operative Crash Injury Study

The Co-operative Crash Injury Study (CCIS) is based on vehicle examinations, with some brief background information about the crash incident available from police sources in many cases. However, due to the nature of the data collected, this database is not considered to be a suitable source of information regarding field of view accident factors.

Truck Crash Injury Study (TCIS)

Within HVCIS, of which the Truck Crash Injury Study (TCIS) is a part, there is coding for vision-related factors: 1 Improve forward vision; 2 Improve rear vision; 3 Improve side vision; 4 Use beacon; 5 Improve lighting; 6 Improve conspicuity which suggests that there could be some contribution from this database to this project. It would therefore seem prudent to undertake an initial investigation to determine the value of such a contribution and it is anticipated that the VSRC will shortly be in a position to have access to this database thus facilitating these investigations.

Police Fatal Files

Investigations into the suitability of this database in terms of what data is recorded, data accuracy, data accessibility, etc, are being made with TRL who hold the information.

Outline Methodology & Deliverables

This sub-task would undertake a thorough analysis of the national (STATS19) database; the in-depth (OTS) database and any other databases confirmed as relevant to explore potential visibility issues. The national data would be used to indicate the scale and significance of any trends or observations in Great Britain, while the in-depth data would explore mechanisms involving vision problems that may lead to the occurrence of accidents. Specific aspects of the data to be addressed would include:

- Accident scenarios and manoeuvres commonly involving vision issues, for example involving accidents at junctions, overtaking or lane changing.
- Vehicle characteristics relating to visibility issues, including mirror design, window and pillar geometry, tinted glazing and other obscuration related considerations.

- Driver characteristics relating to vision difficulties.

The following key methodological steps are proposed:

- Define specific questions and hypotheses to be addressed to best enhance current knowledge.
- Undertake an overview study of the STATS19 data.
- Incorporate contributory factors and vehicle make and model data into the STATS19 analysis for a more detailed exploration of these factors, as outlined above.
- With additional direction provided by the STATS19 results, the detailed OTS analysis would take place to include vehicle, road user and environmental factors, as outlined above. Witness statements and questionnaire responses would be examined together with scene/vehicle photographs and reconstruction evidence for selected cases of interest.
- A report would be produced to include results and conclusions to be incorporated into the main study.

14.2.2 Driver/operator/manufacturer consultations/interviews

Sources of data

Accident data reviews undertaken within Phase 1 and any subsequent novel accident data investigations will help to quantify the scale of any vision-related problems and identify relevant accident characteristics e.g. are the accidents related to type of manoeuvre, time of day, etc. However it is proposed to underpin such data by undertaking driver and/or operator and/or manufacturer consultations with a view to providing more detailed insights into what is happening in the real world and why such incidents may be occurring, as well as providing an insight into visual problems which may not (yet) be being reflected in the accident data. Although a comprehensive consultation with drivers/operators/manufacturers was undertaken by Tait and Southall (1998), this may now be outdated with the introduction of new vehicle designs. Therefore this might be a timely point to review these aspects and so extend the depth of the initial consultations undertaken within Phase 1.

Outline Methodology & Deliverables

Areas to be probed with the drivers/operators/manufacturers would be discussed and agreed with the Department's project officer in advance but could include aspects such as: visual problems drivers/operators/manufacturers are aware of with current vehicle designs; how such problems relate to different vehicle types and/or manoeuvres; causes and solutions to visual problems; examples of good practice; personal experiences of accidents/near misses involving visibility issues; mirror design, use and adjustment; constraints to vehicle design; perceptions and experience of additional technology such as camera monitor systems, radar and ultrasound; the role of equipment and ancillaries in field of view obscuration; etc.

It is proposed to use a combined methodology of both email questionnaires and face-to-face interviews to obtain an appropriate, yet cost-effective, breadth and depth of data collection.

- Drivers will be invited to participate from a number of different sources, such as delivery/haulage companies, bus/coach companies, driver training centres (e.g. National Driver Improvement Scheme, Institute of Advanced Motorists), as appropriate. In addition, interviews could be held with drivers at relevant locations e.g. local truck stops, depots, etc.
- A range of operators will be sampled within the consultation with the intention of reflecting variations in the: type of vehicle operated; area of operation; organisational size, etc. It is anticipated that most consultations will take the form of telephone interviews with visits to key organisations, as appropriate.
- Relevant technical specialists at the vehicle manufacturers will be identified and invited to contribute to the research. A similar approach of telephone interviews and visits will be adopted.

14.2.3 Definition of field of view requirement

The aim of this sub-task is to determine the field of view which the driver ideally needs to see in order to support safe driving. This is not necessarily the same as that specified by the regulations. In fact, earlier work by ESRI (now Loughborough Design School at Loughborough University) for the Department concerning drivers' field of view from large vehicles, suggests that an ergonomics specification based on drivers' needs may be more demanding of vehicle design than that required by legislation. The value of an ergonomics field of view specification is that it provides an idealised benchmark for designers to work towards as well as providing important insights into how to address key problem areas relating to vision. This sub-task is required for two work packages:

- Work Package 2: M_2, M_3, N_1, N_2 & N_3 - View to rear;
- Work Package 5: N_1 – Field of view for non-M_1 derivative vehicles.

Work package 2 will work to define the view to the rear of the vehicle which drivers need when undertaking certain manoeuvres. This work package will be necessarily large since it is covering a wide range of vehicle categories whose characteristics and applications vary significantly. Work package 5, although focussed on N_1 (non-M_1 derivative) vehicles will also be necessarily large since it will consider the field of view to the front, sides and rear of the vehicles.

Sources of data

A number of data sources will need to be drawn from to develop the specification; past research suggests that these are likely to include:

Task analysis – swept path

Driving is a dynamic task and the driver needs to be able to have an awareness of what is happening around the vehicle whilst doing so. The vehicles' swept path and body envelope define the areas required by a vehicle when manoeuvring and therefore define areas of safety-critical interaction with other road users. The position of the vehicle elements in particular road layout examples can be used as specific tests in the SAMMIE system to explore field of view issues. In keeping with ESRI's previous field of view research for the Department, it is proposed to use appropriate CAD modelling, such as AutoTrack for highway design, to precisely define such key critical areas which can then be used to develop the ergonomics field of view specification based on drivers' needs.

Review of drivers' needs

The driver consultations, and to an extent the operator and manufacturer consultations, will provide valuable input into identifying key areas of visual requirement to aid safe driving. Ideally, this activity will be extended within this sub-task to enable opportunities for the project researchers to accompany the drivers in order to enable direct observation of the driving task.

Review of previous field of view specifications

Previous field of view specifications identified in Phase 1 will be re-visited to determine how the knowledge developed within them may be applicable to this sub-task. For instance the need to see into junctions, observe road signs and signals, monitor kerb and lane markings, etc, will be common across vehicle categories.

14.2.4 Desktop evaluation of relative usability

Sources of data

Using data from Phase 1 and from driver/operator/manufacturer consultations various systems for indirect vision will be identified covering mirrors, camera monitor systems, sensors, etc. A market review of such products will then be undertaken to investigate the extent of variation within the market for these products and to gather known performance data. The suppliers/manufacturers of such systems, who will be identified through the consultations and via on-line searches, will be approached to discuss their system range and product specifications as well as to address any specific questions by the project team.

Outline Methodology & Deliverables

The methodology for this sub-task will include:

- Identification of indirect vision systems;
- Market review of product range;
- Review of specifications against ergonomics criteria to assess usability;
- Review of specifications against driving task to determine the extent to which the product will meet drivers' needs. The driving task information will be derived from Phase 1 and from driver/operator/manufacturer consultations.
- Identification of knowledge gaps in product performance. (It is recognised that there are likely to be some aspects of the products' performance which will be difficult to evaluate by desktop methods).
- Identification of products to be short-listed for review within assessment trials.

Where possible it is intended that this sub-task is supported by observations of the products in real or simulated conditions of use either in the field with operators or in-house.

14.2.5 Human Digital Modelling

The SAMMIE CAD digital Human Modelling system which was successfully used to analyse and develop field of view specifications for large vehicles - M_2, M_3, N_2 and N_3 vehicles (Tait and Southall, 1999) and for PNCAP – M_1 vehicles (Shearlaw and Freer, 2002) will be applied within this sub-task. The system has the advantages of:

- Accurate and reliable simulation and testing of vehicle attributes;
- Variable human manikin modelling in terms of percentile range, gender and nationality.
- Valid human manikin modelling through the use of multivariate data opposed to univariate data (where the same percentile value is used for all body segments). This is achieved by means of the ACADRE human model set which is statistically derived to account for the variation in body proportion values exhibited in real users.
- Quick prototyping and testing of proposed solutions.
- Illustrative outputs in a readily assimilable visual form depicted either in the form of 'ground' plots or the 'human model's view' plots.

<u>Sources of data</u>

<u>Driver observations</u>

In order to increase the validity of the modelling it is important to understand how the drivers undertake the driving task by exploring issues such as:

- The adjustments made to the seat to allow comfortable driving and the capture of the driving posture for a suitable range of driver sizes (5th%ile UK male to 99th%ile UK male stature);
- The methods used for the adjustment of mirrors;
- The capture of the interaction points within the vehicle that force the driver to change the driving posture (e.g. reaching to switches and controls) and the resultant mirror issues use that arise from the changed driving posture;

- The frequency of use of these interaction points captured through direct observation of the driver during a normal driving shift.

Such data will be captured through visits to various vehicle category operators.

Vehicle data

The category of vehicles to be modelled and the variants within them need to be defined. Since this sub-task of Human Digital Modelling cuts across all work packages, this sub-task could potentially involve all vehicle categories:

- Work Package 1: N_2 & N_3 – Blind spot to front quarters and to side;
- Work Package 2: M_2, M_3, N_1, N_2 & N_3 - View to rear;
- Work Package 3: M_2, M_3, N_1, N_2 & N_3 - Compare and optimise indirect vision systems;
- Work Package 4: M_1 - A-pillar obscuration;
- Work Package 5: N_1 – Field of view for non-M1 derivative vehicles.

Following identification, manufacturers' CAD data will be solicited and/or representative vehicles digitised via the FARO arm data capture system.

Outline Methodology & Deliverables

Typical activities within this sub-task are likely to include:

- Modelling of vehicles in CAD systems using the manufacturers' data and/or the digitised data.
- The building of mirror Classes I through VI with correct focal length for each vehicle.
- Analysis of the vehicle models to determine the blind spots with reference to a specified field of view requirement through the use of the PNCAP visibility protocol previously defined by SAMMIE CAD ltd. In addition, this will be represented through the use of the mirror projection feature of the SAMMIE DHM system. This allows the volumes of the visible space through mirrors to be visualised using a ray tracing method as shown by the blue volume in Figure 46 which is showing the Class V mirror visibility. This will be performed using 5th%ile UK female and 99th%ile UK male Human models. In this way, this sub-task will therefore assess the extent to which the vehicle design characteristics permit a satisfactory field of view for a specific vehicle category

for any given vehicle-driver combination, identifying any anomalies which may occur. As well as assessing the vision plotted on the ground-plane, it may be beneficial to repeat the plots for planes at some significant distance above the ground, for example at head height for a young child.

Figure 46: Example of mirror projection feature – Blue rays

- Scenarios that were defined by the consultation interviews and the interviews with HGV drivers will be modelled to verify if the described blind spots exist e.g. for N_2 and N_3 vehicles this may include:
  - The close proximity of cyclists and pedestrians in an urban environment when the vehicle is stationary at traffic lights or pedestrian crossings;
  - The potential effects of blind spots during motorway driving during lane change manoeuvres and joining the motorway;
  - The potential effects of blind spots during vehicle manoeuvring in urban environments such as performing a left turn and reversing the vehicle.

  Both RHD and LHD vehicles can be modelled for investigation.
- The issue of poor adjustment of mirrors can be examined by modelling a small UK female (5th%ile), a medium sized UK male (50th%ile) and a large UK male (99th%ile). The implication of poor mirror setup will then be analysed by assessing visibility using the mirrors for the following conditions:
  - The 99th%ile UK male using mirrors setup for a 5th%ile UK female;
  - The 5th%ile UK female using mirrors setup for the 99th%ile UK male;
  - The 50th%ile UK male using mirror setups for both the 5th%ile UK female and 99th%ile UK male.

Each of these conditions will be tested with selected worst case scenarios defined from Phase 1 and 2.

14.2.6 Trials of potential solutions

This is a broad-based sub-task with a number activities associated with it. They are discussed here for completeness although it is recognised that it may not be possible, nor desirable, to commission all of them. The extent to which this sub-task, and the others described above, are to be applied within Phase 2 needs to be considered and discussed by the Department and the project team.

Solution specification

The output of the previous task will identify the field of view problems which need to be addressed in order to improve driver vision from the vehicle.

Having specified these initial requirements for a given design solution, a review will be undertaken to identify the range of suitable alternatives which might exist within the market. This will highlight both examples of best practice in vehicles and also devices that are sold as after-market fitments to improve driver view. The review may also investigate recent patents to identify systems not yet on the market. Whilst some of this information will have been probed within Phase 1, it is likely that certain elements of it will need to be investigated more deeply in order to understand in detail how they could be applied at this point. With respect to direct vision, this may relate to identifying examples of best practice; e.g. investigating concept vehicles and investigating related transport forms; e.g. agricultural vehicles.

For indirect vision solutions this may entail a more detailed market review of mirror and camera monitor systems and comparison of their performance specifications against the specification for solution requirements. Refer to section 14.2.4.

Review of potential solutions

Potential design solutions concerning improvements to direct vision can be readily assessed within the SAMMIE system using ground plane plots to demonstrate the extent of potential improvements which could be derived from alterations to body and trim design. The issue of the height of the driver position will be examined by incrementally reducing the height of the vehicle cab to allow a full understanding of the effects. This will highlight the potential for novel HGV cab designs with a lowered driving position to reduce blind spots.

With respect to indirect vision, design solutions relating to mirrors with different focal lengths and the use of camera monitor systems, can also be modelled and assessed. For example, the 'gull wing' type mirrors used on Coaches were described as a desirable solution and the benefits of these mirror configurations could be determined.

Solution development - Ergonomics requirements

The aim of this task is to determine the form of the solution and its suitability for use by the driver population. For real world assessment, the solutions will need to be installed within the vehicle for assessment. Some solutions may simply be off-the-shelf components which can be readily fitted to the vehicle; others may require some form of development/modification prior to installation.

In terms of indirect vision devices, Phase 1 research has indicated that there are concerns regarding the amount of visual monitoring of indirect vision devices which the driver needs to undertake; therefore it is important that for any solution the information conveyed can be reliably perceived and interpreted. For instance, past research by ESRI in this area defined a usable radius of curvature for mirrors which optimised the extent of the reflected field of view against the accuracy of judgements of: pedestrian offset to the side of the vehicle; the driver's ability to reverse accurately and their accuracy in judging closing speed.

Additionally, it should be noted that if the driver is too visually overloaded to look into the mirror and so detect a hazard, then an alternative system which detects the hazard on their behalf and alerts them to it, through some form of warning tone, might be favourable. However this will need to be considered in the context of other auditory information to which the driver may be attending.

Field trial validation

Operator trials

The purpose of operator trials is to evaluate potential solutions amongst experienced drivers carrying out their day-to-day duties. A cost-effective way to do this is to recruit a fleet operator to participate in the trials. This will link the project to a variety of professional drivers, carrying out their daily duties, and is therefore a realistic form of investigating new solutions. The advantage of this is that it either offers considerable cost savings over driver trials organised as a separate exercise, or alternatively permits a much larger trial to be conducted under the same budget. The disadvantage is that many factors cannot be controlled as they might in a dedicated trial. One way to overcome this is to extend the trial over more drivers/routes/vehicles but this would extend the time allocated. Embarking on an operator trial would be conditional on ESRI/MIRA getting the agreement of a suitable haulier who would be willing to participate. Although no enquiries have been launched at this stage, it is considered likely that participation would be an attractive proposition for a reputable company, because they would be able to demonstrate their commitment to safety and would have access to and early experience of any cutting edge technologies involved in the trials. Alternatively, the project team may piggy-back on trials being independently conducted by operators.

The scenario envisaged is for three types of solution (e.g. a mirror, a camera monitor device and a form of blind-spot detector) to be tested singly and in combinations of two and three together, thus giving six configurations in all. These would be installed on two types of vehicle. One of these would be selected as the vehicle type judged to the most appropriate to benefit from fitting the solutions, and another judged to be less appropriate, to assess the breadth of application of the solutions. The aim of the trial is to obtain data from at least ten different drivers and if possible to have each of these try all of the solution combinations, so preference will be given to partners with a duty roster with regular changes in driver/vehicle allocation. Each driver would be expected to drive with the combination for at least 1 day in order to become accustomed to its use. Ideally this would be extended to 3 days to give some variation in weather, route, traffic conditions etc. However, this would depend on the duty roster because it would only be beneficial if these days were consecutive or following within a short time span.

The methodology envisaged for the trials is for the driver to be interviewed on completion of each trial. This would assess the amount the driver used the solution in comparison with other driver awareness systems, how it affected their overall awareness of traffic, etc. It would also seek their views on the practicalities of operating the devices and any specific problems they encountered in using them.

An alternative approach to the operator trials would be to recruit a driving school offering HGV instruction. This has some advantages over the trials with a fleet operator because there would be an opportunity to gather a large amount of data in a relatively short time, and the instructor would in effect take on the role of an "expert assessor", able to observe in detail how their students were able to cope with the system under assessment. However, it is not known whether a driving school might be willing to change the configuration of a training vehicle, since they might consider it introduces an unnecessary change into a student's instruction, and therefore reduce their chances of passing the test.

MIRA organised trials

These trials would be an alternative way to evaluate solutions, in the event that a suitable partner cannot be found. Alternatively, they might be used to eliminate gaps that occur in a fleet programme, for example if data from one key type of vehicle could not be obtained in any other way. MIRA and its customers have access to skilled test drivers via dedicated contract driver agencies. These drivers are much more experienced than the fleet drivers envisaged in the preceding section, and therefore possibly more likely to be able to highlight the technical aspects of the systems on test. A trial organised in this way would give the partners complete control over all the operating factors such as test route, time, weather etc. However, the cost of running a trial in this way would be borne by the project rather than by the fleet operator, and this would include the cost of hiring a suitable vehicle, the running costs of the vehicles in full, as well as the drivers' wages. In order to limit costs to a reasonable level, the trials envisaged would be limited to three solutions evaluated singly, on two vehicle types and using three drivers, each driving for 1 day. They would be conducted on a single route that was selected to give the widest range of driving conditions within the available time. However, to compensate for the restricted range of driving, the interviews would be more intensive to reflect the driver's greater technical knowledge.

Another possible application of this type of trial would be if side swipe accidents involving left-hand drive trucks on UK roads proved to be a priority for the project.

MIRA owns a left-hand drive tractor unit that could be made available for the testing. However, this vehicle is not regularly used on public roads, so the trials might need to take place on the MIRA Proving Ground, using other vehicles to simulate traffic interactions.

Expert appraisal

Driver consultation

To increase the breadth of the data, thus complementing the in-depth data obtained in the validation trials, it is proposed to undertake wider consultation with drivers by means of static trials. It is envisaged that the test vehicle is taken to an appropriate venue, such as a truck stop, motorway services, etc, and that drivers are invited to use the system in a static setting. Whilst such an approach will undoubtedly lack the realism of the previous task, it will enable wider scale feedback regarding: drivers' likely concerns; issues of acceptability; comments on the scope and form of the solution; comments on its implementation; etc. By providing feedback concerning the solution design and implementation, the drivers' comments will provide a valuable, additional contribution concerning any design refinements as well as providing useful input into the Impact Assessment in terms of addressing driver suitability and acceptability.

Expert consultation

In conjunction with the driver consultations, it is further proposed to consult with relevant experts e.g. those who train the drivers, fleet managers, etc, in order that their opinions as to the benefits and problems associated with the identified solution can also be gathered. Ideally these consultations would involve a brief test drive, thus giving greater validity to their responses which would be similarly used to further refine the design as well as provide input into the Impact Assessment task below.

14.3 Data assimilation

The aim of this task is to consolidate the findings of the previous research tasks in order that the key issues identified in the Work Specification are addressed. That is to say, for each field of view problem, a substantial knowledge base should be created describing:

- What is the cause,
- What each solution would achieve,
- What effect they have on design/manufacture,
- What effect they have on the driver,
- Whether or not they require legislation,
- Costs to inform an impact assessment,
- Casualty reduction benefits.

As the data is consolidated, further questions relating to the clarification of emerging issues may arise. In this case, advice will be sought with relevant experts, many of whom will already have links into the project via the consultation task in Phase 1.

14.4 Comprehensive impact assessment

The project specification calls for a comprehensive impact assessment on the measures proposed by the project. This will be carried out by MIRA, based on its experience from previous work for the Department on Changes in Minimum Tyre Tread Depth Requirements.

The assessment will be carried out according to the guidelines issued by the Department for Business Innovation and Skills. It will include the identification of stakeholders and how they will be affected by the proposed measures. It will examine the costs of implementation and how they should be attributed and also determine the potential benefits and who will receive them. It will also identify consequences which result from the proposed measures. It is likely that benefits will be in terms of the projected saving in vehicle damage costs and the saving in the cost of treating injuries prevented by them. If the solution calls for the installation of some new device on an otherwise unchanged vehicle, the costs will be based on the projected cost of each new device, multiplied by the number that must be installed. If the solution calls for a more fundamental change in vehicle design, MIRA will consult with manufacturers to assess the increase in costs that the changes are likely to incur. In each case, knowledge of the number of affected vehicles will be needed on a year-by-year basis. MIRA will consult with the Department, and may have to make some assumptions, about the implementation of the changes and whether this would require the existing vehicle fleet to be retrofitted or whether the changes would be introduced by requiring new vehicles to be fitted with them after a certain date. Finally, the assessment will review this balance of costs and benefits and advise whether the changes should be implemented accordingly.

14.5 Final report

A report will be produced describing the approach to Phase 2 and the rationale for it. The report will be sub-divided into sections pertaining to each of the field of view issues addressed within Phase 2 and their accompanying solutions. Within each section, the items described in Section 5.2.1 of the project's work specification will be discussed and supported/illustrated by the research evidence. An overview of the project and its outcomes will be presented in the form of an executive summary prefacing the report.

15 REFERENCES

15.1 Literature review

Allen, M. J., Abrams, B. S., Ginsburg, A. P. and Weintraub, L., 1996. Forensic aspects of vision and highway safety. Lawyers & Judges Publishing Co, Inc.

Anslow, Mark. 2004. Study into Trunk Road Accidents Involving Goods Vehicles. Highways Agency SLVR.

APROSYS. 2005. Preliminary Aggressivity Index report AP-SP21-0047.

Basford, L., Reid, S., Lester, T., Thomson, J., Tolmie, A. 2002. Drivers' perceptions of cyclists. Prepared for Charging and Local Transport Division, Department for Transport.

Blower, Daniel. 2007. Truck mirrors, fields of view and serious truck crashes. Report No. UMTRI-2007-25. The University of Michigan - Transportation Research Institute, Ann Arbor, Michigan 48109-2150, U.S.A.

Boggess,B., Wiechel, J., Morr, D., Anderson, J. and Pipo, J. 2008. Anatomical Limitations of the Visual Field of View: An Example of Driving Perspective. SAE TECHNICAL PAPER SERIES 2008-01-1876.

Brown, I.D. 2005. Road Safety Research Report No. 60. Review of the 'Looked but Failed to See' Accident Causation Factor.

Cairney, P. and Catchpole, J. 1996. Patterns of perceptual failures at intersections of arterial roads and local streets. Vision in vehicles V, page 87-94.

Chong, J., and Triggs, T. J., 1989. Visual Accommodation and target detection in the vicinity of a window post. Human Factors, 31(1). The Human Factors Society, pp. 63 – 75.

Cook, Sharon et al. 2007. Powered two wheeler Integrated Safety (PISa): Review of PTW safety technologies and literature.

Cook, Sharon. 2006. Vision and visibility lecture notes. Loughborough University.

Cook, Sharon et al. 2000. Quality and field of vision – A review of the needs of drivers and riders. Loughborough University. Report for Department for Transport PPAD 9/33/39.

Couper, G.J. 2006. HGV blind-spot modelling and reconstruction trial.

Crundall,D. E., Underwood, G. and Chapman, P.R. 1999. Peripheral detection rates in drivers. Vision in vehicles- VII, 1999. 261-269.

Crundall, D. E.; Underwood, G. and Chapman, P. R. 1999. Peripheral detection rates in drivers. Vision in Vehicles – VII, pages 261-269.

Daigo, H., Yokoi, K., and Nakano, H. 1982. Performance of heavy duty trucks with improved field of view. Ninth International technical conference on experimental safety vehicles.

Danton,R., Kirk, A., Rackliff, L., Hill,J., Gisby,R., Pearce, D. and Dodson,E. Left-hand drive HGVs and foreign truck drivers in OTS, report PPRO 4/012/032 for the Department for Transport, September 2008.

Dodd, M. 2009. Follow on study to the heavy goods vehicle blind spot modelling and reconstruction trial. Published report PPR403.

eSafetyAware! Undated. Promoting advanced vehicle safety technologies – eSafety background paper. Available on-line: http://www.esafetychallenge.eu/download/challenge/esafety_background_paper.pdf

Fastenmeier, Wolfgang and Gstalter, Herbert. 2007. Driving task analysis as a tool in traffic safety research and practice. Safety Science. Vol. 45, Issue 9, pages 952-979.

Fenn, B., Dodd, M., Smith, L., McCarthy, M. and Couper, G. 2005. Potential casualty saving from fitting blind spot mirrors (Class V mirrors) to heavy goods vehicles – Final report.

Fitch, J. 2007. Final Report LHD Vehicles Blind Spot.

Flannagan, M.J. and Mefford, M.J. 2005. Distance perception with a camera-based rear vision system in actual driving. Report No. UMTRI-2005-38.

Flannagan, Michael. J. and Mefford, Mary Lynn. 2005. Distance perception with a camera-based rear vision system in actual driving. Report No. UMTRI-2005-38. The University of Michigan - Transportation Research Institute, Ann Arbor, Michigan 48109-2150, U.S.A.

Flannagan, M.J., Sivak, M. andn Traube, E.C. 1997. Effects of Large-Radius Convex Rear-view Mirrors on Driver Perception.

Gattis, J. L. and Low, Sonny T. 1998. Intersection angle geometry and the driver's field of view. Transportation Research Record 1612.

Haslegrave, C.M. 1993. Visual aspects in vehicle design. Automotive ergonomics, Capter 4, page 79-97.

Jacobs Consultancy. 2004. Cost-benefit analysis of blind spot mirrors final report.

Keigan, M.; Cuerdon, R. and Wheeler, A. 2009. Analysis of police collision files for pedal cyclist fatalities in London, 2001-2006. Transport Research Laboratory. Published Project Report PPR438.

Kinoshita., Y. 2007. Development of Front Pillar Structure With No Blind Spot (Second Report). JSAE Technical Paper No. 20075072.

Kirk, Alan and Hill, Julian. 2010. On The Spot accident data collection – Accident causation study – Volume 2: Overview of OTS accident causation data. Vehicle Safety Research Centre, Loughborough University. Unpublished report for the Department for Transport.

Larue, C. and Giguere, D. 1999. Understanding the role of blind spots around heavy goods vehicles: Perception, measurements and 3D visualisation. Vision in Vehicles – VII. Pages 443-450.

Lemay, P. and Vincent, A. 1998. School Bus Visibility: Driver's Field of View and Performance of Mirror Systems on a Conventional Long-Nosed School Bus.SAE TECHNICAL PAPER SERIES 980923.

Millington, V.A., Cuerden, R., Hulse, S., and Brightman, T. 2006. Investigation into 'A' Pillar Obscuration – A Study to Quantify the Problem Using Real World Data. PPR159 S0414/V8.

Ministry of Justice. 2009. Summary of reports under Rule 43 of the Coroners Rules, and responses. Available on–line: http://www.justice.gov.uk/publications/summary-reports-rule-43-coroners-rules.htm

Mosedale, Jonathan; Purdy, Andrew and Clarkson, Eddie. 2003. Contributory factors to road accidents. Transport Statistics: Road Safety, Department for Transport.

Olson & Farber 2003 Forensic aspects of driver perception and response Lawyers & Judges Publishing Company Inc.

Picker, David. 2004. A-pillar obstruction study. Vehicle Certification Agency.

Platzer, G. 1995. The Geometry of Automotive Rear-view Mirrors - Why Blind Zones Exist and Strategies to Overcome Them. SAE TECHNICAL PAPER SERIES International Congress and Exposition Detroit, Michigan February 27 - March 2.

Quigley, C. et al. 2001. Field of vision (A-pillar geometry) – A review of the needs of drivers – Final report. Department for Transport report - PPAD 9/33/39.

Road Safety and Transport Agency. Undated. Danish proposal for direct vision in heavy good vehicles N_2/N_3.

Rönnäng, M., Lämkull, D., Dukic, T. and Örtengren, R. 2004. Task-related Field of View Parameters. SAE TECHNICAL PAPER SERIES 2004-01-2195.
Schouller, J.F. and Hella, F. 1998. The effect of partial restrictions of visibility when driving an industrial vehicle. Vision in vehicles- VI, 1998, page 353-359.

Shearlaw, A. and Freer, M. 2002. ICE ergonomics Ltd. PNCAP Visibility: Defining and Assessing the Safety Critical Field of View.

Shiosaka,Y. 1995. Research on forward direct field of view of trucks- drivable field of view required for urban road driving. International Pacific conference on Automotive engineering. Pages 13-18.

Shinar, D. and Scheiber, F. (1991) Visual requirements for safety and mobility of older drivers. Human Factors, 33, (5), 507-519.

Sivak, Michael; Schoette, Brandon; Reed, Matthew and Flannagan, Michael. 2005. Influence of the visibility out of the vehicle cabin on lane-change crashes. Report No. UMTRI-2005-32. The University of Michigan - Transportation Research Institute, Ann Arbor, Michigan 48109-2150, U.S.A.

Smith, David, B. D.; Meshkati, Najmedin and Robertson, Michelle. M. 1993 the older driver and passenger in Automotive Ergonomics. Peacock, Brian and Karwowski, Waldemar Editors. Taylor & Francis.

Southall et al. 1999. Quality and field of vision - a review of the needs of drivers and riders: Phase 1 report. Loughborough University. Report for Department for Transport – PPAD 9/33/39.

Southall et al. 1998. Drivers' field of view from large vehicles – Phase 2 Report. Loughborough University. Report for Department for Transport.

Swigart, .F. and Farber, E. 1973. Side field of view target areas.

Tait and Southall. 1999. Drivers' field of view from large vehicles – Phase 4 Final report. Loughborough University. Reprot for the Department for the Environment, Transport and the Regions.

Tait and Southall. 1998. Drivers' field of view from large vehicles – Phase 3 Report. Loughborough University. Report for Department for Transport.

The Royal Society for the Prevention of Accidents (RoSPA) 2010 Older drivers – Policy paper. Available online: http://www.rospa.com/RoadSafety/Policy/Statements/older-drivers.aspx.

The Royal Society for the Prevention of Accidents (RoSPA). 2007. Left-hand drive vehicles: Dangers and solutions. Available online: http://www.rospa.com/roadsafety/advice/driving/info/lhd_hgv.pdf

The Royal Society for the Prevention of Accidents (RoSPA) 2006. Cyclists and lorries factsheet. Available on-line at: www.rospa.com/RoadSafety/advice/cycling/info/cyclists_and_lorries_factsheet_0206.pdf - 2010-01-22
Tijerina, Louis 1996. Heavy vehicle driver workload assessment. U.S. Departmetn of Transportation – National Highway Traffic Safety Administration.

Vincent, A. and Lemay, P. 1997. The Effects of Image Size and Luminance Contrast on Object Detection and Discrimination in Cross View Mirrors. SAE TECHNICAL PAPER SERIES International Congress & Exposition Detroit, Michigan February 24-27.

Walker, Guy. H.; Stanton, Neville. A. and Young, Mark. S. 2001. Hierarchical Task Analysis of Driving: A New Research Too. Contemporary Ergonomics 2001, vol 1, Part 23 pages 435-440.

White Willow Transport Intelligence. 2006. HGV Side Swipe Technology Review. Department for Transport.

15.2 Legislation Review

United Nations Economic Commission for Europe Consolidated Resolution on the Construction of Vehicles (R.E.3), Annex 7. Document TRANS/WP.29/78/Rev.1/Amend.2

Road Vehicles (Construction and Use) Regulations, Section 33 "Mirrors and Other Devices for Indirect Vision". SI 1986 No 1078

"Type Approval of Devices for Indirect Vision and of Vehicles Equipped with these Devices", European Directive 71/127/EEC, as amended by 2005/27/EC and 2006/96/EC.

"Uniform Provisions for Devices for Indirect Vision and of Motor Vehicles with Regard to the Installation of these Devices", Regulation ECE46.02

"Mirrors and Other Devices for Indirect Vision", StVZO Section 56, last amended by Amendment 43, Dec 2008.Translation from German by InterRegs, Feb 2009.

Federal Motor Vehicle Safety Standard FMVSS111 Rear View Mirrors, amended to 8/4/2004.

Extract from Canadian Motor Vehicle Safety Standard CMVSS111 Rear View Mirrors

Extracts from Japanese Vehicle Approval Regulations and Standards, Translation from Japanese by ASICS, "Blue Book", 2007

Korean Standard for Rear View Mirrors, Article 50

Retrofitting of Mirrors to Heavy Goods Vehicles Registered in the Community", European Directive 2007/38/EC

"Field of Vision of Motor Vehicle Drivers", European Directive 77/649/EEC, amended by 81/643/EEC, 88/366/EEC and 90/630/EEC.

"Motor Vehicles with Regard to the Forward Field of Vision of the Driver", Regulation ECE125, as amended to 3/2/2008.

APPENDIX 1 – CONSULTATION: PARTICIPANT INFORMATION SHEET

Driver Vision from Vehicles Consultation

Information for participants

Background to this consultation

This consultation forms the initial part of a project being undertaken by Loughborough University and MIRA, commissioned by the Department for Transport (DfT), into driver vision. Previous research has been conducted into the drivers' view from the passenger side of large goods vehicles; the main finding was that there is still a large blind spot. Evidence from accident statistics also indicates that the drivers' field of view, both direct (what the driver can see directly through windows) and indirect (what the driver can see in mirrors and other assistive devices such as camera monitors) is an important factor in the provision of a safe transport system. In particular this research will consider:

- the direct field of view requirement for all M and N category vehicles;
- a requirement for the driver to be able to see a specific object (pedestrian/child) in the direct field of view;
- a link between the drivers' direct and indirect fields of view; and
- other related issues such as the trend for larger vehicles (e.g. bigger and higher)

The main objectives of this project are to provide information on what drivers of 'M' and 'N' category (at least four wheels and used for the carriage of passengers and goods respectively) vehicles **should be able to see, what they actually see** in the real world and **how their field of vision may be affected by vehicle design**. The research will identify blind spots in both the drivers' direct and indirect fields of view and will propose practical solutions to eliminate these.

Aim of this consultation

With respect to driver vision, the aim of this consultation is to engage with major interest groups who will have the knowledge and experience to highlight relevant issues and their relative importance. The following items are prompts for us to talk around; they may not all be relevant to you.

Scale and nature of the problem

How much of a problem is drivers' vision (both direct and indirect (mirrors/cameras)); to what extent might it contribute to accidents; how does it relate to speed/traffic/type of manoeuvre/weather/etc; how important is it compared to other safety issues; what factors may contribute to poor direct and indirect vision; what is the nature of any blind spots; are you aware of scenarios/do you have examples of vision related problems?

Use of vision
Do drivers use direct and indirect vision appropriately/sufficiently; when is it most important for drivers to have good vision both directly and indirectly? What do drivers need to see at what times; to what extent can they achieve this?

Vehicle design issues
What are the issues surrounding different types of vehicles (HGV vs. small car)? Does left or right-handed drive play a role? Are there any examples of vehicles with good or bad fields of vision? Are there any specific issues with the design of windscreen wipers or A, B and C pillars affecting the drivers' field of vision? What might be done to improve driver vision with respect to the structure of the vehicle?

Indirect vision
What measures can be put in place to improve or supplement indirect vision? What specific issues are there with mirror design: type of mirror, location, performance/vibration, field of vision? What might be done to improve drivers' vision through mirrors/cameras? What other methods/technologies might be used? How successful are such improvements?

Driver issues
To what extent are drivers aware of vision problems both direct and indirect; When and how do drivers compensate for poor vision? What factors relating to the driver might contribute to poor vision (vision, perception, training, experience, physical ability, driving position, workload/fatigue).

Any other points of interest to raise
Are you aware of any literature which may be useful to the study?
Who else should we be talking to?

Many thanks.

<contact details of interviewer>

APPENDIX 2 – CONSULTATION: INTERVIEW SCHEDULE

INTRODUCTION
Firstly, thank you for agreeing to talk with me – It is most appreciated.
As you will have seen from my original e-mail the purpose of talking with you is to discuss the extent to which both direct and indirect vision from four wheeled vehicles is an issue. (Re-iterate definition of direct and indirect vision). The study is being undertaken by Loughborough University on behalf of the Department for Transport. Using the attachment in the e-mail, I would therefore like to discuss some of the issues which you feel may be involved.
Before we start, I just want to confirm that you are happy for our conversation to be recorded – this is just to ensure that I don't miss anything when taking notes while talking. Are you happy with this?
All information will be held confidentially.
So far the discussions are taking ½ an hour to an hour – how does this fit with the timing you have available now?

Context of response (One line summary) Can you provide me with a brief summary of your association with motoring and motor vehicles?

INITIAL THOUGHTS (Record vehicle category)
Firstly, I would like to ask you what your initial thoughts are regarding this issue? Reasons for their view
SCALE OF PROBLEM (Record vehicle category)
Does your organisation collect any kind of accident data? If yes, can any specific attribution be made to issues to do with vision? If not, to what extent do they feel that vision from vehicles (both direct and indirect) is a problem – Are they aware from others that this is an issue? What factors may contribute to poor vision – both direct and indirect (probe mirrors, cameras, etc)? What are the scenarios - how does it relate to speed/traffic/type of manoeuvre/weather/etc?

What is the nature of any blind spots (direct and indirect)? Do they have examples of where this is an issue? How important is this compared to other safety issues? In your opinion in terms of accidents on the road, how many do you feel are due to problems related to vision out of/around the vehicle, as a percentage of total accidents? Within these accidents to what extent do you consider direct vision to be a main causal factor or a contributory factor? Within these accidents to what extent do you consider mirror vision to be a main causal factor or a contributory factor?
VEHICLE DESIGN (Record vehicle category)
How is vision affected by: • type of vehicle (vehicle category) • left or right hand drive Are they aware of good or bad examples (specific models if possible) within a particular vehicle category/type? Are there any specific issues with the design of windscreen wipers or A, B and C pillars affecting the drivers' field of vision? What might be done to improve driver vision with respect to the structure of the vehicle?
USE OF VISION (Record vehicle category)
Do drivers use direct and indirect vision sufficiently? Are mirrors being used appropriately? Are other indirect systems used appropriately? When is it most important for drivers to have good direct and indirect vision? through windows/mirrors? What do drivers need to see and at what times? To what extent can they achieve this?
INDIRECT VISION (Record vehicle category)
What measures can be put in place to improve or supplement indirect vision? What do they think of the performance of mirrors (mention classes of mirrors) – Are there any issues relating to their use (type of mirror, location of mirror, vibration of mirror)? What do they think of the field of view provided by mirrors? What do they think of the performance of camera systems (note the function of any camera systems) – Are there any issues relating to their use? If they use a camera system – Do they need mirrors as well?
DRIVER ISSUES (Record vehicle category)
To what extent are drivers aware of problems relating to direct and indirect vision (probe mirrors, cameras, etc)? When and how do drivers compensate for poor vision? What factors relating to the driver might contribute to poor vision (vision, perception, training, experience, physical ability, clothing, driving position, workload/fatigue)? Which types of drivers do you think that this is more important to? e.g. Class of driver, age, experience, level of training, etc? What do you think will be the changes to the driving population over the next 10-20 years?
SOLUTIONS (Record vehicle category)

Are they aware of any aftermarket modifications to improve visibility (traditional mirrors or other technological solutions – sensing devices, cameras, etc.)?
Are they aware of, or have they directly implemented any of these?
Are these solutions useful/successful?
What are the cost implications (purchase, running, replacement, time off road)?

ANY FURTHER POINTS (Record vehicle category)

Are there any further points which I have not covered?
Is there anyone else within your organisation whom we should be talking to?
Are there any other individuals/organisations whom we should contact?
Are you aware of any literature which may be useful to the study?

THANKS

I think that that brings our discussion to a close. Thank you for your time.

If you think of anything further which you want to add, please feel free to contact me.

Also if additional points arise to those we have discussed now, is it OK for me to contact you again?

Intentionally Blank

APPENDIX 3: CONSULTATION: INTERVIEW SUMMARIES

List of consultees

(B) Brigade, Philip Hanson-Abbott
Area of expertise / responsibility: Managing Director

(BRK) Brake, the road safety charity, Cathy Keeler
Area of expertise / responsibility: Deputy Chief Executive

(CB) Cynthia Barlow
Area of expertise / responsibility: Campaigner on driving accidents following death of daughter killed by a cement mixer whilst cycling, Chair of RoadPeace charity

(C) Cemex, Paul Clarke
Area of expertise / responsibility: Logistics Fleet Engineering Manager

(CPT) Confederation of Passenger Transport , Colin Coplin
Area of expertise / responsibility: Technical Executive

(CTC) Cyclist Touring Club, Chris Peck
Area of expertise / responsibility: Policy Coordinator including specific responsibility for vehicle safety

(DSA) Driving Standards Agency, Ashleigh Bateman
Area of expertise / responsibility: Standards and Regulations Directorate and Chair of Driving Exam board, Assistant Chief Driving Examiner

(FTA) Freight Transport Association , Andrew Mair
Area of expertise / responsibility: Head of engineering policy

(HA) Highways Agency, Stuart Lovatt
Area of expertise / responsibility: Lead on development of road safety and training

(HCT) Hackney Community Transport (Large scale operator serving Community Transport Association), George Mutch
Area of expertise / responsibility: Regional Manager

(HSE) Health and Safety Executive, Jim Corbridge
Area of expertise / responsibility: Experienced Specialist Inspector, visibility of workplace vehicles including earth moving, fork trucks and also on-road vehicles when on-site

(LCC) London Cycling Club, Charlie Lloyd
Area of expertise / responsibility: Cycling Development Officer, part of campaigning team and lead on HGV issues

(RAC), John Clayton
Area of expertise / responsibility: Technical Liaison Manager, liaise with manufacturers of vehicles and equipment
(RHA) Road Haulage Association , Ray Edgely
Area of expertise / responsibility: Head of technical services

(RM) Royal Mail, Rami Mistry
Area of expertise / responsibility: Senior Technical Advisor, Fleet and Assets division – responsibility for procurement of vehicles

(RoSPA) Royal Society for the Prevention of Accidents, Duncan Vernon
Area of expertise / responsibility: Road Safety Manager for England, respond to government consultation and promote safety through legislation and directly to consumers

(TESCO1) Tesco home delivery fleet, Andrew Kemp
Area of expertise / responsibility: Occupational road risk manager

(TESCO2) Tesco HGV fleet, Cliff Smith
Area of expertise / responsibility: Fleet engineering manager

(TfL) Transport for London, Chris Lines
Area of expertise / responsibility: Area of responsibility related to road safety. (Chris has left TfL so only brief discussions were held before he left. Re-structuring means that new roles are not yet clear so he is unsure who will be his successor).

(VOSA) The Vehicle and Operator Services Agency, Andrew Tudor
Area of expertise / responsibility: Automotive Engineer, Vehicle safety branch

Consultation responses

Note: the views expressed by the interviewees are not necessarily those of their respective organisations

Initial Thoughts

VOSA: Initial thoughts included the issues highlighted by a study in Edinburgh that illustrated how often pedestrians walk in-front of HGVs when it is not appropriate to do so. This was also highlighted by the number of accidents that occur at junctions where cyclists are injured or killed by HGVs turning. Both issues were related to the poor indirect vision to the front and side of the HGVs.

Nature and Scale of Problem

HSE: Accident data are collected and is clearly a key element of HSE work. Whilst there is no direct figure available for accidents that can be attributed to driver vision the scale of the problem on site, whilst relatively low in absolute terms, is an important consideration in any vehicle related accident in the workplace. For example there are millions of reversing operations each year. There are 250 reported fatalities a year, and 10-15% of these are vehicle related. Some further fraction of these will have a visual component. Three factors are always investigated for every accident: driver quality, vehicle standard and the organisation of the site. On site safety is very different from on the road as on site it can potentially be much more rigorously controlled. Vision is a well known issue and so many steps are taken to avoid vision becoming a concern, including the imposition of one-way systems, segregation of vehicles and people, speed limits, the use of hi-vis clothing, signage etc. However, a case by case approach is always taken. Site control is the primary focus followed by vehicle based systems with a 'banksman' approach to reversing as a last resort. Reversing is often the primary scenario for vision related issues. As such, indirect vision is more of a concern than direct. In these instances detection is more important than identification and the depth of field of indirect vision technologies can make interpretation of the image more difficult for some operators. In such circumstances extra care, for example slower speed and increased observation, is required.

RoSPA: Accident data are not collected but government statistics, news reports, etc. are received and reviewed, and responded to. Driver vision is an issue but the comparative importance or concern over direct or indirect vision is not clear. Recent trends in vehicle design are contributing to the problem. Also the height of the vehicle, in particular the driving position, is particularly critical.

DSA: No accident data collected but well aware of the vision related issues that are dealt with in the various driving training tests. Predominant focus is training, and vision is dealt with through appropriate use of mirrors to minimise the eyes off road time, direct observations (other than forwards) should be kept to a minimum. Vehicles are heavily regulated but vision is still an issue for large vehicles and particularly left hand drive (LHD). Mirrors are generally very good now but do add a blind spot to direct vision. Training issues cover awareness of own mirrors and blind spots but also blind spots of other vehicles. Defensive driving courses cover issues such as not sitting in a heavy good vehicle's (HGV) blind spot on the motorway. Particular scenarios include changing lanes, roundabouts especially for articulated vehicles, and where the very front of HGVs becomes a concern such as at pedestrian crossings. Essentially this can be summarised as any time the vehicle is changing direction and/or speed. Cannot comment on the number of accidents due to vision but it is a paramount issue in learning to drive.

RAC: No accident data but main concern of late is direct vision, essentially issues of third-party technology (sat-nav) being added to, and occluding vision from, the windscreen. Satellite navigation systems are the primary issue for the general public. In their own vehicles (RAC) they have screen based systems that must be visible but no occlude direct vision. The view is that nothing should occlude the windscreen wiper swept area. This extends to stickers and possible window tints that may not be as regulated as they might be. HGVs are a particular concern for vision issues, especially LHD vehicles on UK roads. Particular concerns are the area immediately in front of the HGV and the front quarters. Mirrors do cover some of this area but the field of view of the various mirrors could be more extensive. This leads to the scenario when an HGV is changing lane they may not be aware of a vehicle on their front quarter. This applies to LHD vehicles pulling out, and RHD vehicles pulling back in. The impact of this issue is that the HGV is likely to spin the vehicle that it hits into the path of the HGV. Towing, in particular caravans, is also an area of concern. Additional mirrors are used but they are generally very poor due to vibration at any reasonable speed (>45mph). In addition, other factors such as legislation to allow caravan width to increase from 2.3m to 2.5m combined with a narrowing of lanes where the hard shoulder is allowed as a running lane exacerbates the problem by requiring mirrors to be extended even further out and thus less stiff and more prone to wind buffeting. For HGVs the narrowing of lanes means that mirrors are almost touching.

CTC: Accident data are collected from various sources but some potentially not as robust as official sources, may include word of mouth, forums, weblogs etc. In 34% of accidents vision is a leading contributory factor "looked but did not see". 75% of accidents occur at junctions and involve vehicles turning, in particular: right hand turns across the cyclist's path and pulling out in front of the cyclist. The main issue in London concerns the environment with slow speed traffic but extremely high volumes and lots of junctions. 10% of the traffic is cycles, 10% is HGVs. HGVs are the main concern in cycling accidents with 50-75% of all cyclist deaths in London from HGV incidents. HGVs very high and eye contact with the cyclist is difficult. Blind spots in the corners and front of the vehicle are prime areas for cyclists to be hidden from view. The junction design may be a factor, with a nearside lane to move forward in stationary traffic and a zone along the front of the junction for cyclists to wait. Accidents due to HGVs turning left are a growing problem with almost always very severe consequences for the cyclist.

LCC: Vision is a huge issue and almost all accidents are vision related. Given that cycle use is likely to double in the next 20 years the concerns are very strong. Accident data are collected though their own research and fatality data is obtained from the police, if a cyclist is involved a description of the vehicle is included. Between 2001-2006 fatalities on the roads (excluding motorways): 41% of fatalities were pedestrians, 28% were cyclists and 18% motorcycles, all vulnerable road users. There are about 9 cyclist deaths per year and about 80% can be attributed to issues to do with vision, with the left turn across the cyclist still being the largest >50%. This issue occurs in two forms, from a standing start but also whilst the HGV and cyclist are moving along together. One particular factor is the behaviour of the HGV that typically will move out to the right to turn left in order to be able to actually get around the corner. This moving to the right sends the wrong message to the cyclist, in addition the HGV is also so far out that mirrors designed to look at the near side front wheel area (Class V) cannot see the cyclist. The speeds of the vehicles and cyclists are often very similar and there is a strong dynamic component that cyclists and drivers are probably not aware of. The static field of view plots of direct and indirect areas of vision do not really capture this issue. Mirrors have improved but the problems lie in skills, training and awareness, in particular recognising where vision is restricted.

BRK: Information on accidents caused by vision is received on an ad hoc basis through a number of sources, including the media and court reports. Brake does not collect accident data, but reacts to specific issues such as child safety on the roads. It was stated that the problem relates to large vehicles and blind spots, and not necessarily issues such as passenger car A-pillar design. Brake have produced information sheets for fleet managers (six page document that highlights the issues) which also contains information on potential solutions including equipment that can be retrofitted to vehicles; specific reference was made to a Dobli mirror. BRAKE were involved in research with Dr. Will Bury from Huddersfield University which focused on reversing accidents.

Factors affecting driver's vision include: Vehicle design, range of vision out of windows and mirrors, height of driver in vehicle increasing the size of blind spots. Accident scenarios include any kind of manoeuvre (reversing crashes are high as a percentage) and also manoeuvres at junction. Generally there is a problem whenever there are vulnerable people around the vehicle.

Regarding the nature of blind spots, those affecting HGVs are highlighted nicely by the illustrations on the DOBLI mirror website. Examples of dangerous scenarios include vehicles being positioned at the side of HGVs whilst at junctions. Concern was expressed that the EC consultation on mirror design did not go far enough in specifying larger coverage of blind spots through mirror use.

The issue was thought to be as important as other road safety issues such as drink and drug driving. The participant stated that she did not have data to be able to provide the proportion of accidents that are caused by vision and indirect vision.

VOSA: The vehicle safety branch of VOSA contribute to the TCIS and CCIS data collection efforts and attend accident scenes when it is deemed appropriate. It was pointed out that mirror use data are not collected as part of TCIS/CCIS. VOSA was also involved in the Fresnel lens project.

The following factors were attributed to poor vision:

- Mirrors not correctly setup for the individual;
- The driver not using the mirrors effectively;
- Cognition of mirror input (mirror overload);
- Mirror surfaces blocking direct vision.

Scenarios were highlighted including;

- On a motorway with vehicles either side of the HGV;
- In urban areas at junctions;
- Manoeuvring in urban areas.

These scenarios were considered with difficulty in viewing the side and front of the vehicle.

The issue of direct and indirect vision was considered important, but it was noted that the attendance to various issues occurs in peaks and troughs. The

VOSA staff member was unable to attribute a certain percentage of accidents to vision issues.

TESCO 1: Tesco captures data on accidents through the mechanism of a review board. This board meets monthly to examine the reasons for accidents, including vehicle damage. Common occurrences are lane change accidents and damage to vehicles when manoeuvring in tight spaces. The board includes members of driving staff that contribute to the attribution of blame for accidents. Visibility of the near side rear wheel and the top rearmost section of the vehicle are considered to be poor. There is the potential for standard mirrors on delivery vehicles to be too small. Trials with larger mirrors have resulted in more vehicle damage due to mirror surrounds colliding with obstacles. It was noted that a number of accidents had been attributed to poor vision of the mirror due to steamed up cabs. The potential for drivers operating 3.5 tonne vehicles on standard drivers' licences to be inexperienced in the use of van mirrors. Driver overload with respect to the ability to effectively use mirrors in busy urban areas was noted. Poor adjustment of mirrors was highlighted as a potential problem, although TESCO drivers are encouraged to adjust mirrors before each shift. Sixty five percent of accidents were attributed to vision issues when changing lane or reversing. It was pointed out that the Kent ambulance service had implemented a mirror strategy that is considered to be good. (use of Class VI mirrors). The importance of the issue of vision was given a high priority. There could be more standardisation and further consideration from vehicle operators other than following the letter of the law. This is happening with a number of strategies being implemented in the use of HGVs. More needs to be done to standardise mirror design on smaller vehicles, and a licence should be required to drive 3.5 tonne vehicles. Tesco test their drivers carefully and have high standards, with many existing delivery drivers working for other companies failing TESCOS tests and returning to jobs with DHL etc. This was a cause for concern.

The following additional issues have been highlighted by the following organisations:

TESCO 2:

- Class VI mirrors are being added to all TESCO HGVs
- Testing is ongoing of a number of after market solutions
  - Radar systems that display an issue using LEDs on the A-pillar to aid hazard scanning
- VOSA Guidance on the adjustment of mirrors has been expanded upon by TESCO to include mirror check 'bays' at each depot where markings on the ground are used by drivers to assist their mirror setup.

RHA:

- Class V mirrors are not effective
- Feedback from members highlights mirror overload

FTA:

- Provides benchmarking exercise for local authority vehicles (includes mirror use)
- Retro fit programme (EU) has improved the situation
- Usually FTA members are opposed to retro fit.
- Updated EU legislation has been well received by members once the benefits were seen.
- Drivers should be forced to adjust seats and mirrors at the start of each shift
- Close proximity mirrors are sometimes angled to provide forward visibility for drivers (driver habit).
- FORCE SCHEME (London) is considered best practice.

CPT:
- (context buses) Assault screen and ticket machine can obstruct good vision.
- Test for CCTV reversing camera involves a minimum of the ability to view a 1m high tube 2m away from the vehicle
- Poor visibility behind the bus has caused fatalities even with reversing cameras
- Pedestrians are not aware of the need to avoid walking in front of and behind buses
- Coroner report suggested that manoeuvring spaces at bus stations should be kept clear of pedestrians
- No use of RADAR and Ultrasound in his experience
- 'Gull wing' mirrors on coaches are seen to be very good, but not appropriate for buses due to the need for close manoeuvring

RM: Royal Mail has a fleet of approximately 33,000 vehicles and is the second largest vehicle operator in the UK. Fleet ranges from the car end of the spectrum through to tractor/trailer units. Almost all of their vehicles have no rear view windows for security purposes and thus there is a necessity to be able to drive on side mirrors. The concerns about vision in smaller vehicles are low but larger vehicles are still a potential problem. RM does collect accident data for their own vehicles. Vision is not an overly significant factor but they are always looking to improve their own practices. Particular scenarios including roundabouts and turning left for articulated vehicles, traffic lights and other give way junctions.

HA: Driver vision is not really a big problem in the scheme of things. Essentially drivers need to be aware and attentive and thus current solutions should be adequate. It is more of a concern for larger vehicles as the blind spots are generally greater in number and size. HA does collect accident data but the impact of driver vision within these data is not really within their remit. Driver error seems to be the main issue and so 'did not look' is more of a concern than 'could not see'. Advanced stop lines are seen as a good thing, allowing cyclists to get out of the way of the vehicle. The HA does not recommend sticking anything to the windscreen or in any way occluding primary vision form vehicles including satellite navigation systems, things hanging from rear view mirrors, etc.

CB: Driver vision is the main issue for certain types of accidents. Urban driving with large vehicles is an ongoing problem and cyclists are still being killed. The driver of the concrete mixer that killed CB's daughter used the excuse that he had a blind spot and could not see the cyclist, even though the police evidence suggested that the daughter was visible in at least one mirror. The driver was acquitted. CB followed up with the operator of the vehicle and now those vehicles and drivers have specific training and also proximity sensors fitted. The problem is largely an urban one and the main scenarios leading to accidents are the HGV turning left with the cyclist carrying straight on, and when both are travelling along together in the same direction. RoadPeace do not collect accident data but are contacted by those involved in accidents, post crash response.

TfL: TfL does not collect data - Uses STATS19. He would not like to hazard a guess at the scale of the problem. Regarding cyclist casualties, his general impression is that despite the number of cyclists increasing, the number of deaths appears to be falling. Maybe it seems more of an issue due to the amount of publicity given to these incidents.
Accident scenarios tend to take the form of:
1. Trucks with cyclists to nearside
Fixed axle trucks (3 or 4 axle) - 1/3 of those in accidents had no sideguards.
2. Motorcycle as struck vehicle
Either, other vehicle turning right into side road in front of a motorcycle or, other vehicle turning right out of side road in front of a motorcycle. Not sure if these are entirely blind spot accidents or due to carelessness. Blind spots may be a factor in some cases.
3. Personal observation
He feels that blind spots are more associated with damage only accidents; major collision accidents probably do not involve blind spots so much.
He doesn't feel that field of view accidents are getting worse - It is a problem of speed.

HCT: Not aware of accident data relating to field of vision. Factors contributing to poor vision include: night-time driving; pedestrians/cyclists in dark clothing; driver being distracted by something else. He considers that vision as a factor in accidents is not high – accidents may not always be attributable to vision may be due to lack of concentration.
There can be vision problems to the front of the vehicle, e.g. shorter sitting height driver who is sitting low down may have more difficulties with field of view – still a potential that a child walking in front of bus may not be seen directly.
In the past there was a field of view problem for buses and small minibus types:
- For older buses there was a blind spot in the area of the front doors.

- The rubber surrounds to the doors caused a blind spot in the mirror.
- The old split screen design with an upright wiper could generate about 2" blind spot.

Drivers who are not mobile/overweight may have poorer field of view.

(C) For Cemex their key concern is cyclists following such a fatality with one of their vehicles. There are problems with blind spots:

- Front quarter – There is a problem when cyclist is located ahead of nearside mirrors. Based on organisational experience, Cemex defines the area that the driver needs to see as an area 2m ahead of truck covering whole of width of truck and extending 2m to nearside combined with an area 2m to nearside of truck extending from 2m forward of truck to back of tractor unit.
- Nearside – Addressed through Sidescan.
- Rear – Need the use of a banksman.

Since 2008 no blameworthy accidents (One fatality arising from a cyclist riding off pavement into side of truck – therefore not picked up by mirrors/sensors until too late).

Even when drivers are looking, cyclists may not be seen.

(B): Blind spot areas still to be addressed are:

Trucks - Nearside front of vehicle – laterally beyond Class V 2m requirement.
- To the rear.

Coaches - Front - Low seated position is better than in trucks.
- Side - Bus and coach field of view problems are to nearside like trucks since they have less mirror requirements – Class IV and V mirrors may not be required.
- Rear - Same problem to rear.

Van - Limited visibility yet large numbers - untrained drivers, restricted field of view; operating in populated areas (multi-drop/collection deliveries).

Accident scenarios data is taken from Jacobs report 2003 which was produced for the European commission. Took from this concerns re: side turn collisions and forward running collisions. Also, taken from EU consultation document on retrofit directive, 'Every year, 400 European citizens lose their lives in accidents with trucks, because the truck driver did not see them, when he or she turned . . .'..

<u>Vehicle Design</u>

HSE: Those with limited rear vision are clearly more of a concern but also a well understood problem and there are many systems available and in use to reduce the risk.

RoSPA: High vehicles are a clear concern due to restricted vision around the vehicle. In addition there is a clear trend for increased A-pillar section and thus obscuration. Some larger people carriers are also starting to include a second A-pillar for mirror mounting.

DSA: HGV design is a problem with a large blind spot directly in front of the cab. LHD is an issue particularly at roundabouts where the driver will often have to orientate the cab pointing to the right even though they will essentially be bearing left, and pulling out into the overtaking lane. Recent trend noted for the design of cars where the lines tend to drop much more towards the rear of the vehicle. Possible this is an aerodynamics issue or perhaps just styling but this reduces rear vision. Whilst all cars meet the necessary standards to be driven, the DSA have a slightly different requirement in that they need good visibility for the passenger (examiner). The Toyota IQ has been banned from driving tests because of this issue. A-pillars are also increasing in size. This is particularly noticeable for a motorcycle rider, used to unrestricted forward vision, having to drive a car.

RAC: HGVs are a problem, in particular the area immediately in front of the vehicle and the forward 'quarters'. There is a mirror available over the door (Class V), that views an area around the near-side front wheel but this is not sufficiently wide in its field of view. LHD is also an issue in certain situations, roundabouts, pulling out into overtaking lane, but the same can be said for RHD pulling back in to nearside lane. A-pillar section is an increasing problem providing an increased blind spot. In addition the driving position is now often further rearward of the screen. The angle of the screen can also be a problem in some vehicles affecting the clarity of the view and also increasing glare/reflections form the dashboard. However, the forward view in general from vehicles is probably as good as it has ever been. Whilst not related to design there is an issue with other items being stuck to the windscreen, including technology like sat-nav, but also stickers, tax disk holders, parking permits, etc. Also, tinted front screens are regulated but possibly not well enforced.

CTC: Vehicle design does play its part. HGVs and their high up driving position are a well known problem. The cab height coupled with close proximity to the vehicle is a particular concern for cyclists within London. LHD vehicles are not a perceived issue yet and may actually be a little better as the driver is situated on the near side and has better direct vision of the cycle lane. Buses are also an issue but drivers tend to be better trained. Clearly the driving position is better but there is an improved awareness of cyclists, possible because they 'share the space' more often.

LCC: Tall vehicles are the main problem. HGVs, dumper trucks, cement mixers, essentially all 4 axle trucks are the worst case as they have the highest cabs and are involved in a "high proportion" of all accidents. Potentially there is scope to bring the driver down and look at possibilities such as glass panels in the doors. Size is not the overall issue though, coaches and buses are involved in half the number of accidents that HGVs are though data is not always available. Bus drivers are more concerned with pedestrians and this is believed to be down to tourists and not understanding which way to look. Lorries have also become higher and easier to drive. The height is a clear problem, but with power steering, manoeuvres are quicker and so may be made more suddenly.

In the past the time it took to turn the wheel and the slow speed that the vehicle would have to go may have given cyclists more warning.

BRK: Variables for how vision is affected by type of vehicle: Size of the vehicle, position of the driver, size of windscreen and windows, positioning of mirrors. No evidence for issues on left and right hand vehicles but media reports suggest that left hand drive vehicles have a higher proportion of accidents on UK roads. The participant was unable to describe good or bad vehicles.

VOSA: The height of HGVs was highlighted as a major issue for visibility. The issue of left hand drive vehicles has been improved by the use of Fresnel lenses, and these lenses are being adopted by British companies that operate vehicles on the continent. Also, VOSA has received complaints from members of the public who drive right hand drive vehicles that include a left hand drive wiper swept area design. Possible improvements to the design of vehicles included a reduction in the size of A and B-pillars, and the use of technology such as RADAR systems.

TESCO1: The standard issues were identified for passenger cars, HGVs and delivery vehicles. (height of vehicle, pillars, mirror blocking view, small sun visors). A good example of mirror design used in ambulances was highlighted. Also, the small size of windows in the delivery vehicles used (Mercedes) was highlighted as an issue. In terms of improving vision, a reduction in the clutter of the windscreen with items on the dash board was suggested.

TESCO 2: No additional comments to those above.

RHA: No additional comments to those above.

FTA: Grab handles can obscure mirrors (both standard and retro-fit).

CPT: No additional comments to those above.

RM: Large vehicles are the main area of concern. To address this RM are trialling a Safety Concept Vehicle developed in partnership with DAF and other external and internal customers. This vehicle is equipped with all of the standard mirrors as well as a 'blind spot solution' camera fitted to the A-pillar that shows a view of the area outside of that covered by the Class V mirror and is projected onto a monitor in the cab. This is activated when the left turn indicator is activated. In addition there is a reversing camera on the trailer, activated by engaging reverse. There are also proximity sensors on the nearside step with a range of 20cm; a ramp approach system that will apply the brakes if a substantial object is detected whilst reversing and keep them applied for 3 seconds before allowing the vehicle to continue reversing; a white noise alarm system that is a more socially responsible than "this vehicle is reversing" alarm that can only be heard in close proximity to the vehicle. At the present time the feedback is good but the trial is ongoing. Reversing sensors are being fitted to smaller vehicles as well but there is more mixed feedback for these vehicles with some appreciating the additional information and some finding it an annoyance. Parcelforce vehicles tend to be wider and thus need to be specified with a wider mirror mount arm.

HA: LHD drive vehicles are a growing problem. They are currently running an initiative to provide free Fresnel lenses for LHD vehicle drivers. Main scenario concerns the offside (in RHD orientation) blind spot and the problem of swerving into overtaking vehicles. The height of various vehicles is an often overlooked area. Mirrors not really oriented to give a view of overhead clearance and can easily be forgotten about or overlooked. A-pillar size is also a growing problem but again is an awareness issue.

CB: Large HGV type vehicles are the main problem. The fixed axle vehicles are perceived as more of a problem than articulated vehicles. Coaches and buses are less of a problem. The height of the driver is a significant factor and there is a feeling that the driver does not need to be so high.

HCT: The field of view situation is better now – buses have improved over time due to better, wider mirrors and improved construction such as bigger, wider screens; glazing for full door length is beneficial. Unsure how field of view could be improved further. Reflections on assault screen can be problematic. Prefers to purchase vehicles which have a good driving position to reduce driver fatigue.

<u>Use of Vision</u>

HSE: Difficult to answer but selection and fitting of vision systems, training and frequent use are crucial if visual problems are to be minimised. Training is a key component for many situations and this is one area where secondary systems such as CCTV may have an issue, as training is not normally included when such systems are retro fitted to vehicles.

RoSPA: Very difficult to determine if behaviour is appropriate but it is likely that vision is not always appropriately used. RoSPA produce a guidance document essentially about reversing on driveways "children in and round cars" which takes a behavioural rather than technology based approach. It is understood that younger drivers tend to visually 'scan' their environment trying to look everywhere and not properly viewing the critical areas.

DSA: Difficult to say but training designed to ensure all drivers aware of the issues and trained to use all three mirrors appropriately. There is a training loop hole in that up to 3.5 tonne vehicles can be driven on a standard car licence and so many vans are being driven by people with no additional training. Many of these vehicles will not have an interior rear view mirror. Buses and coaches in service technically should get someone to watch them reverse but this is often not done. Whilst aware of the issues some generic good advice probably not followed by the majority of drivers, including keeping screens clean, slowing down in poor visibility, appropriately using demisters. Recently ran a campaign to remind people to top up their washers with water and a suitable screen cleaner as water on its own is not sufficient.

RAC: Standard is generally OK but there are exceptions. Rear view mirrors often badly adjusted either accidently or deliberately to view a child in the rear for example. Also nearside mirrors can be badly adjusted.

CTC: Difficult to say but training is a significant issue. Bus drivers are better than HGV drivers, bus drivers get specific bulletins to be aware of cyclists. CTC is currently working closely with the Crossrail project, the new railway running across London. This will bring in significant amounts of construction traffic and one day of training is going to be provided for all drivers on cyclists and cycling awareness.

LCC: Training is important. As a rule cyclists are less threatened by buses and bus drivers and more familiar with the issues. In work training plays a big part of bus driving with compulsory cycling awareness sessions. Some borough councils (Lambeth) taking the same approach to council lorry drivers. Also working with the Crossrail project. All Crossrail vehicles will be up to the top standards and will be fitted with detector systems on the left and front of the vehicle. The Olympics is the next big concern with huge amounts of construction traffic in London.

BRK: The issue highlighted was the potential for people to not adjust the mirrors of vehicles also used by another person, and not ensuring that mirrors and the windscreen are clear of frost before setting off on cold days. HGV drivers are well trained to use the mirrors they have and to perform direct observations. Mirror design could be better. It is particularly important that drivers use vision when there are vulnerable people around the vehicle. Drivers need to see anything that is a potential hazard, either fixed or mobile, at a range of distances.

VOSA: Human error occurs in the use of direct and indirect vision which is linked to many factors, such as the speed that the vehicle is travelling and the ability of drivers to assimilate the information from mirrors, and distraction from passengers. It was considered most important to have visibility in urban environments where the prevalence of vulnerable roadusers is higher. Blind spots currently include the side and front of the vehicle (HGV).

TESCO1: Drivers on standard licences (Non-HGV) do not use mirrors correctly, and tend to use mirrors during manoeuvres instead of before. The use of car drivers in the operation of 3.5 tonne vehicles can cause problems in terms of poor mirror use, lack of training. It was considered most important to use the mirrors when turning left at a junction, and turning right at Y junctions (minor road to major road), on roundabouts, and checking where the vehicle is in relation to other road users. Drivers need to be able to see all around the vehicle, and are not able to do so currently due to blind spots.

TESCO 2: Agency staff may not be as well trained

RHA: No additional comments to those above.

FTA: No additional comments to those above.

CPT: No additional comments to those above.

RM: Vision (direct and indirect) is a key part of training and all drivers (including company car drivers) are trained. RM has 'driver coaches' at all main locations to support this. All drivers are also assessed through an internal web based risk assessment system. All drivers failing the assessment will undergo additional training. Even with all of the training it is well known that drivers do not always bother to adjust their mirrors appropriately. Drivers are provided with 'check time' to adjust mirrors and clean screens etc. Skill levels play a significant part, whilst larger vehicles are more of a concern their drivers are perceived as 'professional ' drivers and are likely to take more care with adjustment of mirrors, etc.

HA: Vision is critical but it's appropriate use is the key concern. Training is generally pretty poor as we tend to focus on a 'train to pass the test' philosophy and not a 'train to be a good driver' one. Awareness of the vehicle and the driving environment is seen to be critical and not something that is always appreciated by drivers. Most deficiencies in the vehicle can be accommodated if the driver is aware of them and how they are managed.

CB: The perception is that the driver failing to look or looking but not seeing is more of a factor than not actually being able to see. This has links to the business of urban environments; unfamiliarity of routes; foreign drivers with an unfamiliarity with the roads, signs, and vehicles (if driving RHD vehicles); workload and a lack of general awareness by the drivers. Extra care needs to be taken to ensure that it is clear to perform a manoeuvre. Also drivers need to ensure they set mirrors to their driving position.

HCT: It is important that drivers give field of view their full attention when: the road is busy; night-time when people are more difficult to see; going into bus stations when pedestrians may be where they shouldn't; reversing – uses cameras for this RearVu assist.

<u>Indirect Vision</u>

HSE: It is understood that mirrors, and CCTV should be checked before moving off, during a manoeuvre and mirrors and CCTV are correctly utilised relative to the manoeuvre being undertaken. Manoeuvring should not be done on CCTV alone.

RoSPA: Lots of good solutions out there but training and awareness are critical.

DSA: For cars indirect vision is largely good, legislated for and a key part of training. For larger vehicles mirror use is also critical and integral to training. Mirrors are favoured over other solutions even though other systems can supplement mirrors. Some known issues such as blind spots caused by mirrors themselves and a large HGV blind spot in front of the vehicle. In addition, articulated vehicles at roundabout have a problem with their nearside mirror only covering a view of the trailer whilst making the manoeuvre.

RAC: Mirror design and placement generally very good and come on a long way. However there are still known issues. Retrofit towing mirrors, for caravan towing etc, are notoriously poor. Vibration and deflection due to wind resistance are a big problem and generally render the mirrors useless. Whilst mirror and camera systems are good there is a learning issue in knowing which ones to observe at what times. No real training for trailer towing if driving on an older licence when trailers were included on the general licence.

CTC: Many HGVs are just unsuited to the environment encountered in London. Irrespective of the solutions provided the environment is too crowded with too many junctions for such large vehicles.

LCC: Mirrors are good and have improved, but not ideal on HGVs. They are critical of the European legislation on fitting of mirrors with the Class VI (frontal zone) mirror not being compulsory – this is perceived as a significant omission. Class VI mirrors should be fitted to all HGVs operating in urban areas. The system employed in China and Japan where mirrors are mounted much further forwards, such that they can be viewed through the main screen, is being looked at. This set-up increases the view of the difficult front quarter areas of the vehicle.

BRK: Additional technologies for improving the situation include additional wide angle mirrors, RADAR and ultrasound, CCTV, automatic mirrors that change their orientation during manoeuvres (http://www.lanefx.com/). BRAKE has given awards to various companies that produce camera solutions. No direct experience to allow comment. These products have been shown to improve safety. Cameras should be used in conjunction with mirrors.

VOSA: HGV RADAR, auto stop, reversing cameras, face recognition, lasers, GPS, and self guided systems were mentioned as additional technologies. It was noted that BP (British Petroleum) are currently using a camera system. As discussed, it was noted that blind spots still exist, and that mirror performance could be improved, with the caveat that direct vision should not be further blocked.

TESCO1: Reversing sensors, cameras and improved mirrors could be added to vehicles. Devices such as reversing sensors can be ignored due to false alarms. The performance of mirrors was considered to be poor in distinct situations (see previous). Camera systems were considered to be generally good, but there is potential for overreliance on these systems that can reduce mirror use inappropriately. Camera systems should be used in conjunction with a good mirror use strategy.

TESCO 2: The SENTINAL (Reversing made easy) system is being tested. Also a system that changes mirror angle based on turn to allow visibility of the rear of the trailer at all times (within certain limits). This can cause issues when outside contractor trailers are used (lack of systems).

RHA: No additional comments to those above.

FTA: No additional comments to those above.

CPT: No additional comments to those above.

RM: RM fits all mirrors including Class VI to all vehicles from 7.5 tonnes upwards even through the legislation does not enforce this. However it is felt that the number limit of mirrors has now been reached and hence the trial of other systems in the safety concept vehicle. RM has some specific indirect vision stipulations on their vehicles such as heated mirrors and standard glass mirror surfaces. Apparently unbreakable mirrors provide undue distortion and whilst they are more robust are not considered a good solution.

HA: LHD vehicles have particular blind spot issues when driving in this country that can be alleviated by the use of Fresnel lenses.

CB: Mirrors not perceived as a particular problem but that they do need to be supplemented by other systems. Trixi mirrors are being suggested as a useful addition. These are mirrors attached to traffic lights at junctions to supplement the view down the nearside of the vehicle. The driver should already be looking at the lights and so the positioning of the mirror is logical.

TfL: Even with all the mirrors in place there are still blind spots - and the need to rely on drivers to use them.

Driver Issues

HSE: Drivers are generally aware and systems are in place to highlight the issue, for example hi-viz clothing. Fatigue is not a sufficiently well researched issue in the workplace.

RoSPA: Training courses are run for commercial needs at an advanced level if necessary and also on a volunteer basis for those that approach RoSPA. Essentially this revolves around reflecting on the task and making assessments. Drivers are often aware of the problems relating to vision but individual scenarios and degradation of skills over time do make a difference. As mileage driven increases, risk does increase but experience makes a difference. There is also a 'new vehicle' issue where drivers may not make themselves fully aware of differences between the familiar and the new. Some of this may also only become apparent when a particular situation is experienced. RoSPA have done a number of publications looking at issues such as "Helping driving for longer, safer" that looks at the issues to do with ageing and identifying modifications that can be made to vehicles. This is done with mobility centres and can include driver assessments. There is also a "Driving for work" publication that looks at journey planning and addresses rushing and fatigue which can also be a factor in reduced appropriate use of vision.

DSA: Awareness is generally good and integral to training. Poor visibility can occur due to driving conditions such as driving at night, or in poor weather. Maintaining the vehicle (clean screens) is important but also reducing speed, etc. The ageing population is a concern. HGV drivers have to have a medical every five years and so their sight is monitored. For cars, the system is purely voluntary and even after an accident, if a driver is requested to be tested, they only have to re-do the standard 'read the number plate' test.

RAC: Awareness is there but there is more information to process whilst driving in recent years: mirrors, information on the dashboard, information on the radio, screen based information, hands-free, increased traffic density, all in addition to driving.

CTC: Working modes of drivers are critical. Buses are on an established well planned route and so have a much more controlled environment and set of pressures. HGV drivers can often be under time pressure and so workload may be a factor in not fully observing the environment. All London buses are fitted with CCTV monitoring the driver and this may lead to improved behaviour.

LCC: No comment.

BRK: Awareness is variable, cyclists and motorcyclists are more aware of the problems. Generally HGV drivers are aware. Methods to compensate for poor vision include moving the head to see past pillars. Coping strategies include avoiding situations where manoeuvres are required. Fatigue and distraction are prime issues that contribute to poor vision. In terms of the aging population, the gradual degradation of visual acuity is an issue which is currently only tested in later life. Evidence shows that older drivers reduce their mileage as they get older. The issue highlighted was younger drivers who are used to having technologies at their fingers tips increases the potential for driver distraction.

VOSA: In general, experienced drivers use mirrors and direct vision more effectively than novice drivers, and HGV drivers are well trained in the use of mirrors. Strategies for coping with poor vision included moving the head to see past A-pillar, and mirror obstructions. The list of factors affecting driver performance suggested in the question were agreed with. It was noted that HGV drivers are more heavily monitored in terms of health and training.

TESCO1: Well trained drivers are well aware of issues with visibility. Drivers compensate for blind spots and obstructions by moving their head more. Factors that were considered to affect the performance of drivers included poor nutrition, eye sight degradation, fatigue, the need for nicotine in a non-smoking environment, and bladder problems in older drivers causing distractions. The driving population for the TESCO urban delivery fleet is likely to increase as home deliveries increase (growing trend), this highlights the case for further regulation and licensing of drivers of 3.5 tonne vehicles. It was noted that 50% of applicants who attempt the tests on new drivers carried out by TESCO, fail these tests.

TESCO 2: No additional comments to those above.

RHA: No additional comments to those above.

FTA: HGV drivers over 45 subjected to regular health checks.

CPT: Need to adjust mirrors before each shift if not the last driver highlighted. (2 man job to adjust mirrors in good time)

RM: Drivers are aware of the problems. Training is taken very seriously and applied to all drivers and also continuously assessed. Drivers have time built into their schedules to ensure the vehicle is appropriately set up for use. However drivers can always circumvent training and any checks required. Information processing is an issue and the number of mirrors is perceived to have reached its limit. Other technologies are potentially useful and are currently on trial.

HA: Drivers are often not aware of the issues and do not take appropriate measures to thoroughly check the driving environment before making a manoeuvre. If making a left turn in a large articulated vehicle it would seem sensible to thoroughly check around the vehicle to make sure no one is likely to be in the way. However driver workload and lifestyle can be a contributing factor with drivers rushing to meet deadlines or nodding off due to too much work.

CB: Drivers are not always aware of the problems and additional training is often required. Complacency is considered to be a large part of the problem. Cyclist awareness training one of the particular areas of activity, provided to fleet operators. Cemex is one company that has been worked with to provide specific training. 'Exchanging places' events, where cyclists are offered a chance to sit in the cabs of large vehicles, were discussed; however lorry drivers are not currently being given the experience of cycling. Health is a particular issue and sleep apnea is a known problem where large vehicle drivers are particularly prone to developing the problem and then falling asleep. Annual health checks are a must and sight should be part of those. Regular alcohol testing should also be enforced. The use of 'black boxes' to monitor driver behaviour was mentioned and an example given where bonuses were paid to drivers based on good behaviour. This was done in groups and thus drivers had to take responsibility for their colleagues' actions as well.

HCT: Generally drivers do know when and where to look but the driver is dealing with a large vehicle surrounded by cars and pedestrians as well as looking after own passengers therefore driver can be distracted from looking in the right place at the right time. Accidents can be due to complacency and/or lack of attention rather than poor vision or overloading. Drivers are aware of the importance of field of view by their PSV training.

(B): Drivers have up to six mirrors to monitor. Mirrors on nearside can require driver to turn head by 90° - Camera monitors are positioned closer to drivers line of sight therefore less eyes off the road time, i.e. less forward viewing distraction.

Solutions

HSE: Lots of solutions available for vehicles without rear view windows including: safety bumpers which can provide a soft warning of collision and/or an audible alarm; ultrasonic sensors, though these are limited to slow speeds; radar which provides a much wider and faster scanned area, vision systems (CCTV), transponder systems that react to tagged workers, CCTV colour systems than can react to specific colours in the workplace e.g. high viz jackets; infrared systems; head up display systems than can be used in conjunction with CCTV for example. Tipper lorry users at some quarries and some delivery companies are examples of users that have established a requirement for systems such as CCTV to be fitted to their on road vehicles. However there was a trend, starting 3 to 4 years ago, for companies to double up on systems, for example combining CCTV and radar, or ultrasonic sensing, with a view that no one system was ideal on its own. With sensing systems there is also a well known concern over unwanted alarms, essentially alarms that highlight obstructions that have already been perceived and are deemed to not be an issue.

RoSPA: Cameras are available for all around the vehicle. Sensors of different types are also available. However, two issues are apparent, the first is the information processing by the system, so can it detect the appropriate object (i.e. bike shape) and then the communication to and information processing by the driver. Manufacturers find it difficult to do real world tests and so a lot of testing is essentially 'in production'.

DSA: Technology available is 'excellent' but the cost is an issue. However judgement is still a fundamental requirement requiring understanding of what is happening and interpretation of the view, image or other communication. Active ABS systems noted that use radar to scan ahead of the vehicle and can apply the brakes if necessary. However technology should not be relied upon.

RAC: Some good technology available but often with limitations. Reversing sensors are an issue with inadvertent alarms and having to deal with towing vehicles. Vision systems can be good but where should the screens be mounted? These need to be visible but should not obscure the swept area of the windscreen. Work being done with London ambulance to have reversing cameras but again there is a screen issue, especially for vehicles with many aftermarket systems.

CTC: Some solutions potentially useful. Cynthia Barlow who lost her daughter to a cycling accident involving a HGV and who is Chair of Road Peace, the national charity for road crash victims, is running a campaign to improve vehicles including audible warnings.

LCC: A number of warning systems are available. Audible warning systems are available to warn the cyclist ("vehicle turning left") activated with the indicators.

In addition a flashing screen can be used 300mm square fitted just behind the front wheels. However there are still fatalities even when these systems are fitted, possibly due to the fact that the indicators may be activated too late within the manoeuvre. There are also sensor systems which detect objects in the near side front corner. These can be 'all time on' systems which seems to suffer from driver desensitisation from them picking up items that are not a concern e.g. railings. Sensors can also be indicator activated with an internal and external warning. At present the efficacy of such systems is undecided but the indicator linked systems "seem like a good idea".

BRK: Camera systems, RADAR and ultrasound were mentioned. New technologies don't solve the problems but do improve the situation. Mirrors are cheap in comparison to other systems.

VOSA: The use of additional devices such as Fresnel lenses and camera based systems were thought to improve the situational awareness of drivers. The use of camera based systems by BP was highlighted.

TESCO1: TESCO implemented blind spot mirrors on all 3.5 tonne delivery vehicles, which was seen as successful. This solution was relatively cheap, costing a few pounds per vehicle.

TESCO 2: Optimal solution will combine mirrors and additional technologies.

RHA: Most operators will only meet the legislative requirements, not go beyond.

FTA: New vehicles with 'bull noses' to reduce CO2 (improved aerodynamics) have the potential to increase visibility issues.

CPT: Driver workload in urban environments is the biggest issue. Also, see VOSA memo on coach and bus mirrors.

RM: Lots of technology solutions available but most are not standard fit items due to the cost. However RM is keen on health and safety and so will assess these systems and fit them where there is a benefit. Many additional solutions are being trialled on the safety concept vehicle.

HA: Additional technology can help but the driver is ultimately the key. No amount of additional technology or vision systems can solve driver vision problems if they are not used or not used appropriately.

CB: Nearside proximity sensors on large vehicles are considered essential and should be compulsory in urban environments. These should only be active with the left turn signal. Cemex have these fitted to their vehicles and have 4 sensors along the length and the driver is made aware of which sensor triggered the alarm. The vehicle also has an audible warning for other road users. Initial perception by some drivers is "why do I need these" yet there have apparently been near misses that have highlighted the benefits of having the system fitted. Whilst not vision related, side guards are considered important safety features on large vehicles and thoughts are being given to some form of guard or cowling for the front nearside wheel to prevent cyclists being dragged under on collision.

TfL: Aware that some organisations are trying hard to address blind spot problems, some using technology which can be quite costly - therefore there is a commitment by some organisations to try to resolve these problems.
From what he is aware the technology seems to be acceptable (it has been adopted by organisations - they have stuck with it) but not sure how applicable it is across different truck types.
Relevant technology on the horizon or available but perhaps not in a format applicable to trucks.

HCT: The technology put into mirrors to maximise vision has achieved a good result. Housing the mirrors in arms has helped to reduce vibration. If mirrors got any bigger they would create blind spots. Camera systems are good and the view has improved. Cameras and mirrors are aids to support the driver in their task and are generally acceptable to drivers. There are no significant running/replacement costs for mirrors/cameras which are increasingly being made to be more robust and absorb impact shocks.

(C): Safety improvements applied to their trucks include:
- Additional blind spot mirrors
- Audible warning speaker
- Reversing camera
- Side scan – When left hand signal is activated, nearside scanning system also activated – display in cab shows where cyclist is by showing which scanner is activated along length of truck
- Warning signage to side and rear
- Side guards to nearside.
- Side guards to offside – intoxicated pedestrians crossed road and went under truck from offside.

Costs are in the order of £1,000 per vehicle.

Cemex are also supporting awareness-raising initiatives. (Police training around the country in 2009 by enabling cyclists to sit in cabs and truck drivers to ride cycles – Participants come from offending cyclists who can avoid a penalty if undertake training; Cyclists' week in June; also activities in Manchester, York, Bristol (Biker Breakfast) and Cambridge. Such events work better with other agency support, e.g. police, cyclists group, etc who introduce participants to the Cemex truck).

(B): Camera viewing angle extends beyond Class V and can replace Class V and VI. There is a directive under discussion to enable indirect systems to replace Class I-IV mirrors. Theoretically it is possible to have an in-cab display which will give a birds eye view of what is around the vehicle. In the future cameras will replace conventional mirrors. He envisages that either side of the steering wheel will be a display monitor showing rear vision. Both mirrors and cameras can fail. Power failure being looked at by ISO committee.

Viewing angles have been changed from 2.5 to 1.5m. This is based on market place feedback due to the need to reduce number of false alarms.
Brigade started with reversing systems which were installed on side by some customers for a side sensing system. Brigade has now developed specific side systems which can be integrated with rear ones and is looking to develop step scan which aims to reduce damage to/by vehicle steps.
Sidescan was introduced to market 6-8 years ago. Evidence of success is anecdotal – Brigade have no accident data – Suggest talk to operators. While hard data may not be available as to value of systems, operators do need to show that they are being proactive.
Looking towards people recognition systems so system can not only display an external image but interrogate it for critical hazards and alert driver. Can do this statically but dynamically this is more difficult.

Advantages of camera-based systems include:
- Mirrors more prone to accidental damage than cameras.
- Cameras don't themselves cause blind spots unlike mirrors.
- Camera use not affected by steamed up windows.
- One camera may possibly replace more than one mirror.
- Possible to integrate view into fewer displays (monitor/mirrors).
- Good in low light conditions.
- Good image representation quality.

Customer requirements include:
- Where best to locate forward field of view camera
- One camera to cover Class V and VI
- Many customer requirements are to meet regulations – but risk assessment by operators may mean that additional systems are purchased – operators can specify what they want. This makes additional systems very specific to the customer – difficult to generalise from this clusters of additional visual support needed.
- More demand in Holland.

Further Points

CTC: In-cab distraction is a contributing factor. 5% of lorry drivers use their mobile phone whilst driving.

BRK: Issues of buses in urban areas should be considered. We should be looking at coroner reports (Rule 43). Also contact Occupational Road Safety Alliance (Driving for better business campaign).