The Development of Improvements to Drivers' Direct and Indirect Vision from Vehicles – Phase 2

For: Department for Transport

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MIRA

Loughborough University

The development of improvements to drivers' direct and indirect vision from vehicles. Phase 2. (AR2639)

Department for Transport [DfT]

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EXECUTIVE SUMMARY

This report describes the work undertaken in fulfilment of Phase 2 of the research project relating to the development of improvements to drivers' direct and indirect vision from vehicles. Phase 1 of the project (reported separately) recommended that the following areas were researched further within Phase 2.

N_2 and N_3 blind spot determination

This work area formed the main areas of investigation within Phase 2.

Accident data

STATS19 data for 2008 was analysed using cluster analysis to obtain representative scenarios for light and heavy goods vehicles (N category vehicles) where 'Vision affected by vehicle blind spot' was recorded on the database as a contributory factor (no. 710). Seven cluster scenarios were identified, four of which were considered to be of interest to the study:

- Articulated left-hand drive LGVs over 7.5 tonnes changing lane to the right and colliding with cars.
- LGVs over 7.5 tonnes changing lane to the left and colliding with cars.
- LGVs changing lane to the right and colliding with cars.
- Goods vehicles turning left and colliding with vulnerable road users.

Driver/Trainer interviews

Interviews with LGV drivers and trainers identified driving scenarios in which blind spots may be an issue including: changing lanes, pulling away, reversing, manoeuvring and negotiating junctions. Problematic blind spot areas were cited as the rear, the front corners and along the sides. These findings tend to corroborate the accident scenarios identified.

In addition, it was found that drivers considered that their awareness of the visual difficulties associated with blind spots was good. The trainers supported this view highlighting the role of training and the importance of mirror set-up and checking. Most drivers were content with the number and coverage of their mirrors (although the validity of this finding is dependent upon their understanding of what an appropriate level of coverage is).

Field of vision – digital human modelling

Digital Human Modelling (DHM) was used to model and analyse current vehicles to understand the visibility afforded to the driver in a 3D environment. In order to add validity to the modelling, cases from the On The Spot (OTS) database were used to exemplify the accident cluster scenarios selected for investigation. The category N vehicles selected for modelling were based on prevalence within the fleet as follows:

- N_2 – DAF LF 45; Renault Midlum; IVECO Eurocargo.
- N_3 – DAF XF 105; Volvo 480 (Left hand drive); Scania R420.

Drivers' direct and indirect vision was modelled using anthropometric data for the upper and lower extremes of the driving population: 99th%ile and 4th%ile UK males. This was combined with observed postures from the driver interviews to provide two distinct eye positions for the evaluation of direct and indirect vision.

Analyses were first undertaken to identify the limits to the combined direct and indirect vision for both percentile measures in all six vehicles. These variables were then applied to the OTS cases and the implications of these limits to vision investigated.

Vision related issues identified from this work included:

- Blind spots are present between the volume of space visible through the Class V mirror and the volume of space visible through the window apertures to the side of the vehicle
  - These blind spots have been shown to have the potential to hide vulnerable road users and vehicles from the driver
- Poor alignment of mirrors reduces the area of coverage. (This links to the driver interviews confirming the importance of correct set-up and drivers being enabled in this)

- Image distortion at the edge of the mirrors.

In addition, mirror based solutions to the identified blind spots were explored and revisions to area of coverage of Class V mirrors were made.

Quality of vision

Concerns raised in Phase 1 and within the DHM work above regarding the quality of the image provided by mirrors and the drivers' ability to correctly interpret what they see was the focus of field trials undertaken within Phase 2 of the project.

The Class IV, V and VI mirrors of a Volvo FH tractor unit were assessed within the trials. The areas of ground plane visibility prescribed for each were centralised within the mirror and visual targets (car, cyclist, child pedestrian and a bin bag) were presented to twenty trial participants who were category N_3 vehicle drivers. Each target was presented singularly to the drivers who took representative glances in the mirror. Following each observation, the driver was asked to report:

- If the target was visible (on some occasions no target was presented)
- What the target was (car, cyclist, child pedestrian or bin bag)
- Their confidence in that interpretation on a scale of 1-7
- Whether the target was visible by direct vision.

To assess the potential impact of distortion at the mirror edges, an additional target position just outside the prescribed area was assessed for the Class V and VI mirrors.

The study found:

- Correct detection rates across all mirrors exceeded 93%.
- Correct recognition rates were at least 90% across all mirrors.
- Correct detection and recognition rates were compromised towards mirror edges.

These findings suggest that Class IV, V and VI mirrors are capable of providing good indirect vision of the prescribed areas. However, correct adjustment is important since a misaligned mirror may cause some of the prescribed area to only be viewable at the mirror edge where detection and recognition rates are poorer. It is recommended that the scale of the problem of poor adjustment is investigated and mechanisms to assist improved step-up encouraged e.g. the adoption of mirror adjustment bays, improved mirror designs that require no adjustment or provide a mechanism for easy adjustment by the driver. It should be recognised that other factors may impact accurate mirror use including: rain; dirt on the mirror and windows; driver inattention; driver attending to another visual task; time pressures, etc. Alternative technologies such as cameras and sensors were also discussed.

Indirect vision technologies

An expert appraisal to investigate the performance of standard mirrors, an extended view mirror (Spafax), cameras and sensors was undertaken. A 1m ground plane grid system was marked out extending 3m to the front of the vehicle; 5m to the nearside and 2m to the offside. This was sufficient to cover the Class V and VI prescribed areas and the extended area specified in the GRSG proposal amendment to regulation No. 46 (January 2011).

The data recorded included:

- If, and to what extent, the target could be seen by direct vision
- If, and to what extent, the target could be seen by the indirect vision system
- The approximate orientation of the target as presented in the system
- A rating of the level of confidence in recognising the target via the system.

Maps showing detection and recognition responses over the grid were produced to aid the comparison of the technologies. These indicated that:

- With respect to detection:
  - Within the Class V prescribed area, all systems provided complete detection
  - Within the GRSG proposed area, the extended mirror outperformed the standard Class V mirror; indicative results suggest that the camera system would also outperform the standard Class V mirror
  - To the side there was less overlap between direct and indirect vision indicating a greater potential for blind spots (and reflecting the findings in the DHM task)

  - Within the Class VI prescribed area, the standard mirror and the camera system provided complete coverage – the sensor system showed failures at the nearside edge and along the front of the vehicle
  - The camera system helps to address blind spots caused by the mirrors themselves.

- With respect to recognition:
  - The mirror systems presented the most extreme changes in orientation of the target, often presenting the target in positions ranging from on its side to upside down
  - The camera system displayed a greater proportion of the target compared to the standard mirrors
  - Both mirror and camera images are likely to be impacted by external factors such as rain, dirt, glare, etc.
  - Distortion of larger objects resulted in a pronounced bending effect of the image
  - Such distortions were most pronounced at the edges of the mirrors
  - Due to the greater impacts of orientation and distortion, the mirror images were less intuitive in interpreting the external scene e.g. for direction of motion of the target.

M_1 forward field of view – A/B pillar obscuration

Accident data

STATS19 data for 2008 was analysed using a new Cluster analysis methodology to obtain representative scenarios for M_1 vehicles where 'Vision affected by vehicle blind spot' was recorded on the database as a contributory factor (no. 710).

Nine cluster scenarios were identified, three of which were considered to be of interest to the study:

- Entering or using a roundabout and colliding with a pedal cyclist

- Entering or using a junction and colliding with a motorcycle or car that approached from the right-hand side of the driver
- Entering or using a junction and colliding with a pedal cyclist or car that approached from the left-hand side of the driver.

Field of vision – digital human modelling

DHM was used to model and analyse current vehicles to understand the visibility afforded to the driver in a 3D environment to the front of the vehicle. In order to add validity to the modelling, cases from the On The Spot (OTS) database were used to exemplify the accident cluster scenarios selected for investigation. The category M_1 vehicles selected for modelling were based on prevalence within the fleet as follows:

- Volkswagen Golf
- Volkswagen Touran
- Hyundai i10.

The Volkswagen models share the same platform with the Touran having a split A-pillar compared to the single A-pillar of the Golf. Drivers' direct and indirect vision was modelled using two different driver extremes: 99^{th} percentile Dutch male and the smallest UK female capable of driving the vehicle.

Analyses were first undertaken to identify the limits to the combined direct and indirect vision for both percentile measures in all vehicles. These variables were then applied to the OTS cases and the implications of these limits to vision investigated.

Vision related issues identified from this work included:

- Blind spots are variable in both size and position based on the design of the A / B - pillar, the position of the pillar and the eye-point of the driver
- 'Looking around' the pillar eliminated the blind spots caused by A and B-pillar obscuration of the modelled vehicles. However, this requires the driver to be aware of the blind spot and to make a deliberate action over and above a glance in the appropriate direction

- A-pillar size would need to be substantially reduced to have a noticeable effect on the driver's view
- Whilst structural strength is important for secondary safety, manufacturers should be encouraged to balance this against the primary safety needs for improved vision and so should be looking to reduced A-pillar thickness.

M_1 and M_2 rear field of view – visibility of rear obstacle

Field of vision – digital human modelling

DHM was used to model and analyse current vehicles to understand the visibility afforded to the driver in a 3D environment to the rear of the vehicle. The vehicles selected for modelling were:

- M_1 – Volkswagen Touran
- M_2 – Ford Transit long wheelbase minibus.

Drivers' direct and indirect vision was modelled using two different driver extremes: 99th percentile Dutch male and the smallest UK female capable of driving the vehicle.

Analyses were undertaken to identify the limits to the combined direct and indirect vision for both percentile measures in both vehicles. These variables were used to assess direct and indirect vision.

- Direct vision was assessed by means of:
  - Target markers defined within ISO/TR 12155
  - A wall-like target (5m wide, 1m high)
  - Defining minimum target heights necessary in order to be seen by direct vision.
- Indirect vision was assessed by means of:
  - The mirror requirements as specified for each class of mirror within the relevant standards – ECE46-01, ECE46-02, 2003/97/EC and FMVSS111.

Vision related issues identified from this work included:

- M_1 vehicle
  - Class I mirrors are fully compliant
  - Class III mirrors when set up optimally to provide an appropriate rearwards view fall marginally short of the field of view requirements for ECE46-02 and 2003/97/EC in relation to the areas closest to the rear of the vehicle, particularly on the nearside. It is likely that they could be adjusted to comply, but only with compromising rearwards view
  - Class I compliance is theoretical since in reality the rearwards field of view is compromised by internal fixtures such that it is only applicable to the uppermost half of the rear window
  - The same rearward limitation impedes direct vision where only objects greater than 1400mm in height could be seen directly behind the vehicle
  - The areas of obscuration to the rear of the vehicle range from 6.5-10m on the ground plane and 0.5-1.1m on a plane 1m above the ground. Thus there is potential for a child or other obstacle lower than 1m to be obscured.
- M_2 vehicle
  - Class I and II mirrors are fully compliant
  - Class I compliance is theoretical since in reality the rearwards field of view is heavily compromised by internal fixtures such that it is minimal and as such the mirror fails to comply with the standard
  - The same rearward limitation impedes direct vision where only objects greater than 1800mm in height could be seen directly behind the vehicle
  - For practical purposes the rearwards visibility of this vehicle is essentially zero and could not be relied upon
  - The specification given in Directive 2001/85/EC that a person 1.3m tall standing 1m behind the vehicle is considered to be visible in direct vision is not met.

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1 INTRODUCTION

1.1 The need for primary safety research

In very recent years, effort has been directed to understanding accident causation and the potential roles of new safety technologies in crash avoidance, complimenting the now established activities of casualty reduction and injury mitigation in secondary safety. The body of secondary safety knowledge is mature and includes a solid base of accident statistics, methodologies for data analyses and understanding of the evaluation of safety designs and technologies. However, the knowledge base in primary safety is less well developed and this is something which the Department for Transport has, and is, addressing.

1.2 The role of driver vision within primary safety

Within primary safety, vision is a key element affecting vehicle control and hazard perception. This is essentially a human factors / ergonomics consideration as illustrated in Figure 1.

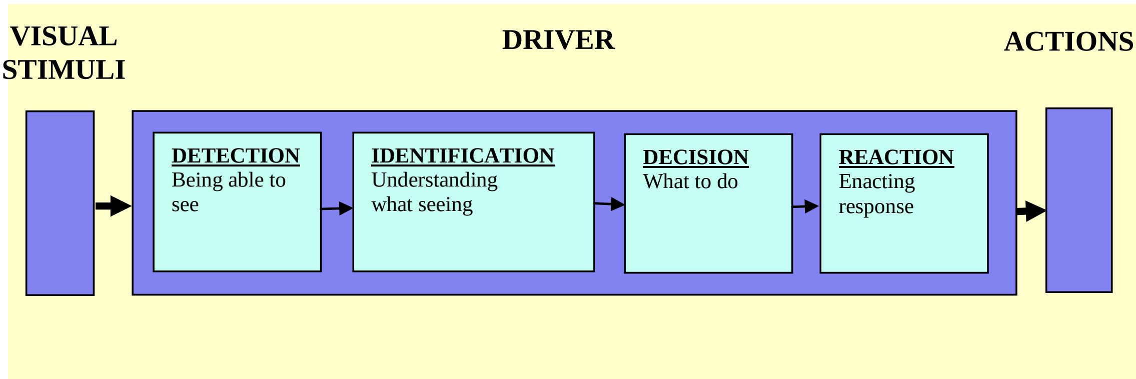

Figure 1. Drivers' visual processing

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) which they then enact using the appropriate vehicle controls (reaction). Failure in any of these processes can result in an accident.

Research by Treat et al[1] (1977) indicates that failures in drivers' perception may be a causal factor in up to 32% of accidents and a contributory factor in up to 50%. Using Treat's estimates for a causal factor up to 32% and multiplying this by casualty numbers and associated costs, the estimated annual cost is nearly £4,000 million (using 2008 casualty and cost data).

1.3 Project overview

As a means to reducing accidents relating to perceptual failures, the over-arching aim of the project was to investigate 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 view in which other road users can be easily seen.

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 or detecting 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 drivers' indirect field of view
  - Provide recommendations for amendments to the European legislations, where appropriate.

[1] Treat, J. R., Tumbas, N. S., McDonald, S. T., Shinar, D., Hume, R. D., Mayer, R. E., Stanisfer, R. L. and Castellan, N. J. (1977) Tri-level study of the causes of traffic accidents. *Report No. DOT-HS-034-3-535-77 (TAC)*.

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.

1.4 Project research to date and proposed direction for Phase 2

To date the first phase of the project has been completed, the aim of which was to review existing data sources to determine the current status of the knowledge base in this area and identify pertinent gaps for further research. This was based on:

- Literature review: which was sourced from: Department for Transport past research; Academic and technical database searches; web-based reviews and literature provided by project consultants.
- Accident data review: based on past relevant data analyses already in the public domain.
- Consultations: which probed expert knowledge beyond the published form using consultations with organisations directly or indirectly related to the motor industry and / or road infrastructure or who were deemed to have a view on the issue of driver vision.
- Legislative review: which reviewed the principal global regulations and standards to identify key technical criteria and the specified design limits to them.

The resultant knowledge gaps identified by Phase 1 related to a number of key priority research areas which were developed into work packages for Phase 2:

- Work Package 1: N_3 Forward blind spot determination to help to address Large Goods Vehicle (LGV) and Vulnerable Road User (VRU) accidents.
- Work Package 2: M_1 Forward field of view – A/B pillar obscuration to investigate issues of VRUs being obscured by car A/B-pillars.
- Work Package 3: M_1 and M_2 Rear field of view – Visibility of rear obstacle to investigate the adequacy afforded by legislation for rear vision.

These three Work Packages are concerned with determining if drivers are able to detect a potential hazard in their vicinity which is the initial stage in the driver's visual processing task illustrated in Figure 1.

- Work Package 4: Mirror image quality to investigate the clarity of the image presented to the driver by indirect viewing devices.

This Work Package builds upon Work Package 1 by assuming that there are no physical barriers to drivers detecting a hazard i.e. the indirect viewing devices (mirrors) eliminate blind spots and so investigates drivers' perceptual failure due to not identifying what they are able to see. This relates to the second stage in the drivers visual processing task illustrated in Figure 1.

- Work Package 5: Impact assessment which builds upon the previous Work Packages by evaluating the societal costs and benefits to any solutions identified by the previous Work Packages.

2 WORK PACKAGE 1: N_2 AND N_3 BLIND SPOT DETERMINATION

2.1 Aim

Existing mirrors (Class II, IV, V and VI) do not provide an adequate view to the front quarters and to the sides of the vehicle and can suffer from maladjustment or lack of adjustment by the driver. It is therefore important to fully understand the areas around category N_2 vehicles (requiring Class V mirrors) and N_3 vehicles that cannot be seen and to propose efficient and effective solutions to these problems. As part of this work a new volume based vehicle field of view specification will be defined with the aim of improving standardisation and minimising ambiguity. Where applicable, subsequent Work Packages will further assess these solutions and will be rated as part of an impact assessment.

2.2 Rationale

Phase 1 data, including feedback from the consultations, identified that vision from category N_3 vehicles was still a concern including blind spots to the front quarters and to the sides of the vehicle and highlighted scenarios that have led to accidents and fatalities. A review of the latest accident statistics indicates that for all pedestrian and pedal cycle fatalities in accidents with a LGV with a front/side impact, it is not possible to definitively cite a downward trend with a possible exception being fatal pedestrian accidents with an LGV front impact. This data therefore tends to broadly corroborate the Phase 1 findings of existing field of view problems for N_3 vehicles. Additionally, due to rising transport costs and the need to use sustainable transport forms, cycling may grow in popularity in the future thus potentially exposing more riders to road interactions with LGVs. The 'Transport Statistics Bulletin - Reported Road Casualties Great Britain: Main results 2009' states that although pedal cyclist fatalities fell by 10% between 2008 and 2009, total reported casualties increased by 5% in the same timeframe although cycle traffic levels were estimated to have risen by only 4%. Whilst it would be unreliable to make any predictions based on such data, it does perhaps imply the degree of uncertainty in future casualty reduction regarding this class of road user.

Phase 1 also identified that current standards based upon a ground plane requirement for field of view do not adequately represent the viewable volume needed by drivers and thus an alternative specification methodology is required.

2.3 Task 1: Accident data

2.3.1 Introduction

The aim of this Task was to ensure that the wider project activities were based on issues that were identified in the GB accident data. It was important that the overall project was strongly based on the real-world accident situation from which the issues of importance were identified from the perspective of the type and frequency of events and the resulting casualty severity outcomes. However, it was also useful to be able to identify in the data those issues which were considered to be of importance by 'users' and experts but which may not necessarily appear as significant problems in the accident data.

While existing studies were carefully studied during Phase 1, this Task analysed recent national police-gathered accident data (STATS19) and in-depth data from the UK Government's On The Spot project. The On the Spot Project (OTS) was commissioned by the Department for Transport and the Highways Agency to collect independent, on-scene, in-depth data on the causes and consequences of road traffic collisions (RTCs). This project was undertaken by two organisations, the Transport Safety Research Centre (TSRC) and the Transport Research Laboratory (TRL). The TSRC collected data in Nottinghamshire and TRL in Thames Valley, with the exact sample areas chosen to broadly reflect national road casualty statistics. The work was commissioned to collect a total of 500 cases per year for three Phases: 2000-2003 (Phase 1)[2], 2003-2006 (Phase 2)[3] and 2006-2010 (Phase 3). On-scene investigation provided a unique perspective on the causes of RTCs as it allowed the collection of 'perishable' data, which was the information only available in

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[2] Hill J.R. & Cuerden R.W. (2005). Development and Implementation of the UK On the Spot Data Collection Study – Phase 1. Department for Transport Road Safety Research Report No. 59.

[3] Cuerden, R., Pittman M., Dodson, E. and Hill, J. (2008). The UK On The Spot Accident Data Collection Study – Phase II Report. Department for Transport Road Safety Research Report No. 73.

(For both reports see: http://www.dft.gov.uk/pgr/roadsafety/research/rsrr/theme5/)

the immediate aftermath, such as vehicle positions, trace marks and debris, use of child restraints and protective clothing, weather, traffic conditions and temporary sight obstructions. It also allowed investigators to speak to witnesses and involved road users, and in more serious collisions to have seen the initial vehicle damage before secondary damage was caused by casualty extraction or vehicle removal (without causing any delays to the vital work of the emergency services). OTS investigations covered highways, vehicles, road user behaviour and injuries, with all information collated into a bespoke database with over 3,000 fields. All personal identity data were stored securely and separately, and were destroyed, typically within 5 years after collection.

In order to focus the analysis, STATS19 data for 2008 was analysed using a new Cluster Analysis methodology to obtain representative scenarios for light and heavy goods vehicles (N Class vehicles) where 'Vision affected by vehicle blind spot' was recorded on the database as a contributory factor (no. 710). In discussion with the other project members the results of this analysis were then used to undertake a case review of the OTS database in order to identify relevant case examples for closer examination.

2.3.2 Methodology

The method employed to move from accident data to accident scenarios was a data mining technique known as agglomerative or hierarchical ascending cluster analysis (Cluster Analysis). This progressively groups together the most similar records of a dataset, where the notion of similarity is defined mathematically. Here, each record describes an accident and so the cluster analysis identifies groups of similar accidents. These groups or clusters have (by definition) common characteristics and can be interpreted as constituting accident scenarios. The foremost advantage of applying this method is that the results are objective and reproducible, with an additional benefit that the representativeness of the resultant accident scenarios is clearly defined.

The algorithm for computing the (dis)similarity or 'distance' between clusters of accidents is specified at three levels:

- At field level, the algorithm was set to compute a distance in the range 0–1 for any two values of a field with 0 where the values are the same and 1 where they are not the same.
- At record level, the distance between two accidents was defined as the sum of the distances between the fields—the *city block* or *Manhattan* distance.
- At cluster level, the distance between two clusters was defined as the average of the distances between each pair of records in the groups—the *average linkage method*.

Field	Type	Value	Description
Vehicle movement	Nominal	1 2 3 4	Forwards Forwards – left Forwards – right Backwards
Accident severity	Ordinal	0.0 0.5 1.0	Slight Serious Fatal

Table 1. Sample numerical values for quantifying the similarity between accidents

For nominal fields, i.e. those that are defined in categories that have no intrinsic order, the distance or dissimilarity between two values is either 0 or 1, depending whether the characteristic is the same or different for two accidents. Making reference to Table 1, if in two accidents the vehicles are both moving 'forwards-left', the distance is 0; if one is moving 'forwards' and the other 'backwards', the distance is 1. For ordinal fields, i.e. those defined in categories that have an intrinsic order, the range is set to span 0–1 in equal increments for ordinal variables, e.g. the distance between a serious accident and a fatal accident is 0.5 (1.00-0.5).

The hierarchical cluster analysis begins with one cluster for each record and iterates through a grouping procedure until ending with one cluster for the whole dataset. No particular set of clusters is right or wrong: each is a valid representation of the data. The question is rather the usefulness of a set of clusters for a particular purpose. Clearly, neither extreme, one for each record or one for the whole population, is of interest. For the purpose of identifying typical scenarios it was considered relevant to have a relatively small number of clusters that covers much of the population. Programming code was written to assist in the identification of around six clusters to contain about 75–80% of the population for initial consideration. In conjunction with further code to identify natural gaps between the clusters, the final number was chosen manually after examination of the data.

The technical specifications of the algorithm underlying the cluster analysis were selected from a range of standard methods. Further details are available in the literature [4, 5, 6, 7]. The details provided above are intended to suffice in principle for the clusters to be independently derived starting from the same datasets using any software. The order of cases in the input dataset should make no difference.

2.3.3 Results

The national accident database STATS 19 (2008) contains 1,906 goods vehicles for which a vehicle blind spot was registered as a contributory factor to the accident (Table 2). The three groups of goods vehicles by weight (which equate to 3 vehicle Categories: N_1, N_2, N_2 & N_3), totalling 733, were selected as the target group for analysis. Vehicles that were parked, that did not make contact with another vehicle or object, or for which there was unknown or missing information in any of the fields were excluded from further consideration. This left 704 goods vehicles.

Vehicle type	Vehicle Category	
Car		1009
Goods vehicle: over 7.5 t	N_2 or N_3	511
Goods vehicle: under 3.5 t	N_1	157
Goods vehicle: 3.5–7.5 t	N_2	65
Bus or coach		53
Other		111
Total		1906

Table 2. Vehicle types with 'Vision affected by vehicle blind spot' as contributory factor

[4] Romesburg, H.C. 2004 Cluster analysis for researchers, Lulu Press, North Carolina.

[5] Martinez, W.L. and A.R. Martinez. 2005. Exploratory data analysis with MATLAB®, Chapman & Hall, London.

[6] Lenard, J., R. Danton, M. Avery, A. Weeks, D. Zuby and M. Kühn. 2011. Typical pedestrian accident scenarios for the testing of autonomous emergency braking systems, ESV paper no. 11-0196.

[7] Skyving, M., H-Y. Berg and L. Laflamme. 2009. A pattern analysis of traffic crashes to older drivers, Accident Analysis and Prevention 41, pp. 253–8.

A simplified dataset formed from a selection of the fields available in STATS19 was prepared for the 704 goods vehicles for which 'blind spot' was identified as a contributory factor (Table 3). Where the categories for each field differ from those in STATS19, they were formed by aggregating categories in the source database.

Field	Type	Value	Description
Accident severity	Ordinal	0.0	Slight
		0.5	Serious
		1.0	Fatal
Vehicle type	Ordinal	0.0	Cat N_1 <3.5t
		0.5	Cat N_2 <7.5t
		1.0	Cat N_2 & N_3 >7.5t
Articulated vehicle	Nominal	1	Not articulated
		2	Articulated
Vehicle movement	Nominal	1	Forwards
		2	Forwards - left
		3	Forwards - right
		4	Backwards
First point of contact	Nominal	1	Front
		2	Back
		3	Right
		4	Left
Drive side	Nominal	1	Right
		2	Left
Collision partner size	Ordinal	0.0	VRU
		0.5	Motorcycle
		1.0	Car+

Table 3. Simplified dataset from STATS19 for cluster analysis of goods vehicles

The outcome of the cluster analysis is shown in Table 4. Each column describes the characteristics of a cluster. Cells highlighted in green indicate (a) that the distribution of numbers in the given field is significantly different from the distribution in the total population of 704 goods vehicles (chi-squared test to 99.5% significance) and (b) that the particular numbers highlighted are over-represented. The 'representativeness' figures are derived directly from the 'accident severity' category, expressing the latter as row percentages.

Cluster 1 can serve to illustrate the interpretation of Table 4. It is the largest cluster, containing 176 of the 704 goods vehicles or 25% of the population. Almost all of the vehicles (170) in cluster 1 are heavy goods vehicles over 7.5 tonnes (N_2 & N_3). Reading down the column, these vehicles are mostly articulated (159) (suggesting that they are N_3 category LGVs), were moving forwards and towards the right (154), and made first contact with either the front (50) or right (120) surface. Remarkably, these are all left-hand drive vehicles (176) and all but one collided with a car-sized (or larger) vehicle.

	Cluster								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8–11**	**Total**
Cluster representativeness (%)									
Slight	26	25	15	12	8	5	4	3	100
Serious	14	14	29	2	18	4	10	10	100
Fatal	6	6	25	0	19	25	19	0	100
Total	25	24	16	11	9	5	5	4	100
Accident severity									
Slight	168	161	97	76	54	32	27	22	637
Serious	7	7	15	1	9	2	5	5	51
Fatal	1	1	4	0	3	4	3	0	16
Total	176	169	116	77	66	38	35	27	704
Vehicle type									
Cat N_1 <3.5t	0	2	91	6	18	0	18	14	149
Cat N_2 <7.5t	6	14	8	11	10	5	6	2	62
Cat N_3 >7.5t	170	153	17	60	38	33	11	11	493
Total	176	169	116	77	66	38	35	27	704
Articulated vehicle									
Not articulated	17	84	116	32	66	0	35	19	369
Articulated	159	85	0	45	0	38	0	8	335
Total	176	169	116	77	66	38	35	27	704
Vehicle movement									
Forwards	18	0	0	0	66	38	0	6	128
Forwards - left	4	132	1	6	0	0	35	3	181
Forwards - right	154	32	1	71	0	0	0	14	272
Backwards	0	5	114	0	0	0	0	4	123
Total	176	169	116	77	66	38	35	27	704
First point of contact									
Front	50	80	1	0	25	16	2	8	182
Back	1	0	111	1	5	3	1	7	129
Right	120	1	3	74	17	9	5	5	234
Left	5	88	1	2	19	10	27	7	159
Total	176	169	116	77	66	38	35	27	704
Drive side									
1 Right	0	169	116	77	66	38	35	19	520
2 Left	176	0	0	0	0	0	0	8	184
Total	176	169	116	77	66	38	35	27	704
Collision partner size									
VRU	0	6	82	1	21	10	26	11	157
Motorcycle	1	2	16	1	10	1	6	4	41
Car+	175	161	18	75	35	27	3	12	506
Total	176	169	116	77	66	38	35	27	704

Table 4. Accident scenarios for goods vehicles

A detailed breakdown of the vehicle and pedestrian movements is provided in Table 5. This is fully consistent with Table 4, showing for example that the 154 vehicles in

Cluster 1 described as moving 'forwards-right' above were mostly changing lane to the right (138) rather than turning right (10).

	Cluster								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8–11**	**Total**
Vehicle movement									
Reversing	0	5	114	0	0	0	0	4	123
Waiting to go - held up	0	0	0	0	2	2	0	0	4
Stopping	0	0	0	0	3	1	0	0	4
Starting	1	0	0	0	20	12	0	0	33
Turning left	3	12	1	2	0	0	30	0	48
Waiting to turn left	0	1	0	0	0	0	0	0	1
Turning right	10	6	0	9	0	0	0	9	34
Waiting to turn right	1	0	0	0	0	0	0	1	2
Changing lane to left	1	117	0	2	0	0	3	2	125
Changing lane to right	138	24	1	61	0	0	0	2	226
Overtaking moving vehicle - offside	2	0	0	0	6	3	0	1	12
Overtaking static vehicle - offside	0	0	0	0	1	0	0	0	1
Overtaking - nearside	0	0	0	0	1	0	0	0	1
Going ahead left-hand bend	0	2	0	2	0	0	2	1	7
Going ahead right-hand bend	5	2	0	1	0	0	0	2	10
Going ahead other	15	0	0	0	33	20	0	5	73
Total	176	169	116	77	66	38	35	27	704
Collision partner movement									
Reversing	0	0	1	0	1	0	0	0	2
Parked	0	1	7	1	0	0	0	2	11
Waiting to go - held up	0	1	22	1	4	2	0	2	32
Stopping	0	1	2	0	1	2	0	0	6
Starting	0	1	0	0	3	3	1	0	8
Turning left	4	3	0	0	0	0	5	0	12
Waiting to turn left	0	3	0	0	0	0	0	0	3
Turning right	2	1	1	2	2	2	0	0	10
Waiting to turn right	1	0	1	0	0	0	0	0	2
Changing lane to left	4	1	0	1	0	2	0	0	8
Changing lane to right	1	1	0	0	1	1	0	0	4
Overtaking moving vehicle - offside	30	4	0	13	6	1	1	2	57
Overtaking static vehicle - offside	0	0	0	0	0	0	1	0	1
Overtaking - nearside	2	9	0	1	2	0	4	0	18
Going ahead left-hand bend	0	4	0	3	0	0	1	3	11
Going ahead right-hand bend	2	4	1	1	0	0	0	1	9
Going ahead other	130	132	8	53	32	20	16	13	404
Total	176	166	43	76	52	33	29	23	598
Pedestrian movement									
Crossing from driver's nearside	0	1	18	1	4	3	3	1	31
Crossing from nearside - masked by parked or stationary vehicle	0	0	4	0	0	0	0	0	4
Crossing from driver's offside	0	0	7	0	3	0	0	0	10
Crossing from offside - masked by parked or stationary vehicle	0	0	4	0	0	0	0	0	4
In carriageway, stationary - not crossing (standing or playing)	0	1	11	0	0	0	0	0	12
Walking along in carriageway, facing traffic	0	0	1	0	0	0	0	0	1
Walking along in carriageway, back to traffic	0	0	3	0	0	0	0	0	3
Unknown or other	0	1	27	0	7	3	3	3	44
Total	0	3	75	1	14	6	6	4	109

Table 5. Details of road user movements in accident scenarios for goods vehicles

2.3.4 Conclusion

In summary, the cluster analysis highlights the following scenarios:

1. Articulated left-hand drive LGVs over 7.5 tonnes changing lane to the right and colliding with cars (25% of all casualties, 14% of serious, 6% of fatal) (N_2 & N_3 vehicles)
2. LGVs over 7.5 tonnes changing lane to the left and colliding with cars (24% of all casualties, 14% of serious, 6% of fatal) (N_2 & N_3 vehicles)
3. Goods vehicles (mostly small goods vehicles - N_1) reversing into vulnerable road users and motorcycles (16% of all casualties, 29% of serious, 25% of fatal)
4. LGVs (N_2 and N_2 & N_3 vehicles) changing lane to the right and colliding with cars (11% of all casualties, 2% of serious)
5. Non-articulated goods vehicles (N_1, N_2 and N_2 & N_3 vehicles) moving directly forward into other road users, with over-representation of pedestrians, cyclists and motor-cyclists (9% of all casualties, 18% of serious, 19% of fatal)
6. Articulated goods vehicles over 7.5 tonnes (N_2 & N_3 vehicles) also moving directly forward into other road users (VRUs and cars), (5% of all casualties, 4% of serious, 25% of fatal)
7. Goods vehicles (all N Classes) turning left and colliding with vulnerable road users (5% of all casualties, 10% of serious, 19% of fatal).

Clusters 1, 2, 4 and 7 were considered to be of particular interest to the study. On this basis the OTS database was interrogated and 12 in-depth case examples representing these clusters were provided to Task 3 for consideration.

2.4 Task 2: Driver interviews

2.4.1 Aim

In Phase 1 of the project - consultations regarding field of view issues were undertaken at an organisational level amongst a range of key stakeholder groups. The aim of this Task was to complement the Phase 1 findings by consulting at an individual level with those directly engaged in the driving task. The intention was to undertake a series of interviews and observations with drivers of category N_2 vehicles (requiring Class V mirrors) and N_3 vehicles to:

- Explore field of view issues - in particular the nature of any blind spots
- Understand the driving task to inform analysis through the use of digital human modelling (DHM).

The interviews were designed to address:

- Discussion of blind spot issues
- Discussion about the adjustment of mirrors at the change of shift
- Discussion about the perceptions and experience of additional technology such as camera systems, radar and ultrasound
- General discussions about the design and location of mirrors and the issues that arise
- Discussions about the obscuration of direct vision by items or equipment placed or mounted on the dash board of the vehicle
- The adjustments made to the seat to allow comfortable driving and the capture of the driving posture for a suitable range of driver sizes (smallest female capable of driving the vehicle to 99th percentile Dutch male i.e. tallest European population')
- The methods used for the adjustment of mirrors.

In addition, four LGV driving instructors were also interviewed for their understanding of the nature and causes of field of view problems; the potential solutions to them and the performance of such solutions where known.

2.4.2 Driver interviews

2.4.2.1 Recruitment

To explore these issues further, volunteer participants representing a variety of driving occupations were approached. A sample size of 20 drivers was targeted with a representation of both N_2 and N_3 driving experience. The interview required the driver and their vehicle in situ and required physical anthropometric measurements and photographs to be taken to inform Task 3 – Digital Human Modelling within this Work Package.

A full cross-section of companies, comprising both large and small operators, were identified and approached to ask for their participation in the project. Initially the response was positive with major companies agreeing to participate in principal. However, when the project team attempted to set dates for visits the agreements were not honoured. A variety of reasons were given, for example the time of year (being near the end of the year and the run up Christmas) and the current financial climate. In addition, specific difficulties arose with accessing N_2 drivers compared to N_3 drivers due to the nature of their usage. N_2 vehicles are predominantly used for local deliveries within towns and cities and make multiple stops throughout a 24hour day. Consequently they are never in one place for very long. Although numerous attempts were made to interview this particular group of drivers the process proved to be problematic, primarily due to the issues it would cause to the daily running of their businesses.

As a consequence, the study was conducted with a sample of 15 N_2 / N_3 drivers based around the Midlands during the period of October 2010 to March 2011. Those companies that did take part were drawn from both large and small operators which enabled reflection on different operating procedures.

2.4.2.2 Final Sample

A total of 15 LGV drivers (N_2 and N_3) across the Midlands region took part in the interviews. All participants met the following inclusion criteria:

- Working age (16 – 65 years).
- Male and female (although only 1 female participant was recruited in the sample).
- Currently holds a LGV licence.
- Voluntary participants in the study.

Participants were asked if there were any reasons why they felt they are not able to take part in the study and excluded if they answered 'yes'. However, as all participants held a clean driving licence and fell within the selection criteria - no individuals were excluded.

2.4.2.3 Questionnaire

A copy of the full questionnaire used in the interview can found in Appendix 1.

2.4.2.4 Results

The following information outlines the results found from the interview study. This information was used to shape and define Task 3 within this Work Package.

2.4.2.4.1 Vehicle details

Vehicles sampled - by manufacturer

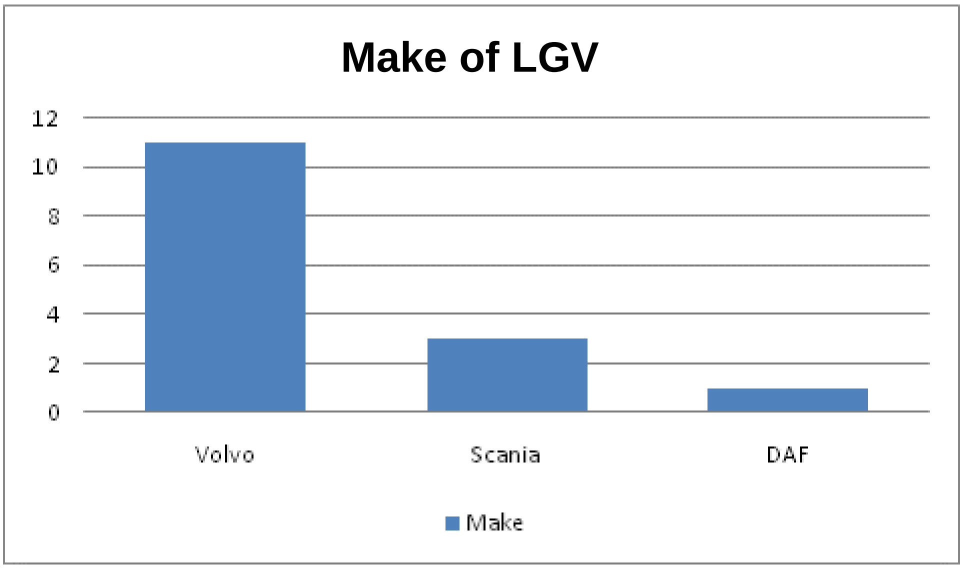

Figure 2. LGV vehicle sample by manufacturer

Predominantly Volvo's were measured within the sample group. This was a result of an agreed collaboration with a major company whose entire fleet was Volvo. Different models were measured within this fleet.

Age of vehicles sampled

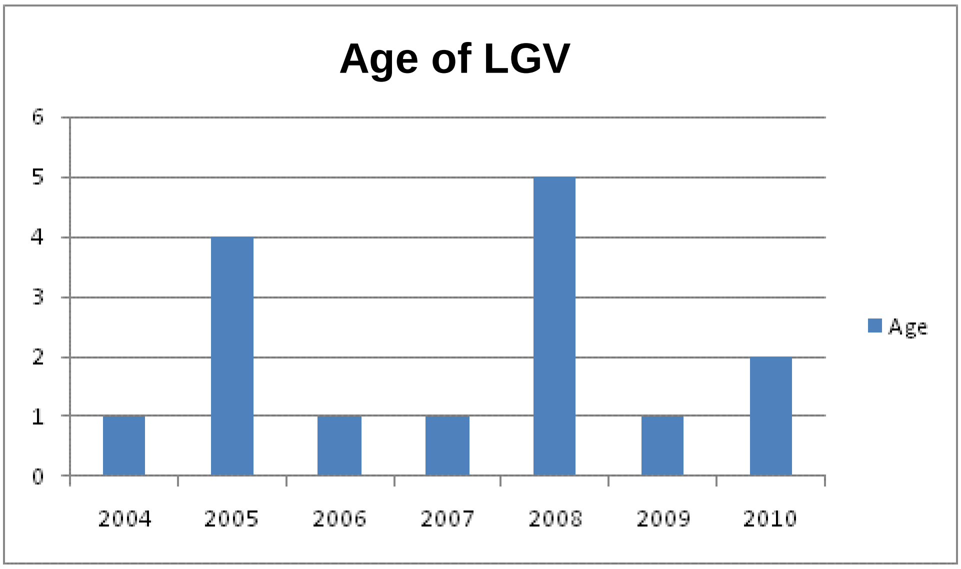

Figure 3. LGV Age

A good spread was obtained across vehicle age from 2004 to 2010 vehicles. The majority of vehicles were either 2008 or 2005 age.

Mirror V fitment

All of the 15 LGV's measured were fitted with a Class V mirror.

Mirror VI fitment

Of the 15 LGV's measured, 11 were fitted with a Class VI mirror.

Seat Adjustability

All vehicles measured had a good range of adjustability to the seat. The main differences were in seat base adjustability. Only 4 out of the 15 vehicles had this feature.

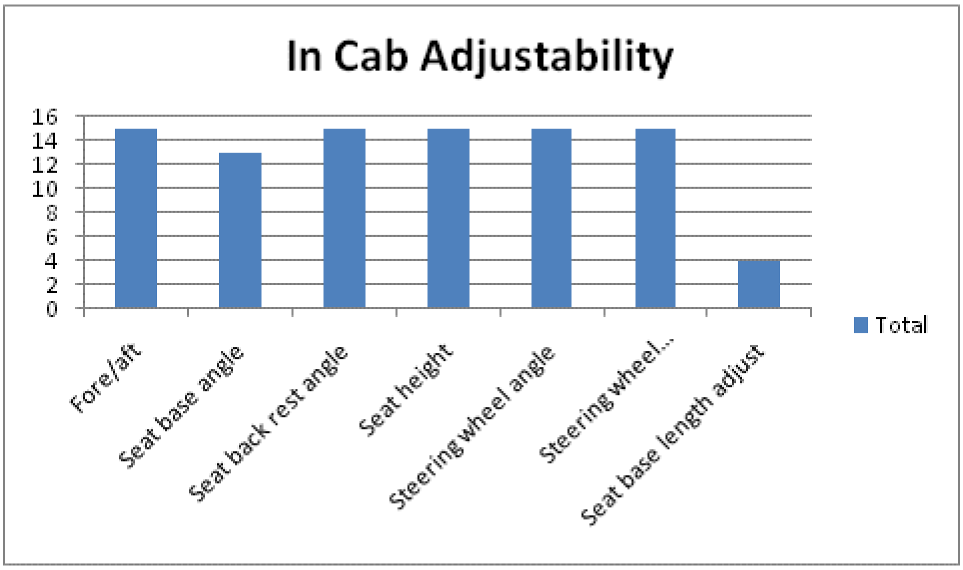

Figure 4. LGV Seat adjustability features

2.4.2.4.2 Driver details

Anthropometric Measures

A range of anthropometric measures were taken. The graphs below represent two example measures. The sample was predominantly male and percentiles for stature ranged from 4th percentile - 99th percentile. This is taken from a data range of British

Adults 18-64 (ADULTDATA 1998[8]). For Sitting Height the percentile range was from 1st percentile – 89th percentile. This data was obtained from the same source.

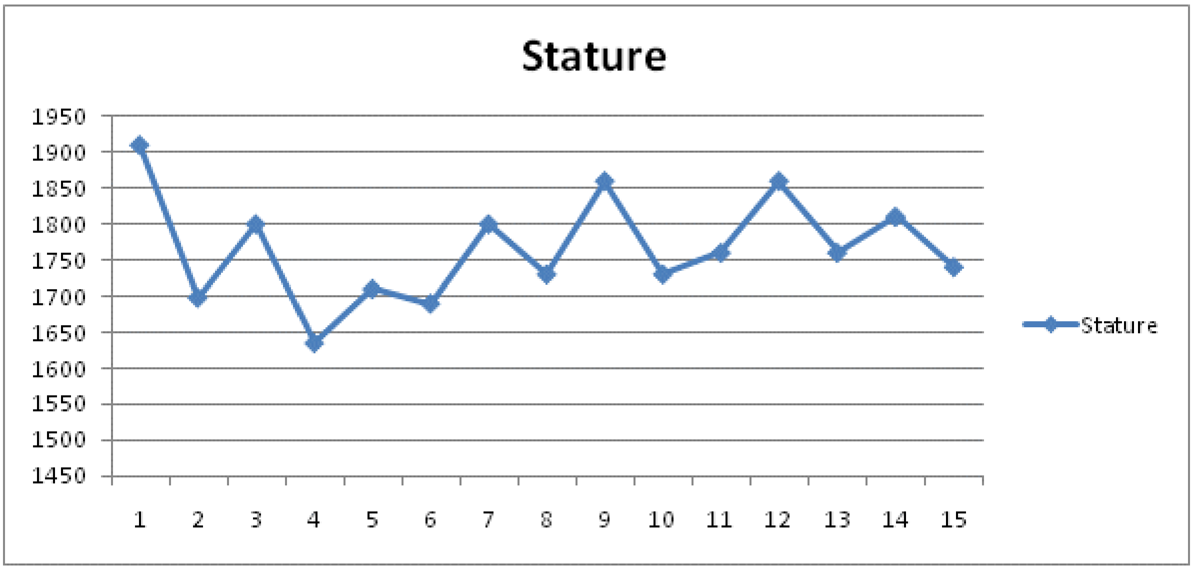

Figure 5. Stature measurements of sample population

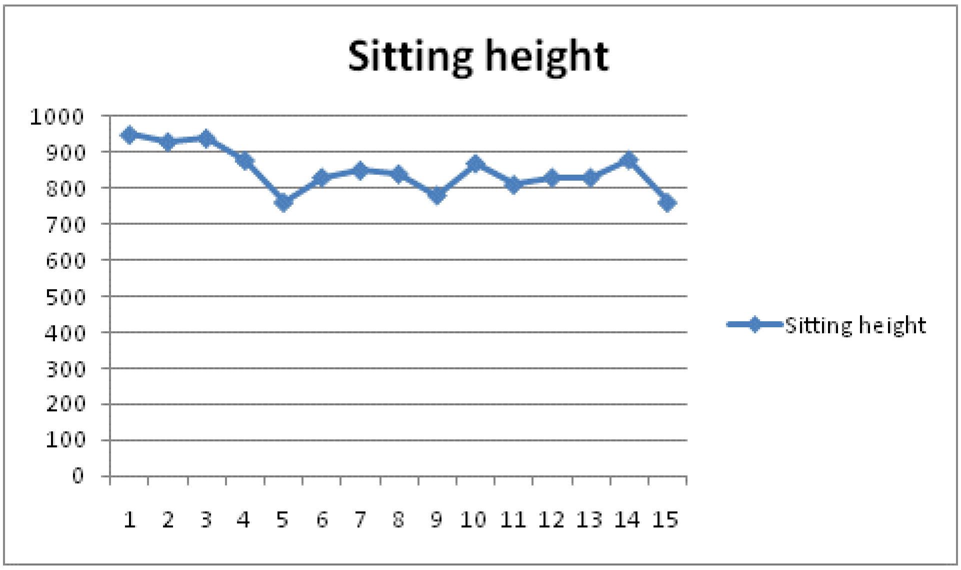

Figure 6. Sitting height measurements of sample population

<u>Driving experience</u>

A good cross section of the number of years driving a LGV was obtained. This ranged from 3 - 38 years. This enabled a rich source of information from both novice and experienced drivers.

[8] Adultdata., 1998. *The handbook of adult anthropometry and strength measurements – data for design safety*. L. Peebles and B. Norris, eds. Department of Trade and Industry.

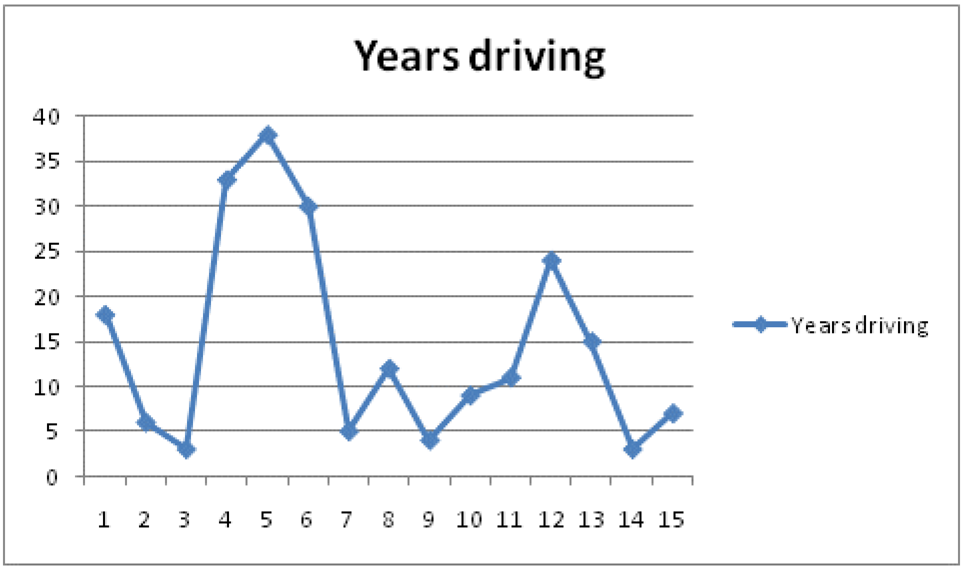

Figure 7. Number of years driving experience

Driving hours

The majority of drivers interviewed drove approximately 40hrs per week. It should be noted that participant No.5 is an outlier because they were not very cooperative throughout the interview.

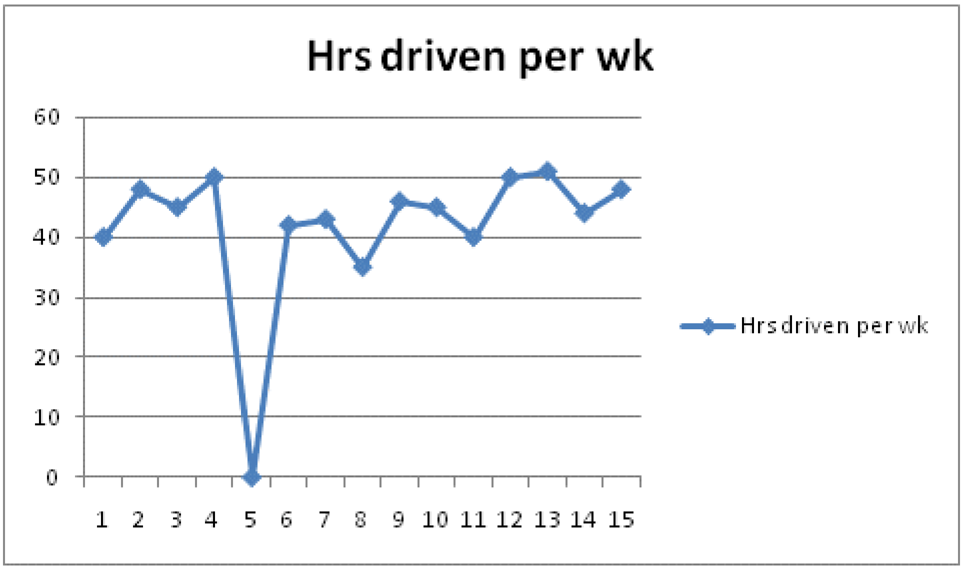

Figure 8. Number of hours driven per week

Driving in Cities, Towns, Motorways & Europe

Of the 15 drivers interviewed:

- All of them had regular experience with driving in towns and cities.
- All of them regularly drove on motorways.
- Only 2 had experience in driving in left hand drive countries.

Drivers adjustment of seat when first entering the vehicle

From the sample of drivers interviewed all of them stated they adjusted their seat when first entering the cab prior to driving.

1	Yes
2	Every time
3	Yes
4	Yes religiously
5	Yes
6	Yes
7	Yes
8	Yes and steering wheel and mirrors
9	Yes
10	Not always but most of the time
11	Yes drive mainly Scania and they are one of the better ones
12	Yes
13	Yes
14	Yes
15	Yes

Table 6. Drivers' seat adjustment

2.4.2.4.3 LGV Blind Spots

Driver awareness

Drivers were asked about their awareness of problems caused by poor vision e.g. mirror blind spots. The responses indicate that all drivers felt their awareness of visual difficulties associated with blind spots was good. A number mentioned the importance of training with one suggesting that experience is a further factor. Problematic blind spot areas picked out were to the rear, the front corners and down the sides. Using junctions was an activity cited in relation to blind spots.

1	well understood issue - relatively minor issues, not really discussed between drivers
2	Very aware due to regular training sessions. I think additional hazard perceptions should be included in test for car drivers
3	Very aware
4	Yes aware but experience is a bigger factor
5	quite rarely
6	Mostly junctions - last minute see a car. Best mirrors on coaches
7	most drivers - especially here have a lot of driver training, hazard perception plus fuel training and fuel efficiency
8	Aware of all blind spots
9	Down sides of vehicle, cyclists, junctions are aware
10	Should be extremely aware, backside of wagon - can't see at all. Front corners
11	Really well
12	Yes 100% aware
13	Very aware
14	90% aware
15	Mostly yes

Table 7. Drivers' awareness of blind spots

<u>Situations where blind spots are critical</u>

Drivers were in agreement on particular situations where blind spots become more problematic. Some examples given were changing lanes, roundabouts, junctions and reversing. A further trend was the other road users that LGV drivers perceive to be at risk, this included cars, cyclists and pedestrians.

1	Cars coming around roundabouts, observation from mirror
2	Junctions are the worst ones (slip road exit). Roundabouts (obscuration by mirrors) and Changing lanes
3	Junctions, mirrors can block a complete road; roundabouts; vehicles to the side
4	Pulling off and cars sitting in blind spot
5	N/A
6	At junctions
7	Reversing
8	Changing lanes on motorway, junctions, traffic lights. Also identified road signs as blind spots
9	Manoeuvring vehicle in and out of stores. Turning at junctions. Changing lanes
10	Cars coming up behind and changing lanes
11	Changing lanes. Slip roads and cars coming on
12	See pedestrians, cyclists, motor cyclists and sometimes cars
13	People walking in front of cab
14	On motorway cars overtaking
15	Reversing to shops and roundabouts

Table 8. Drivers' responses to situations where blind spots are critical

2.4.2.4.4 Impact of weather conditions

A mixed response was given by drivers regarding the impact of weather conditions on mirror performance. For those drivers who considered that weather conditions did have an impact, most mentioned rain as being problematic and one mentioned wind bending the mirror out of suitable alignment. Heated mirrors were generally considered to go some way towards alleviating some of the difficulties associated with rain.

1	No mirrors cleaned if necessary
2	Heated mirrors, keeps mirror clear even if they have been rained on
3	Possible, driving in the rain
4	No
5	Yes
6	No
7	When mirrors wet always worse even when heaters are on
8	Weather conditions generally make driving conditions worse
9	Yes sometimes
10	Can do when mirrors get wet, not all heated. What about a wiper?
11	No
12	Yes
13	Yes
14	Slightly
15	So long as mirrors are working. In high wind the nearside mirror bends in. Also means more movement of head

Table 9. Drivers' responses to the impact of weather conditions on visibility

2.4.2.4.5 Actions of other vehicles

A strong trend was apparent regarding LGV drivers' views on other road users and their understanding and expectations of LGVs on the road. The drivers felt there is a real lack of understanding of the difficulties they are faced with. Many drivers stated that they considered that other road users were not aware that they can't be seen. There were also comments as to poor practices by other road users such as undertaking and not using indicators. Cars and cyclists were all considered to be problematic to LGV drivers.

1	Car drivers not using indicators at roundabouts
2	Don't hold back and give the LGV enough room - hazard awareness
3	too close, awareness they can't see them. Perception that other road users don't know how much the LGV driver can see them
4	not really other than pulling off
5	N/A
6	Walking behind when reversing
7	Lack of indication
8	No other road users are aware of LGV drivers difficulties when manoeuvring
9	Don't understand they can't be seen
10	Cars just don't care, push bikes think they own the road especially on dual carriageways - careless
11	Just not aware
12	They're not aware
13	Not looking where they are going
14	Overtaking on the inside - at traffic lights cannot see cyclists on inside
15	Undertaking and filling the space

Table 10. Actions of other drivers that cause problems

2.4.2.4.6 Methods used for compensating poor vision

A variety of methods were incorporated for dealing with poor vision. The most commonly cited were vehicle positioning at junctions and getting out to undertake a direct visual check. The driver changing their position inside the cab and driving with more caution were also mentioned.

1	Leaning around mirrors, depends on junction
2	Vehicle positioning in different situations
3	Move body around cab to get better view. Position vehicle toward the way of turning to gain visibility
4	Not really (blind spot cannot really be accommodated) pulling off left for right turn
5	No
6	Cleaning mirrors
7	Move your position especially when reversing
8	Re-position vehicle so they can see because mirrors are not sufficient for that. Reversing Manoeuvre check it before you start
9	If manoeuvring get out and check. Drive and lean over to check
10	Changing vehicle position so you can see down the road
11	Take it easy - bit more careful. Can anticipate what people will do
12	Vehicle position at junctions
13	Not really - really bad would get out and do a visual check
14	Yes
15	Position at junctions. Get out when reversing

Table 11. Methods adopted by drivers to compensate poor visibility

2.4.2.4.7 Vehicle Design

In terms of improvements that can be made to driver vision with respect to the structure of the vehicle, the most common response related to incorporating a window behind the passenger seat. Pillar and mirror obstruction was noted as problematic but drivers acknowledged that compromises might be necessary due to crashworthiness requirements. Additional mirrors to the front and sensors were mentioned as potential methods for improvement.

1	Nothing
2	Compromise is not good because crash worthiness is more important
3	Bigger windows lower
4	Side behind passenger seat – window
5	N/A
6	Mirrors put on same as coaches
7	Not a lot can be done without weakening the vehicle. Obstructed at times by mirrors and door pillars at junctions. Lack of windows to rear of seat. Sometimes move vehicle to be able to see
8	Side window. Distance mirror could do with a 3rd one that brings it into focus
	No
10	Camera at the back and extra mirror at the front
11	More sensors for proximity
12	Square - get rid of A-pillar
13	Volvo needs bigger mirrors
14	Volvo - mirrors need to change their shape - very wide
15	Class 6 mirror and sensors

Table 12. Suggested vehicle design solutions

2.4.2.4.8 Awareness and use of aftermarket vehicle modifications

Predominantly drivers were not aware or had no experience in using aftermarket modifications. Some drivers had experienced reversing cameras. One driver who elaborated stated that the cameras were useful but should not be relied upon.

1	Aware of but not used other than rear facing camera
2	Not used
3	No
4	N/A
5	N/A
6	No
7	N/A
8	N/A
9	Got reversing aids on them
10	Yes used cameras on newer LGVs - really helpful when close but can't rely on them
11	No
12	No
13	Yes
14	Mirror to front of cab and camera
15	N/A

Table 13. Drivers' awareness and use of aftermarket modifications

2.4.2.4.9 Devices or systems fitted to the vehicle

Just over two-thirds of the drivers (11/15) had experience of some form of additional device or system fitted to their vehicles. The most common systems fitted to the vehicles that were measured were cameras with 7 of the 15 vehicles having this system fitted. One vehicle had sensors fitted which appeared to cause difficulties for the driver in terms of false alarms.

1	Rear facing camera - pop up screen can be on whilst driving
2	N/A
3	Class 5 only
4	Camera on trailer
5	N/A
6	Reversing camera
7	Cameras fitted
8	Cameras - very rarely use during normal driving only when reversing. Bleepers totally useless - especially the step one - if we listened to bleepers wouldn't go down most roads
9	Camera Yes
10	Yes
11	No
12	Yes
13	Yes cameras on the back and some have sensors
14	Yes
15	N/A

Table 14. Devices and systems fitted to the LGV the currently drive

2.4.3 Trainer interviews

2.4.3.1 Recruitment

In parallel to the driver interviews, trainer interviews were undertaken to explore the field of view issues, in particular the nature of any blind spots and to understand in more detail the driving tasks associated with this. It was considered that the trainers, like the drivers, would contribute direct personal experience to the project and at the same time provide a context of best practice as well as informed view of the potential weaknesses in drivers' approach to the driving task. The interviews were conducted on an individual basis and used volunteer participants from a driver training background or business. The interviews took place within the Midlands area from January 2011 to March 2011.

2.4.3.2 Final Sample

In total four trainer interviews were completed. All participants met the following inclusion criteria:

- Working age (16 – 65 years).
- Male and female (although no females participants were recruited in the sample)
- Had a driver training background or business.
- Voluntary participants in the study.

The profile of the sample was driven predominantly by availability and a personal interest in the topic area.

The participants were asked if there were any reasons why they felt they were not able to take part in the study and were excluded if they answered 'yes'. However, no individuals were excluded.

2.4.3.3 Questionnaire

A copy of the full questionnaire used in the interview can found in Appendix 2.

2.4.3.4 Results

The following information given below outlines the results found from the interview process. This information was used to shape and define Task 3.

2.4.3.4.1 Trainer Details

The range in the number of years of instructing drivers for a LGV licence was from 24 - 39 years. This enabled good quality insights to be gathered from experienced trainers.

Total years instructing LGV drivers

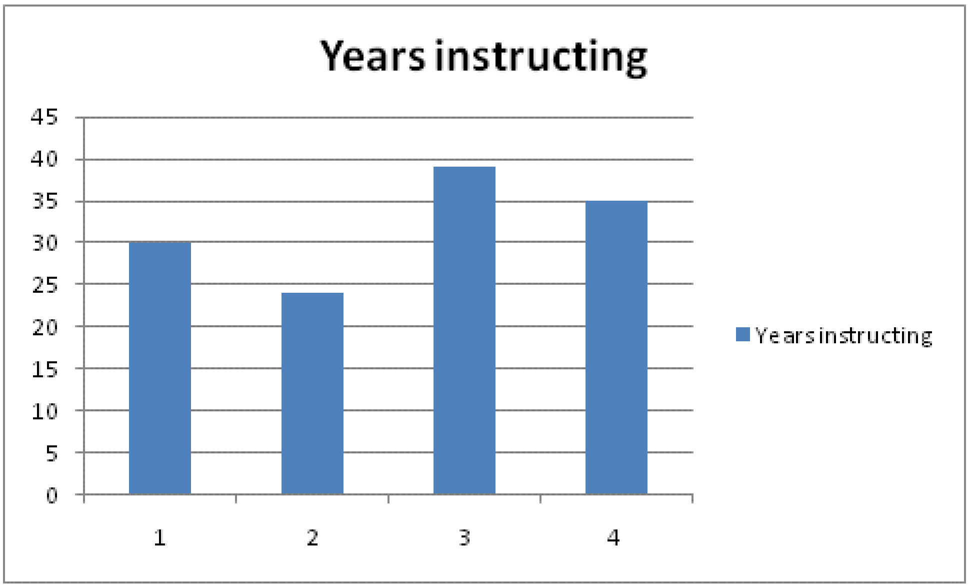

Figure 9. Number of years instructing LGV drivers

All of the trainers had over 24 years LGV driving experience.

Total number of years driving LGV's

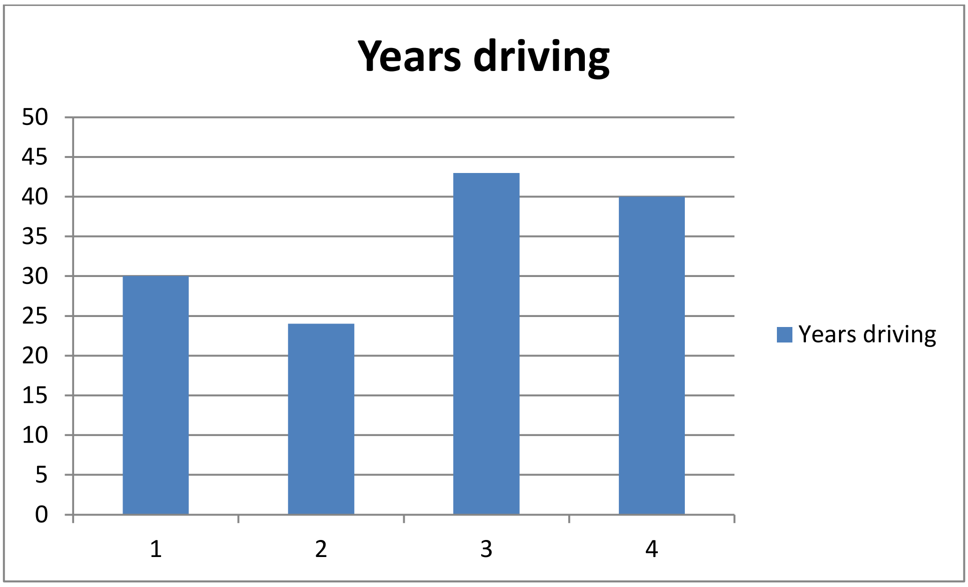

Figure 10. Number of years driving LGV's

2.4.3.4.2 LGV Blind Spots

Driver awareness

With respect to the trainers opinions of LGV drivers' awareness of problems caused by poor vision, all considered that LGV drivers have a good awareness of blind spot issues. This is demonstrated in how regularly the drivers have to check them.

1	In the company quite well
2	Very good awareness
3	Most drivers are aware
4	Fairly aware in how frequent they have to check them

Table 15. Drivers' awareness of blind spots

Training guidance provided

Within the training given to LGV drivers blind spots were always mentioned. Some trainers showed CPC videos and undertook observation tests whilst all emphasised the need to adjust mirrors when first entering the cab prior to driving.

1	Driver assessment debriefs. More obvious for what you are checking especially at roundabouts for example. CPC video - watch the bear and explain what that is about in relation to cyclists
2	RAF training, further training after passing test, periodic training. Initial mirror set up and general observation test
3	Integral with seat position. Seat high as possible then adjust mirrors
4	Shouldn't check them on a times basis. They should follow a mirror signal manoeuvre route into a junction, periodical checks, mirrors to confirm position particularly when close

Table 16. Types of driver training provided

Situations where blind spots are critical

The trainers each described a number of scenarios where there were potential problems with visibility. These ranged from manoeuvring, especially reversing, to side swipes on motorways.

1	Moving over, static objects, reversing, pulling forward
2	Special sticker prism for nearside.
3	Artic training - fixation with blind spot training over right shoulder. So can forget about other mirrors
4	Side swipes on motorways, reversing and articulated cannot see the blind side when Manoeuvring

Table 17. Trainers' opinions on situations where blinds are critical

2.4.3.4.3 Impact of weather conditions

3 out of 4 trainers agreed that weather conditions do have an impact on visibility when driving; in particular rain and dirt were mentioned. Mirror wipers and heated mirrors were stated as potential solutions to these problems.

1	No blind spot is a blind spot. More of a view to see blind spot creates other blind spots - bigger the mirror bigger the blind spot
2	Yes misty / dirty. Nearside mirror unable to clean. Should have heated mirrors or wipers
3	Wipers on older models but really need heated mirrors
4	Yes because of dirt and rain

Table 18. Trainers' responses on the impact of weather conditions

2.4.3.4.4 Actions of other vehicles

All the trainers stated their belief that other road users have a real lack of awareness of the driving task faced by LGV drivers and consequently problems occur. Cyclists were the most frequently mentioned type of other road user and passing on the nearside/undertaking was also cited as problematic. Furthermore they agreed that other road users didn't know where the blind spots of LGV's are and the potential danger they cause.

1	Lack of knowledge that there in the blind spot. If you can't see my mirrors I can't see you. Undertaking as well
2	Lack of blind spot awareness. Training for others and cyclists
3	Due to lack of education cars / cyclists about LGV's. Lack of knowledge of the highway code
4	Sitting in your blind spots for a long time. In lane and there in lane 3 both moving into lane 2. Cyclist down nearside

Table 19. Trainers' views on the actions of other road users

2.4.3.4.5 Methods used for compensating poor vision

The trainers stated that they actively encourage drivers to move their body in the cab to enhance their field of vision rather than retaining a static seated posture. They also encourage drivers to undertake regular scanning of the environment and to adopt good practice in vehicle positioning at junctions.

1	Move don't be static, look round and lean
2	Experience. No subjective assessment in testing
3	Permanent scanning around vehicle noticing other vehicles observation
4	Straddle lanes but not so much that there is a gap for a car to drive through

Table 20. Methods used for compensating poor vision by drivers

2.4.3.4.6 Vehicle Design

In terms of the amendments that can be made to improve driver vision with respect to the structure of the vehicle the trainers were in agreement that positive changes which could be made related to moving towards a cab with a greater glazed area. They also considered that the design of the mirror casing and arm could be improved by reducing the casing and size of the mirror arm.

1	More towards glass car - glass cab
2	Mirror design - too much over engineering in plastic
3	Deeper windscreens and vision doors
4	Thinner the pillars and where they put the handles. Mirrors for where the bunk area is - a window there would help

Table 21: Potential solutions to poor visibility through vehicle design

2.4.3.4.7 Awareness and use of aftermarket vehicle modifications

The trainers were aware of aftermarket modifications. With respect to camera systems, there was a mixed response. One trainer felt that the transition of looking outside the cab to gather information to looking at a screen within the cab was presently too difficult.

1	All of the above - tried everything
2	Detective sensors, cameras, Fresnel lenses when going overseas
3	Extra mirror - clip on larger mirrors for overtaking extensions
4	Use Fresnel lenses, camera systems not a big fan. Reverse camera is good but because you're so used to looking outside to find a camera in the cab is difficult to use

Table 22. Trainers' awareness and use of aftermarket vehicle modifications

2.4.4 Discussion

2.4.4.1 Summary of findings

- LGV drivers report that they are aware of problems associated with poor visibility in particular blind spots.
- Drivers and trainers reported similar driving scenarios in relation to potential blind spot problems
  - Changing lane (the trainers also mentioned side swipe issues)
  - Manoeuvring
  - Reversing
  - Pulling away
  - In addition the drivers mentioned roundabouts and junctions.
- There is strong agreement across both groups (drivers and trainers) that the awareness of other road users is poor. They consider that other road users do not understand the LGV driving task nor do they appreciate the blind spot issues faced by LGV drivers. Undertaking as a manoeuvre and cyclists as a particular road user group were mentioned by both drivers and trainers as problematic. Problematic blind spot areas were cited as the rear, the front corners and along the sides.
- Methods used for compensating poor visibility included:
  - Movement of the driver in the cab
  - Vehicle positioning at junctions
  - Driving with caution – scan the environment, try to anticipate what other road users will do

- The drivers also mentioned getting out of the cab to undertake direct visual checks.

- With respect to vehicle design, both groups considered that it would be useful to enhance direct vision especially with respect to visibility from the rear sides of the cab.
- Mirror design was mentioned by both groups in relation to reducing their size, although one driver cited the need for bigger mirrors. This discrepancy probably relates to the conflicting demands of the need for direct and indirect vision.
- Aftermarket modifications have been experienced by some drivers and all of the trainers. The most commonly mentioned technology was a camera system, although there was a note of caution regarding their use by both groups of respondents.
- The majority of drivers and trainers considered that weather conditions do have an impact on mirror performance. Both groups cited rain as problematic, with trainers also mentioning dirt. Both groups suggested heated mirrors as a potential solution.

2.4.4.2 Implications of findings

- The driving scenarios reported as problematic by drivers and trainers in relation to potential blind spot problems reflect those identified within the accident data cluster analysis i.e. changing lane, reversing, pulling away. This suggests that drivers are aware of the situations of high risk and the interviews suggest that some implement behavioural measures to try to overcome these e.g. changing posture in cab to get a better view, positioning of vehicle at junctions, etc. Effective use of the mirrors to support the drivers in some of these scenarios is therefore very important if LGV driving safety is to improve further; however this may be affected by:
  - Driver anthropometry and how this relates to blind spots (to be investigated in the next Task within this Work Package).
  - The driver's interpretation of what they see in the mirror which will in part be influenced by the quality of vision the mirror affords (to be investigated in Work Package 4).
  - Correct adjustment of mirrors.
  - Driver workload.

- In relation to mirror design, it is important to address the balance between the needs of direct and indirect vision. Mirrors need to show sufficient field of view coverage, minimise the blind spots within it and provide images of sufficient quality (these aspects will be assessed within this Work Package and Work Package 4) whilst at the same time minimising the impact to direct vision (implications for mirror housing and location). Further improvements to mirror design to mitigate against the effect of rain are to incorporate heating elements within them. These are currently available, but not across all vehicles and mirror types.
- An alternative to mirrors in balancing the needs for direct and indirect vision is the use of camera systems. These are further investigated within Work Package 5.
- The responses provided by the drivers and trainers suggest areas of focus with training programmes:
    - Continue to make LGV drivers aware of their blind spots, the at-risk driving scenarios and the behavioural measures which can be implemented to address them.
    - Continue to advise drivers of the importance of correct mirror set-up and provide clear criteria as to what they need to achieve and how to achieve this.
    - Re-iterate the importance of clean, dry mirrors.
    - Encourage drivers to be aware of the limits to indirect vision aids be they mirrors or cameras such that appropriate reliance is placed on them.
- With respect to other road users not understanding the LGV driving task or appreciating the blind spot issues faced by LGV drivers, raising awareness amongst other road users groups is a potential way forward. This is an activity currently undertaken jointly by Cemex and the Metropolitan Police in which the Police encourage cyclists to experience the LGV driver's view of the area immediately around the vehicle by enabling them to sit in the driver's seat of a Cemex LGV. Anecdotally, this initiative appears to be beneficial in improving cyclists understanding of the visual challenges faced by the LGV driver.

2.5 Task 3: Digital human modelling

2.5.1 Aim

To fully understand the areas around category N_2 vehicles (requiring Class V mirrors) and N_3 vehicles that cannot be seen by the driver through direct or indirect vision.

2.5.2 Rationale

The following analysis was designed to explore the blinds spots that exist in category N_2 and N_3 vehicles. This has been done using the SAMMIE Digital Human Modelling (DHM) system that has a long history of being applied to the design and assessment of a range of vehicle types. The rational for the analysis of blind spots is to test a selection of category N_2 and N_3 vehicles (selected from a top ten list of vehicle registrations in the UK using SMMT Motorparc data) to determine where any blind spots exist using mirrors that have been adjusted to meet the relevant area of coverage standards. By searching the STATS 19 database the prevalence of accident types that are associated with blind spots were identified which allowed individual OTS cases to be used to determine if the identified blind spots could have contributed to the accident. This was followed by the analysis of the potential for maladjustment of mirrors to contribute to the identified accident types. The following section provides a description of the methodology that was used.

2.5.3 Methodology

The DHM system has the capability of assessing indirect vision from a vehicle by projecting the volume of space that is visible to a driver by using a mirror (Figure 11).

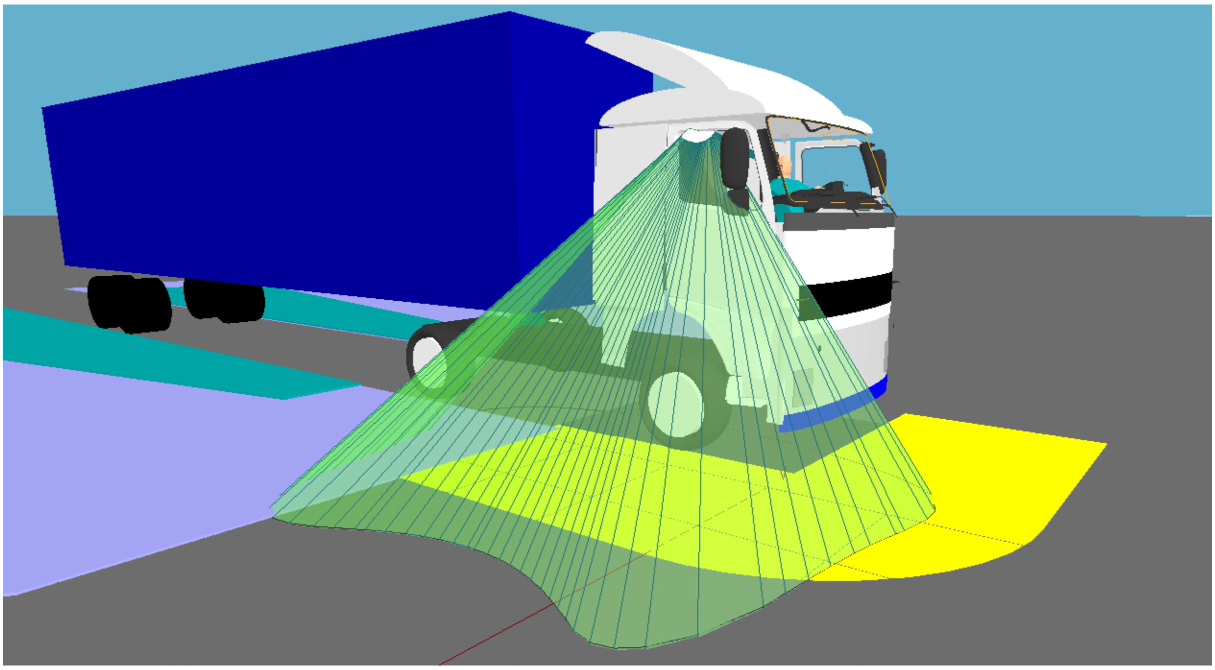

Figure 11. The green semi-transparent object encloses the volume of space that is visible to the driver in the Class IV mirror

This is combined with the ability to assess direct vision by projecting though window apertures (Figure 12) to allow a volumetric model of the combination of direct and indirect vision to be established. The power of this technique is that it provides a three dimensional model of how the volumes of space that are directly and indirectly visible to a driver combine to allow the identification of blind spots.

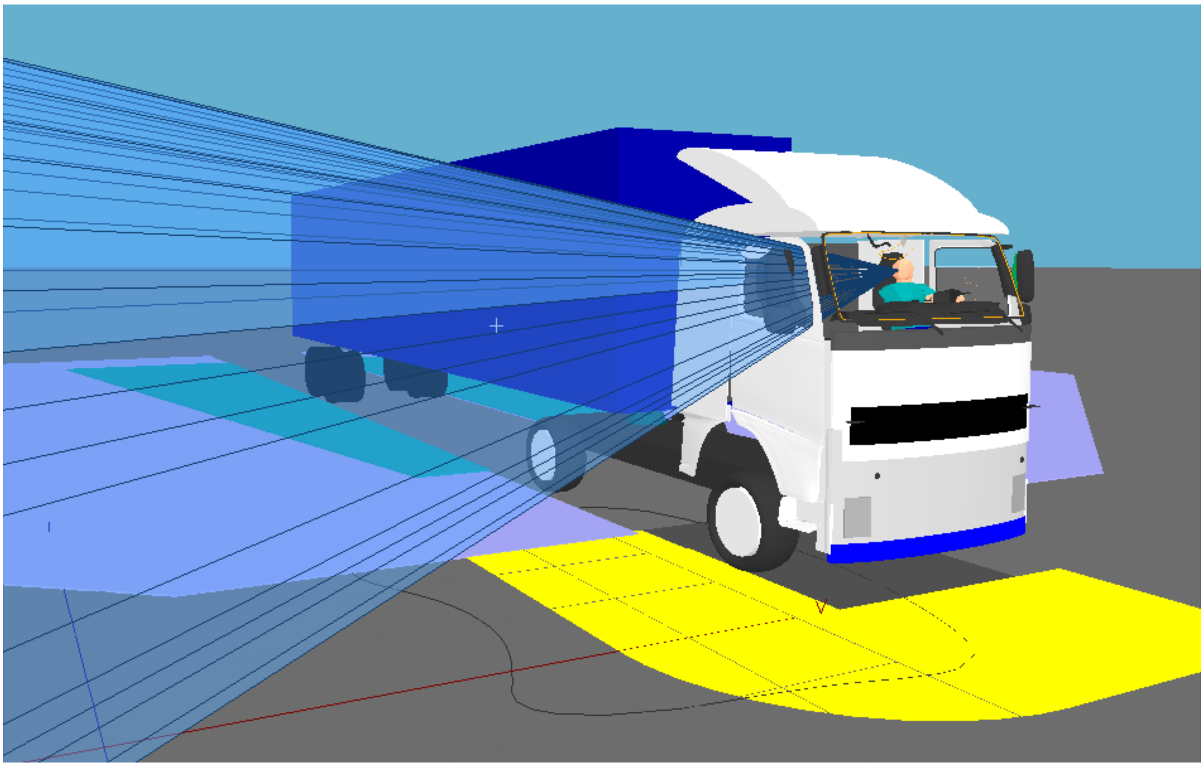

Figure 12. The blue semi-transparent object encloses the volume of space that is visible to the driver through the passenger window

This technique relies upon the following data;

- Vehicle geometry and mirror radius of curvature and adjustability range
- Postures that are adopted by a range of driver sizes to account for variability in the eye point, and therefore interaction with mirrors

2.5.3.1 Vehicle selection and capture of vehicle geometry

The selection of vehicles to be analysed was performed using the top ten list of new vehicle registrations for category N_2 and N_3 vehicles. This was done to ensure that the vehicles that were analysed would be examples that were prevalent in the operated LGV fleet. The vehicles that were selected are as follows:

Category N_2

- DAF LF 45
- Renault Midlum
- IVECO Eurocargo

Category N_3

- DAF XF 105
- Volvo 480 (Left hand drive)
- Scania R420

The process of vehicle selection included the specification that the vehicles should include a Class V mirror as defined in Directive 2003/97/EC. In the case of the IVECO Eurocargo, the vehicle did not meet the requirement to include a Class IV mirror on the driver's side of the vehicle, however, this vehicle was selected for analysis as it exhibited a potentially useful window configuration as discussed in Section 2.5.6.3.3. The left hand drive Volvo 480 was selected for analysis on the basis of the prevalence of side swipe accidents that involve left hand drive LGV's that was highlighted by the STATS 19 database analysis.

These vehicles were then used to generate three dimensional CAD data using a FARO arm data capture system. The following vehicle geometry was captured;

- Window apertures
- Door surface geometry
- Interior A-pillar surfaces
- Interior dash geometry
- Steering wheel adjustability range
- Seat surface geometry and adjustability range
- Location of the standard hip point using the SAE H-point manikin
- Mirror surround geometry
- Mirror surface geometry and adjustability range

These data were subsequently surfaced using PTC PRO/Engineer CAD software and imported into the SAMMIE DHM system where adjustment ranges were recreated based upon the FARO arm captured data.

2.5.3.2 Posturing of the Digital Human Models to allow the creation of a range of eye points

The driver interviews that were performed at the start of Phase 2 of the project provided an opportunity to capture driver postures and anthropometric data from a range of driver sizes. Figure 13 shows the range of postures that were captured with a 99th%ile UK male (only 1% of the UK population taller) on the left and a 4th%ile UK male (Only 4% of the male UK population are shorter) on the right.

Figure 13. The variety of driver postures exhibited by drivers with a 4th%ile to 99th%ile stature range using UK anthropometric data (ADULTDATA 1998)

Initial testing was performed with each vehicle and it was determined that it would difficult for a driver smaller than a 4th%ile UK male to effectively reach the pedals from the lowest possible seat position. The range of driver sizes used for the DHM analysis was therefore 4th%ile UK male to 99th%ile male. The anthropometric data for the 99th %ile and 4th%ile UK males were combined with the observed postures to provide two distinct eye positions. This was done to determine the effect of eye position range on direct and indirect field of view. The H-Point position data gathered during the vehicle data capture using the SAE H-point manikin (Society of Automotive Engineers 2010) was used to position the Digital Human Models in each vehicle.

2.5.3.3 Analysis methodology

The methodology was designed to identify blind spots in the combined direct and indirect field of view from N_3 and N_2 vehicles with mirrors adjusted to meet the standards defined in Directive 2003/97/EC. The blind spots that were identified were then examined to determine the size of visual target that can be obscured from the identified range of driver sizes. This was followed by the analysis of specific OTS cases to determine if blind spots could have been a contributory factor to the accidents. An analysis was then performed that examined the variability in mirror adjustment that had the potential to increase the size of blind spots. Finally, renders were produced which demonstrate what can be seen in Class II, IV, V and VI mirrors.

Solutions to the significant blinds spots were identified and where appropriate tested using the DHM system. The following sections describe each analysis stage in detail.

2.5.3.3.1 Analysis stage 1: Identification of blind spots

The first stage of the analysis was to identify if blind spots exist for correctly adjusted mirrors in category N_2 and N_3 vehicles. The standard templates for the areas to be visible in Class II, IV, V and VI mirrors were created in the DHM system based upon the data found in Directive 2003/97/EC (Figure 14).

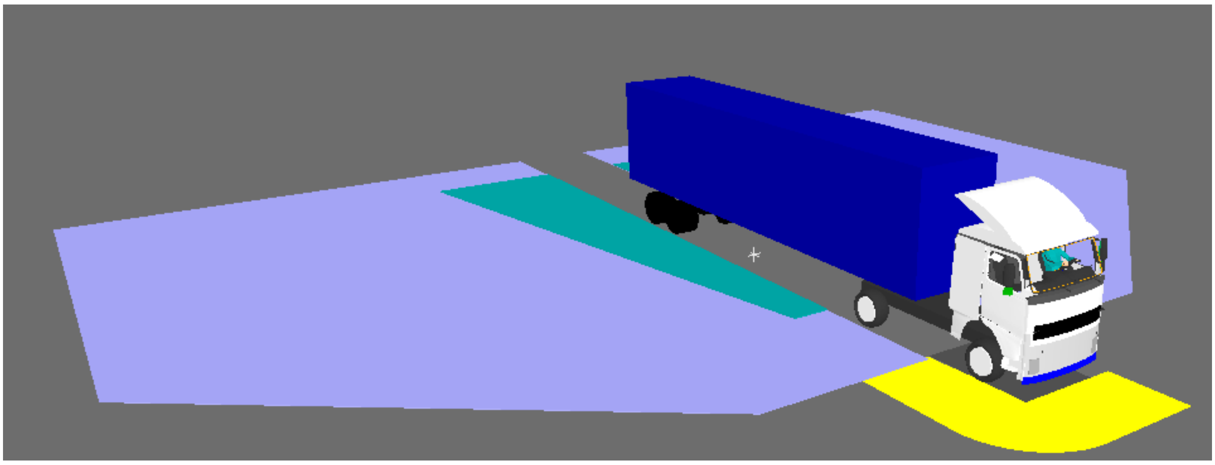

Figure 14. The mirror adjustment assessment templates build using the data in Directive 2003/97/EC (left hand drive vehicle)

In order to allow an analysis of indirect vision the mirrors of each vehicle were adjusted within their adjustment limitations to ensure that the standards were met. The Class V mirror was adjusted so that side of the vehicle was visible to the driver, in order to allow vulnerable road users such as pedestrians and cyclists to be seen by the driver, as can be seen in Figure 15.

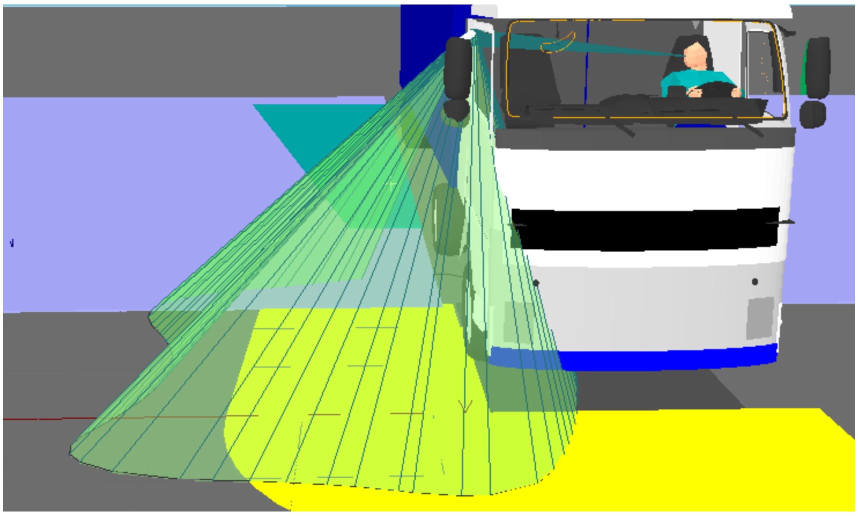

Figure 15. The Class V mirror adjusted to cover the recommended area and allow the side of the vehicle to be visible to the driver

In all cases where the Class VI mirror was fitted the position of the mirror that was captured in the data acquisition phase met the standard (see Figure 16 for an example of this) and so adjustment of the Class VI mirror orientations was not necessary during the analysis.

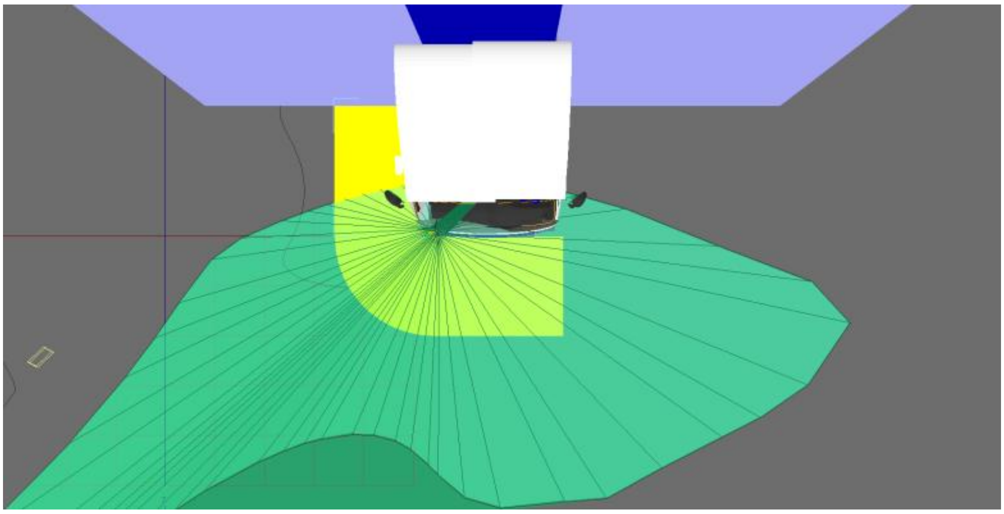

Figure 16. The digitised Class VI mirror position allowed the standard area shown in Directive 2003/97/EC to be enclosed within the projected visible volume

An example of the projection of all mirrors fitted to the Volvo 480 Left hand Drive LGV can be seen in Figure 17.

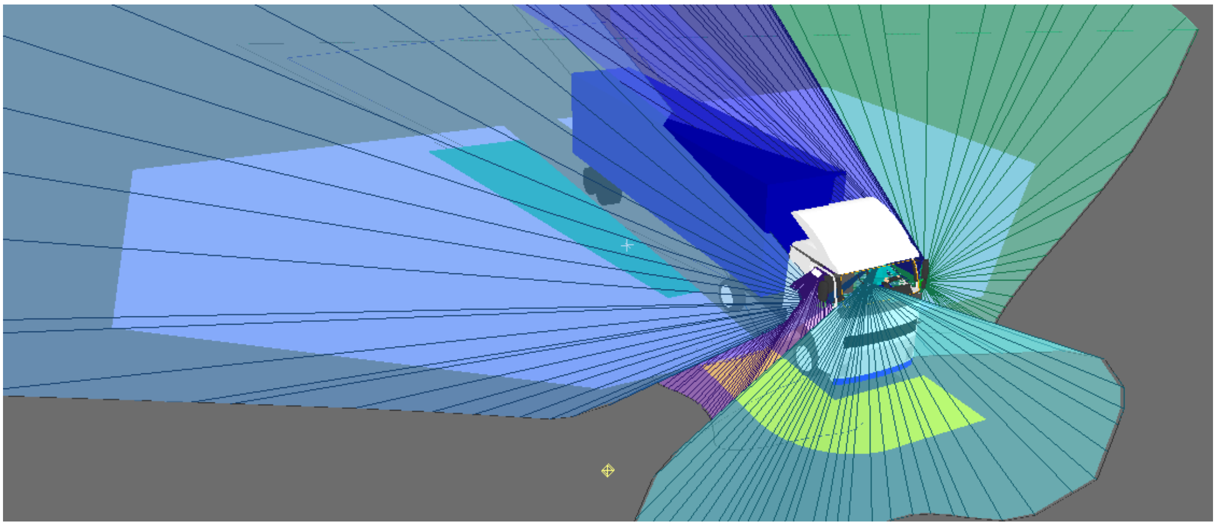

Figure 17. The mirror projections showing that the mirrors of the Volvo 480 left hand drive LGV meet the required standards for visibility

The analysis of direct vision was performed by projecting through the window apertures. In all cases the direct vision through the side windows was partially obscured by the Class II and IV mirrors and their associated housing. Paths were therefore created to allow the projection of the obscured volume of space hidden by mirrors. Figure 18 shows an example of the output from this process, with the projection through the passenger window being shown in a blue semi-transparent volume (the visible volume of space is enclosed by the boundaries of this volume), and the space that is obscured by the mirrors being shown by the red semi-transparent volume (the volume of space obscured by the mirror housing is enclosed by this volume).

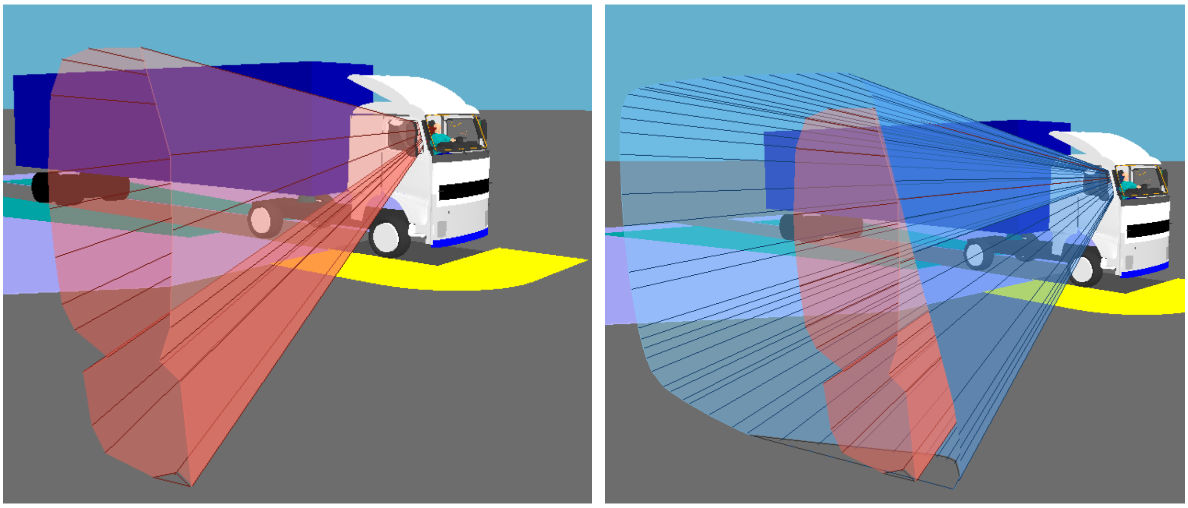

Figure 18. The projection of the volume of space obscured by the Class II and IV mirror housing (red semi-transparent volume) combined with the volume of space visible through the passenger window (blue semi-transparent volume

Figure 19 shows all of the window aperture projections combined with the projection for the obscuration produced by the driver's side Class II and IV mirror housing.

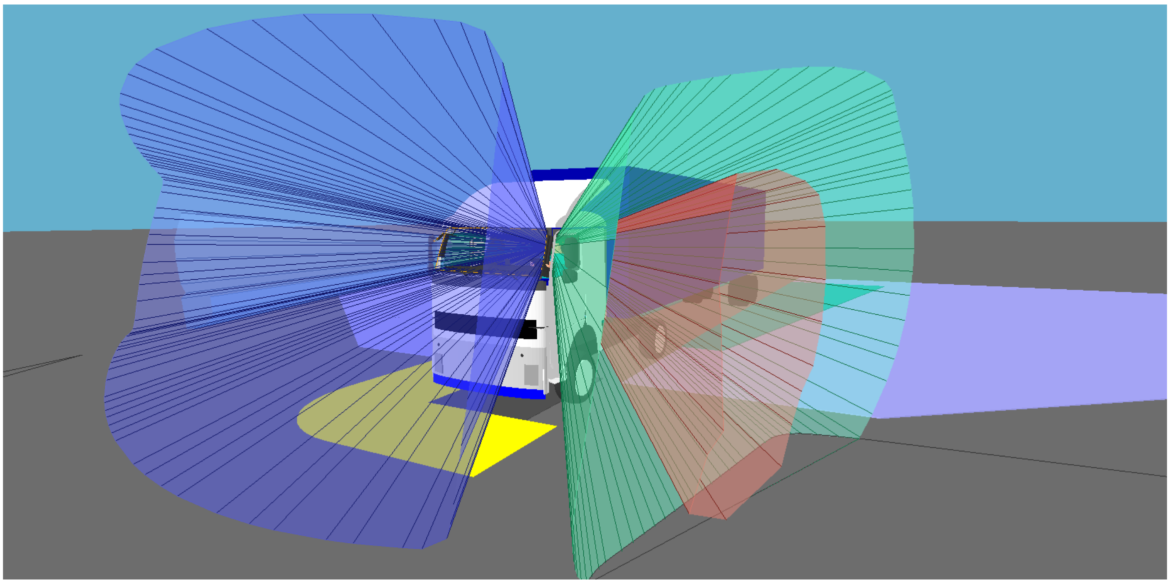

Figure 19. Projections that illustrate the visible volumes of space through window apertures and the obscuration caused by mirror housings

The identification of blind spots was performed by using a combination of three dimensional analysis combined with the production of two dimensional plots at a range of three heights. These plots were produced using the combination of the indirect and direct vision volume projection at three specific heights, i.e. ground level, 1m above the ground and 1.56m above the ground. The 1.56m value has been taken to represent the visibility at 95%ile UK male shoulder height. The plots show three visual areas: green is the area visibility from direct vision through window apertures; blue is indirect vision through mirrors; and red is the area not visible to the driver. An example of this can be seen in Figure 20.

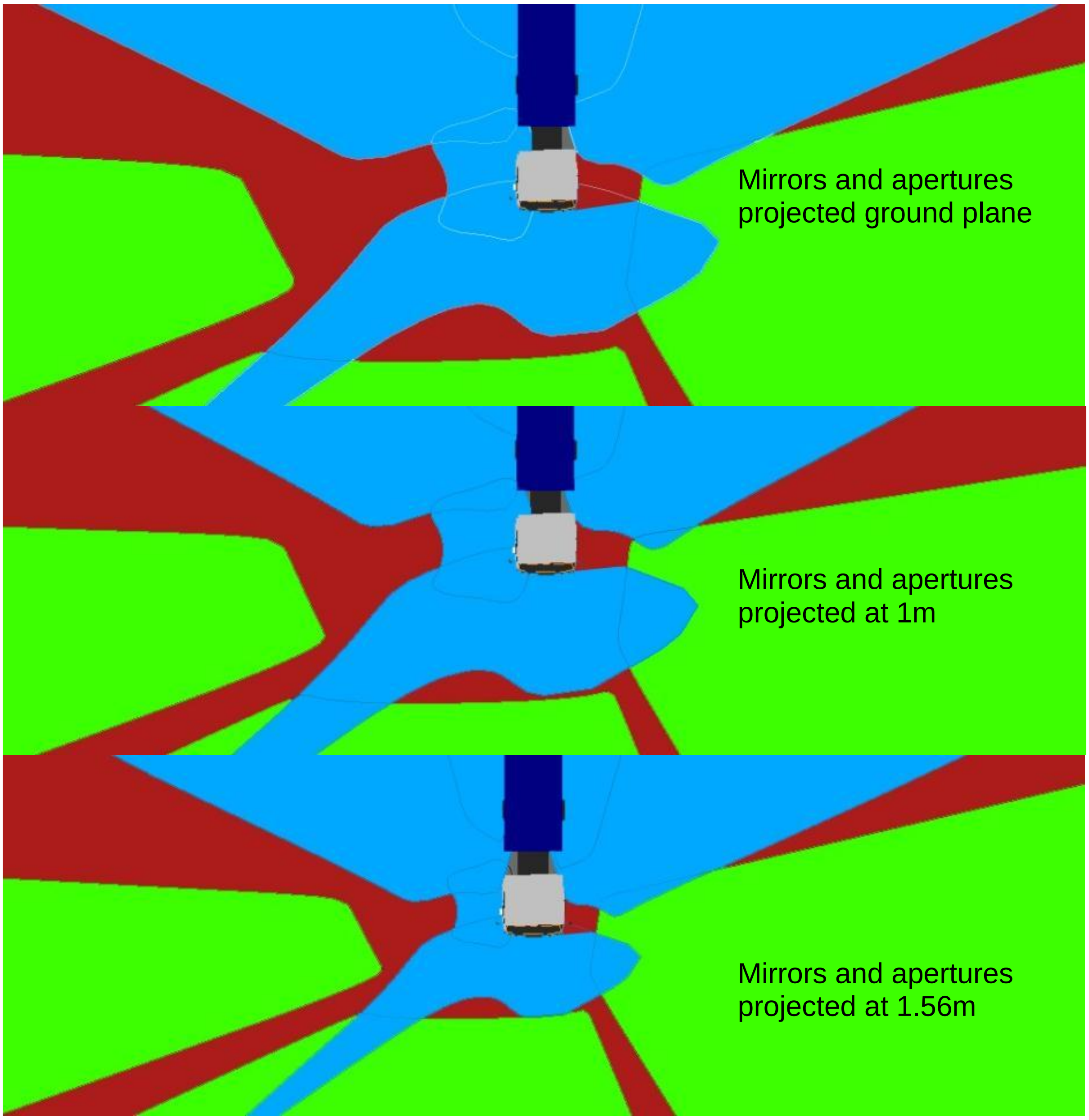

Figure 20. The blind spots identified by projecting the mirrors and window apertures at three different heights

These plots were produced for the two eye points defined for the 4th%ile UK male and the 99th%ile UK male based upon an analysis that showed significant differences between the plots that were produced for the two eye positions. Figure 21 shows these differences with the white projections relating to the 4th%ile eye position, and the black projections relating to the 99th%ile eye position.

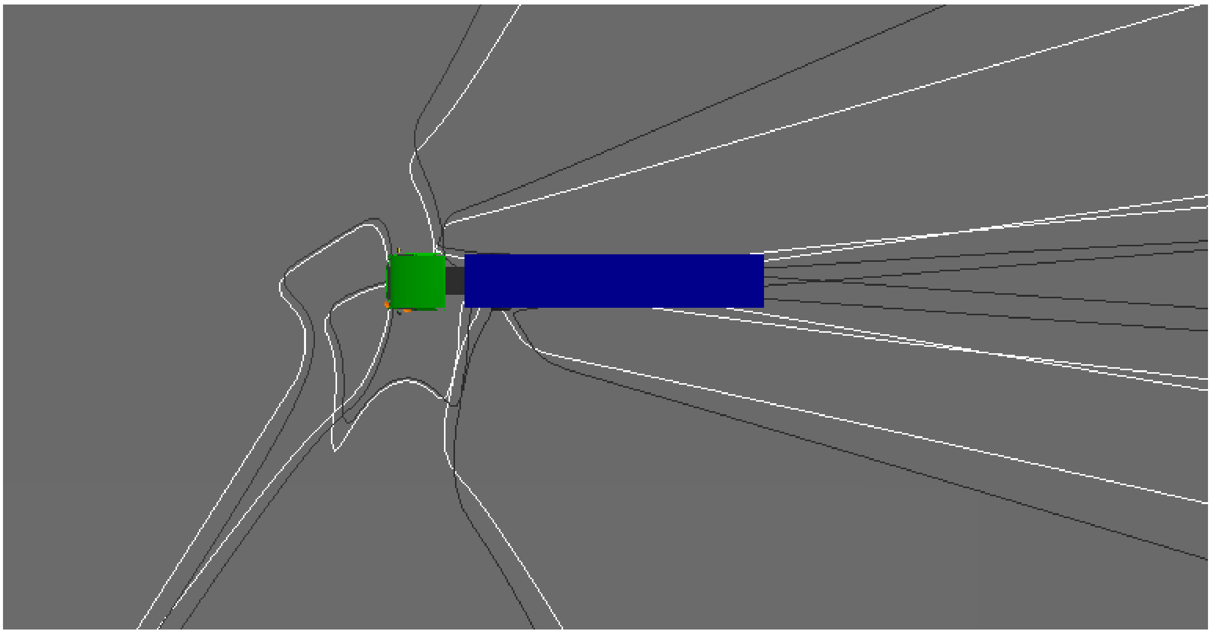

Figure 21. The difference that eye position makes to the mirror and aperture projections on the ground plane for the SCANIA R420

The identified blind spots were then explored in detail to determine the size of the object that can be hidden from the driver, and the implications of this in terms of positioning. For example, Figure 22 shows a blind spot that was identified on the passenger side of each N_3 vehicle. This blind spot sits between the volume of space visible through the Class V mirror, adjusted to meet the standards defined in Directive 2003/97/EC and the volume of space visible through the window aperture. This blind spot was able to obscure four cyclists, line abreast with 50%ile female stature (UK data).

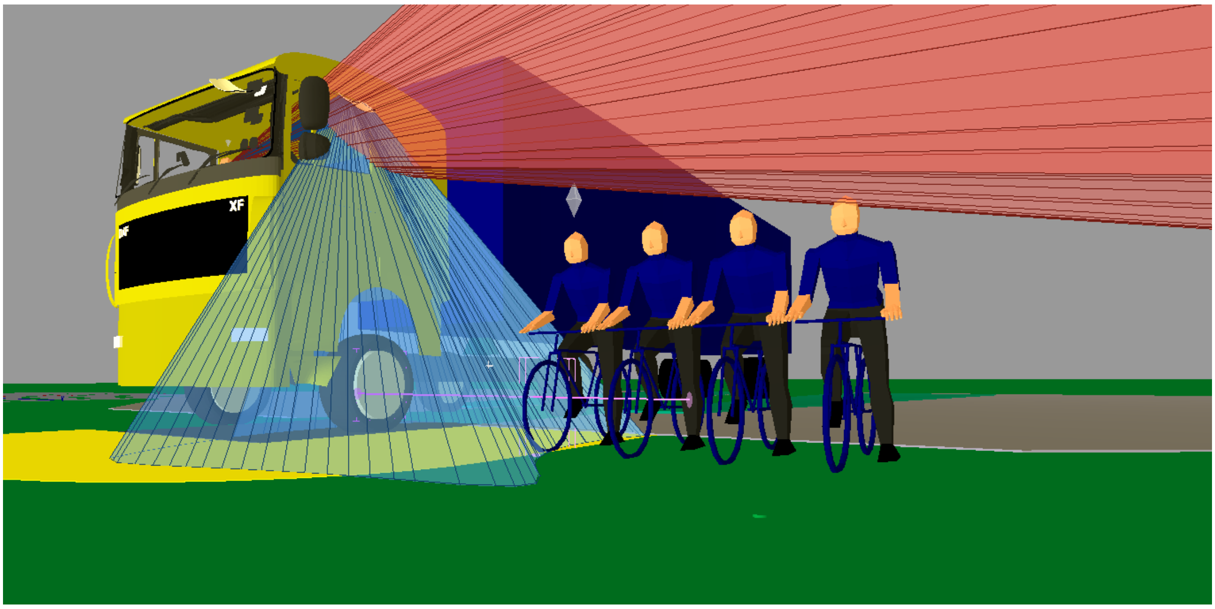

Figure 22. A blind spot identified by the DHM analysis

2.5.3.3.2 Analysis stage 2: OTS scenarios derived from STATS 19 analysis

The blind spots that were identified in analysis stage 1 were further examined by recreating accident scenarios that were derived from the analysis of STATS 19 data. The STATS 19 analysis highlighted accidents that occurred involving vulnerable road users at junctions and side swipe accidents for category N_3 vehicles. For category N_2 vehicles side swipe accidents were also identified, combined with accidents that occur when pulling out of T-Junctions. Specific OTS scenarios were identified that involved these situations and the road layout that was found in each case was modelled in the DHM system. The potential causes of the accidents that related to the use of direct and indirect vision were identified.

2.5.3.3.3 Analysis stage 3: Simulating the reflected image shown in Class V and VI mirrors

The radii of curvature of Class IV, V and VI mirrors have the potential to distort the image seen on the mirror surface by the driver. In order to illustrate what can actually be seen by a driver in critical scenario based situations CAD software was used to render the mirror surfaces.

2.5.4 Analysis results for category N_3 vehicles

2.5.4.1 Analysis stage 1 identification of blind spots

2.5.4.1.1 An analysis of the compliance with EC Directive 2003/97/EC on mirror coverage at the ground plane level

The following section illustrates the compliance of each vehicle with the EC directives on mirror coverage at the ground plane for Class II, IV, V and VI mirrors using the mirror projection technique in the Digital Human Modelling software.

2.5.4.1.1.1 The compliance of the Volvo 480 category N_3 left hand drive LGV

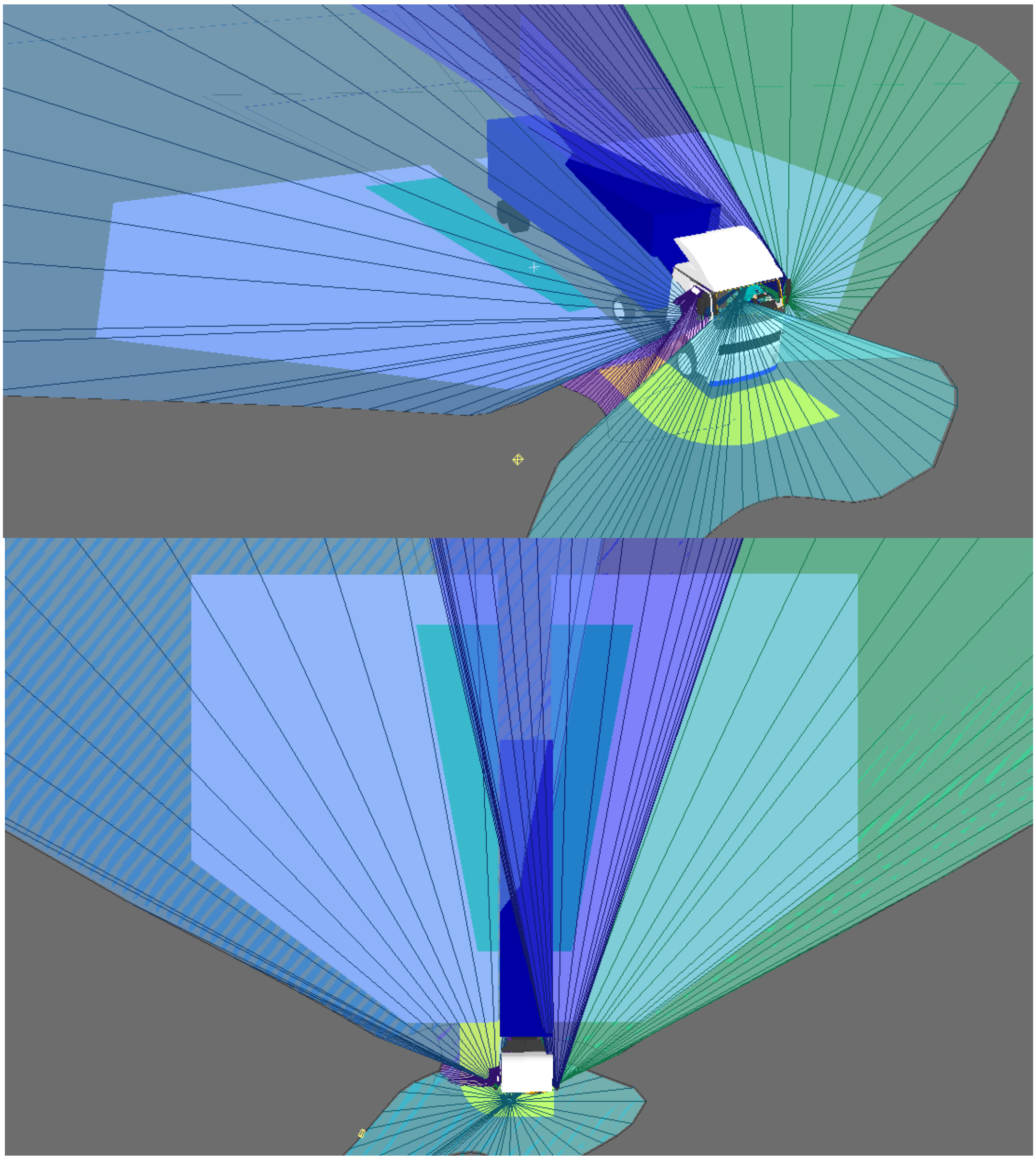

Figure 23. The compliance of the Volvo 480 category N_3 vehicle with the recommended area of visibility at the ground plane

Figure 23 shows that the mirrors mounted on the Volvo 480 category N_3 vehicle were able to be adjusted to comply with the standard templates for the areas to be visible using mirrors found in Directive 2003/97/EC.

2.5.4.1.1.2 The compliance of the SCANIA R420 category N_3 Right hand drive

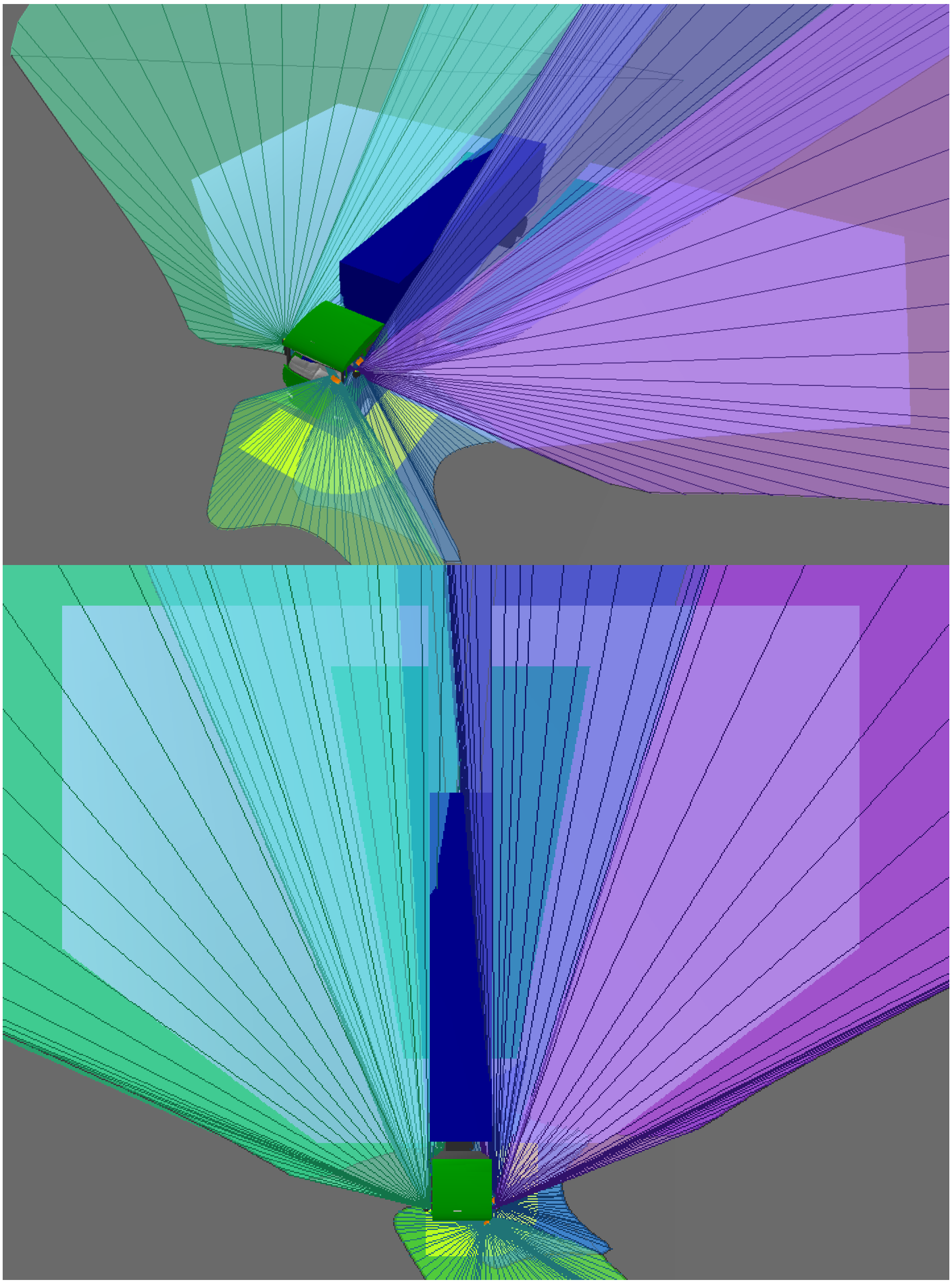

Figure 24. The compliance of the SCANIA R420 category N_3 vehicle with the recommended area of visibility at the ground plane

Figure 24 shows that the mirrors mounted on the Scania R420 were able to be adjusted to comply with the standard templates for the areas to be visible using mirrors found in Directive 2003/97/EC.

2.5.4.1.1.3 The compliance of the DAX XF R420 category N_3 Right hand drive

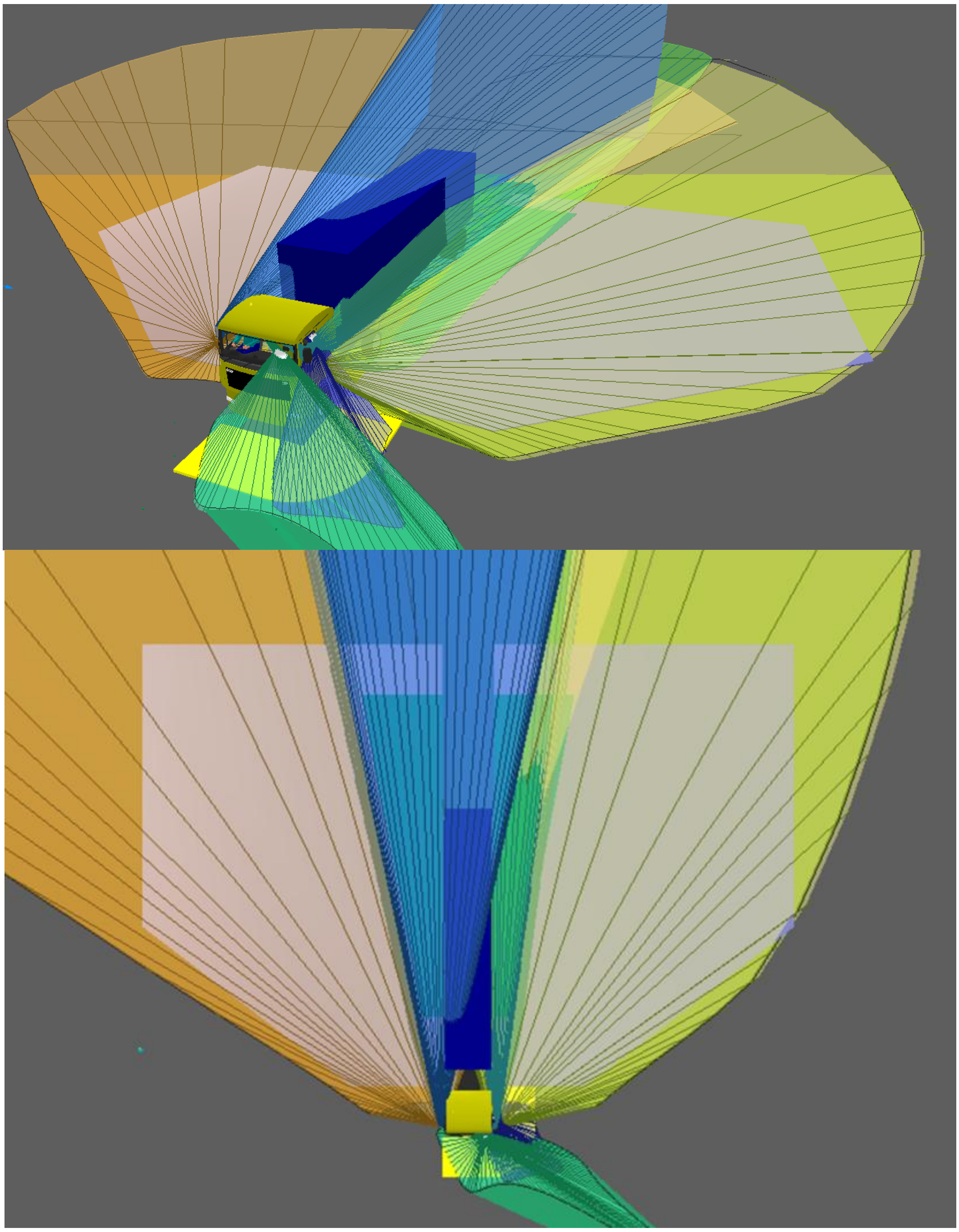

Figure 25. The compliance of the DAF XF category N_3 vehicle with the recommended area of visibility at the ground plane

Figure 25 shows that the mirrors mounted on the Volvo 480 were able to be adjusted to comply with the standard templates for the areas to be visible using mirrors found in Directive 2003/97/EC.

2.5.4.2 An analysis of the difference that driver eye position has on indirect vision: Volvo 480 left hand drive

The plots for the three N_3 vehicles shown in Figure 26 demonstrate significant difference in indirect vision between the two eye points that have been defined. This highlights the need to perform the analysis stages defined in the analysis methodology section using the two distinct eye points for the 4th%ile UK stature driver and the 99th%ile UK stature driver to ensure that the differences in eye position do not produce significantly different results during the identification of blind spots.

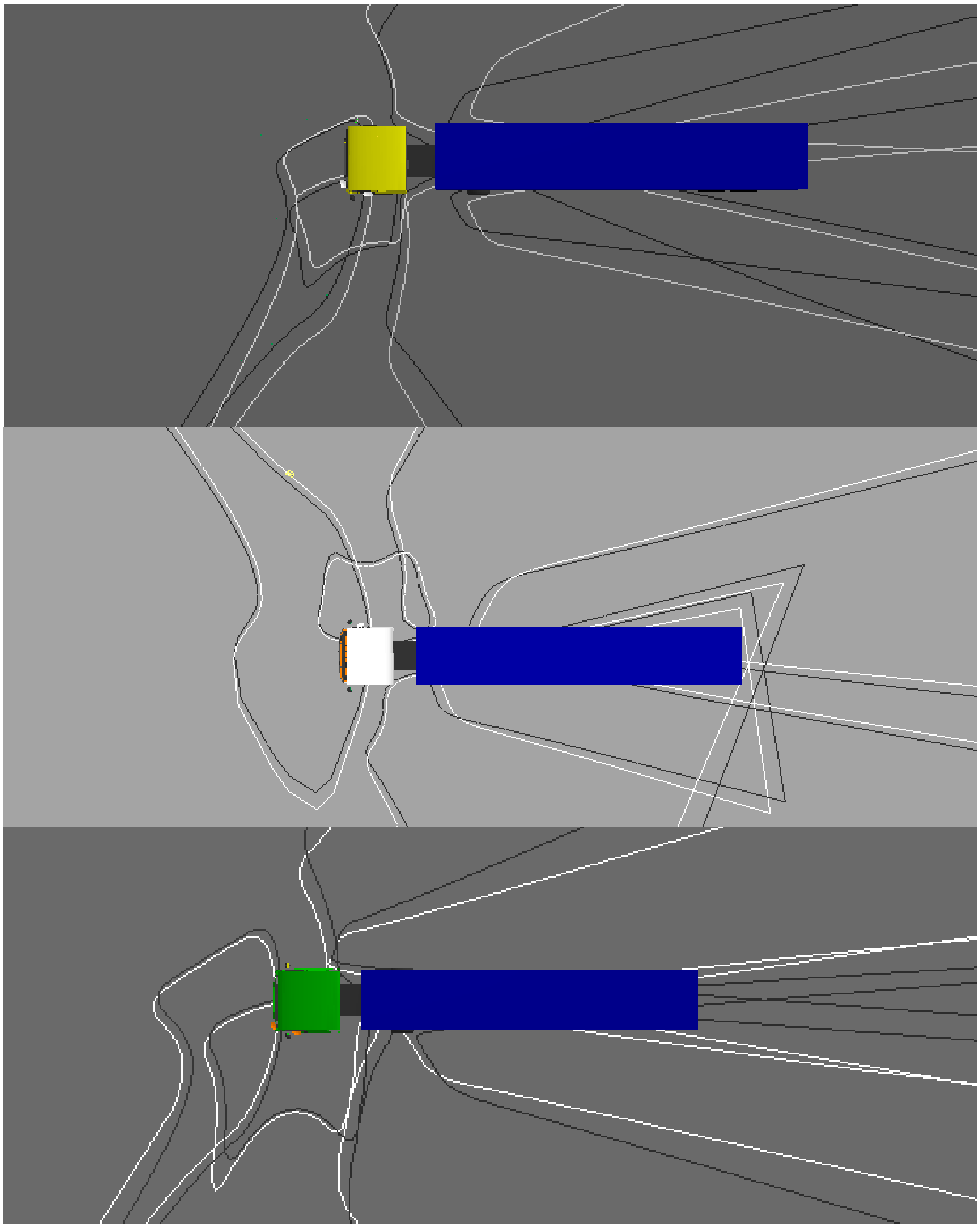

Figure 26. The projection of all mirrors onto the ground plane using the 4th%ile UK male eye point (white projected lines) and the 99th%ile UK male eye point (black projected lines)

2.5.4.3 Identification of blind spots: Volvo 480 category N_3 left hand drive LGV

2.5.4.3.1 Mirror and aperture projections for the 4^{th}%ile UK male

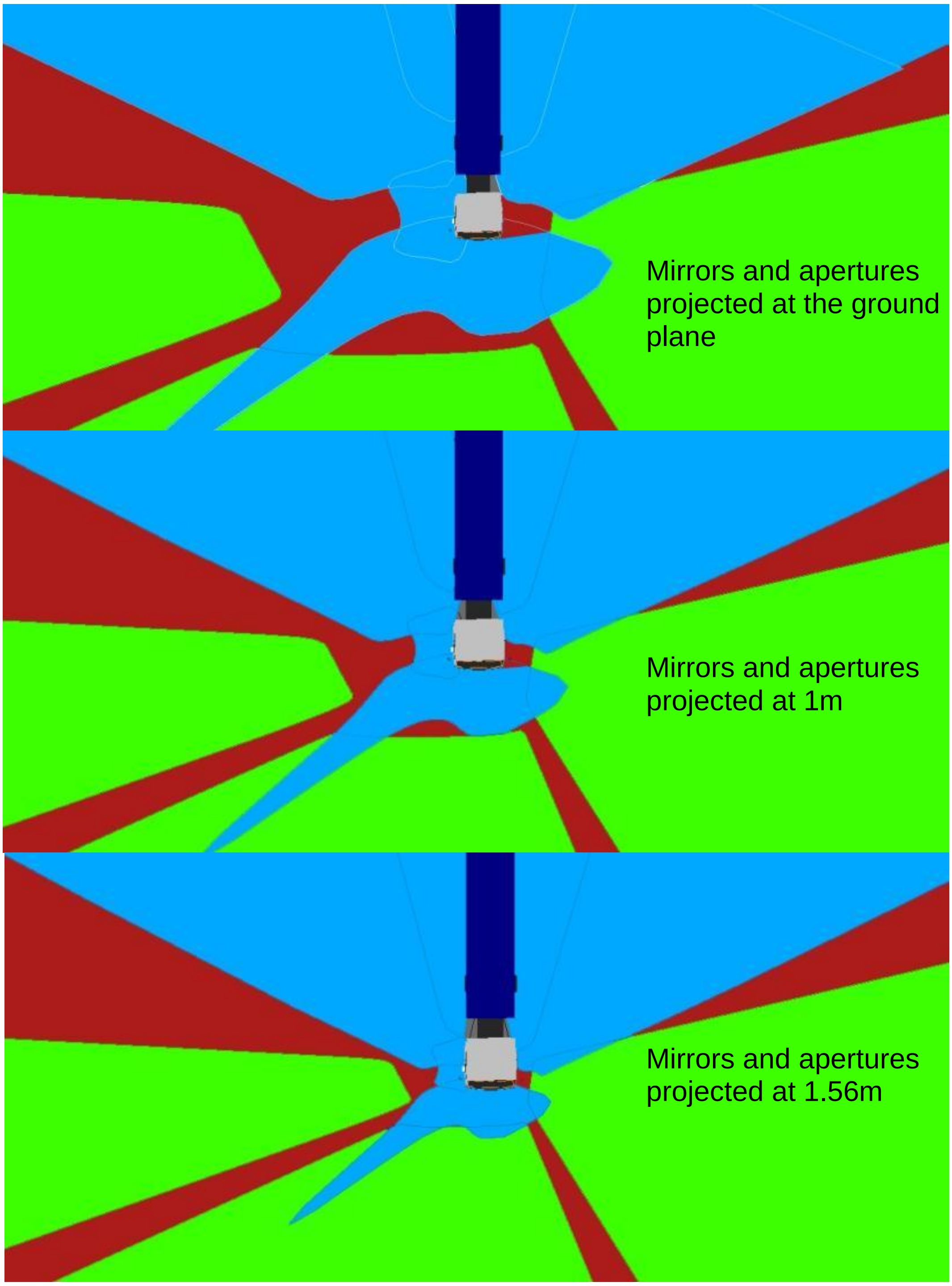

Figure 27. The projection of all mirrors onto the ground plane, 1m above the ground plane and 1.56m above the ground plane using the 4th%ile UK male eye point

2.5.4.3.2 Mirror and aperture projections for the 99th%ile UK male

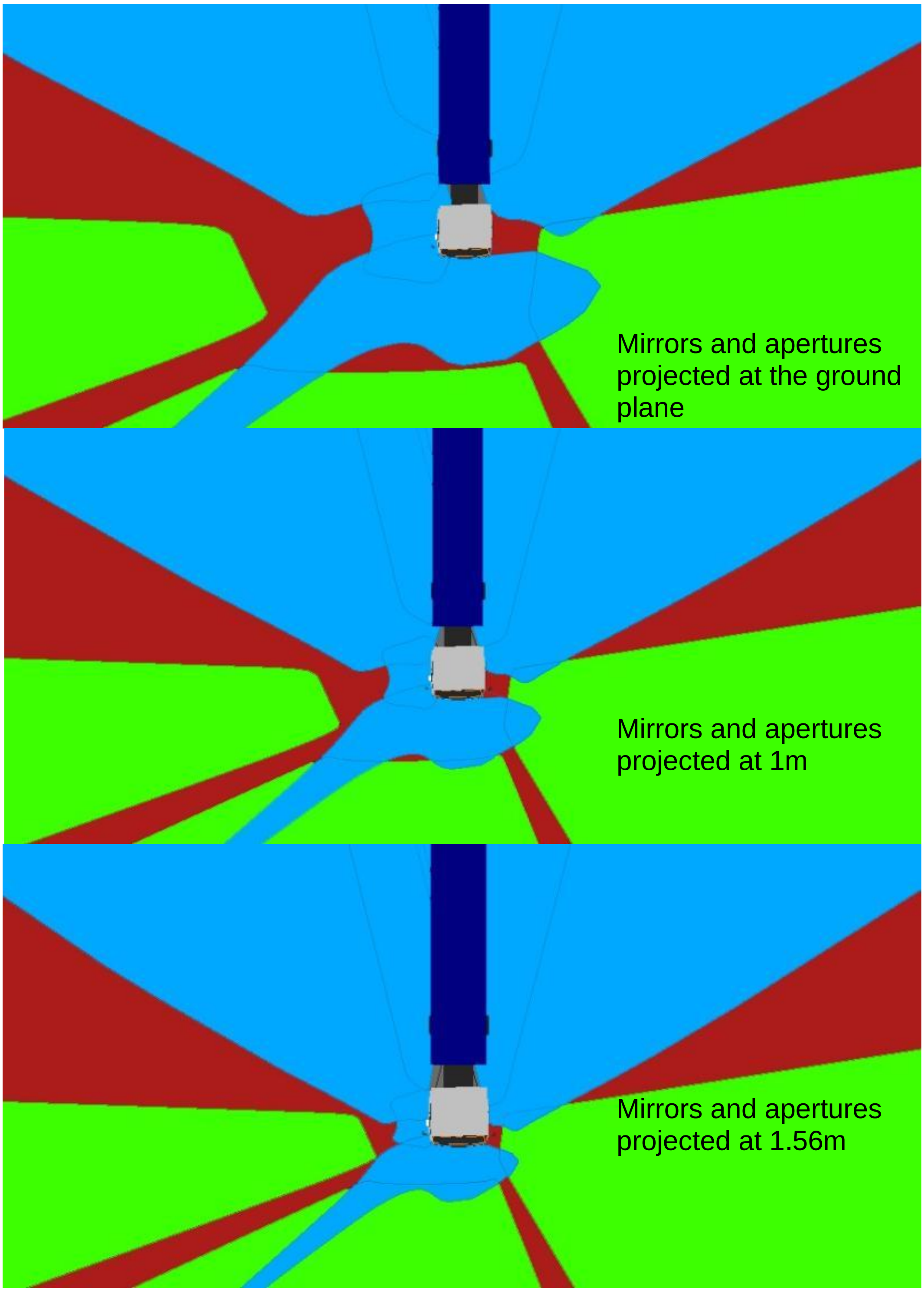

Figure 28. The projection of all mirrors onto the ground plane, 1m above the ground plane and 1.56m above the ground plane using the 99th%ile UK male eye point

2.5.4.3.3 The identified blind spots for the Volvo 480 left hand drive

Figure 27 and Figure 28 show the projection of all mirrors and apertures onto the ground plane, 1m above the ground plane and 1.56m above the ground plane for the Volvo 480 category N_3 vehicle for 4th%ile and 99th%ile UK male eye points respectively.

Figure 29 shows that this process highlighted two specific blind spot areas of interest, one on either side of the driver's cab. These two blind spot areas are consistent in all of the projected heights used. Blind spot 3 is only present at heights below 1.56m. The other blind spot areas identified using the technique are associated with the A-pillars and B-pillars of the vehicle.

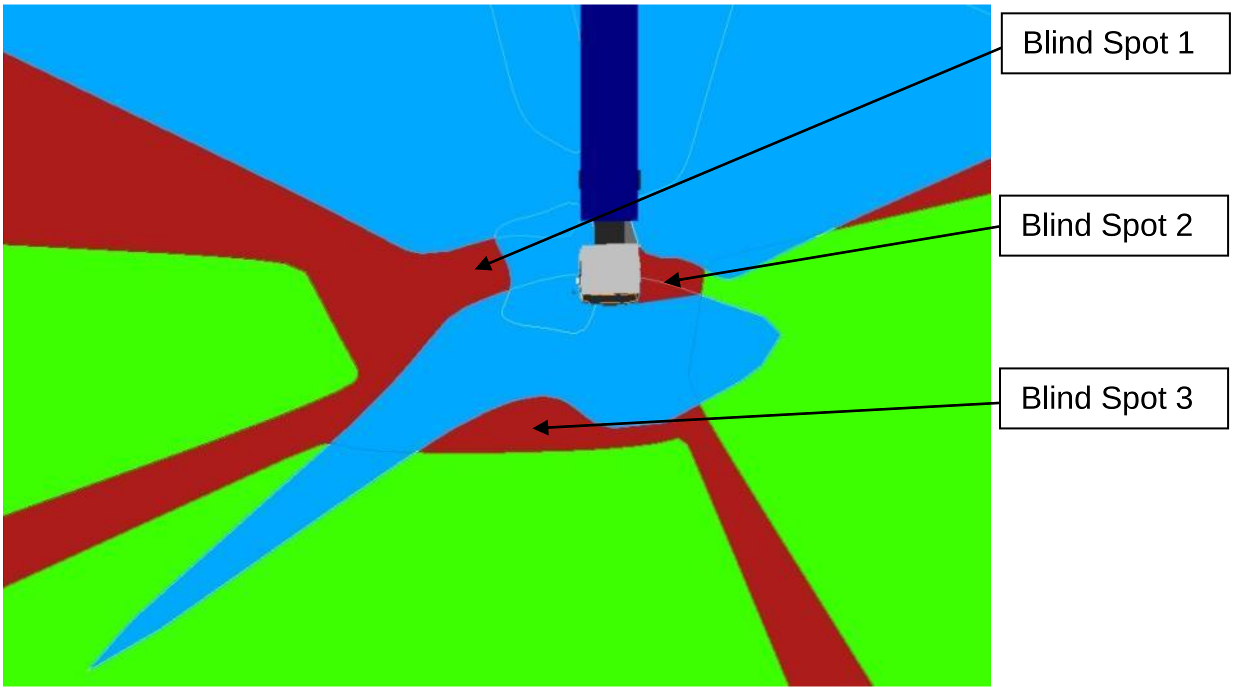

Figure 29. The three blind spot areas that have been identified using the projection of direct and indirect volumes

2.5.4.3.4 The objects that can be obscured from driver vision by blind spot 1

Figure 30 shows the blind spot between the volume of space visible through the Class V mirror and the volume of space visible through the window aperture for a 4th%ile UK male driver. This blind spot was able to obscure three cyclists, line abreast with 50%ile female stature (UK data). Figure 31 shows that the three cyclists are also not visible within the projected volume for the Class IV mirror.

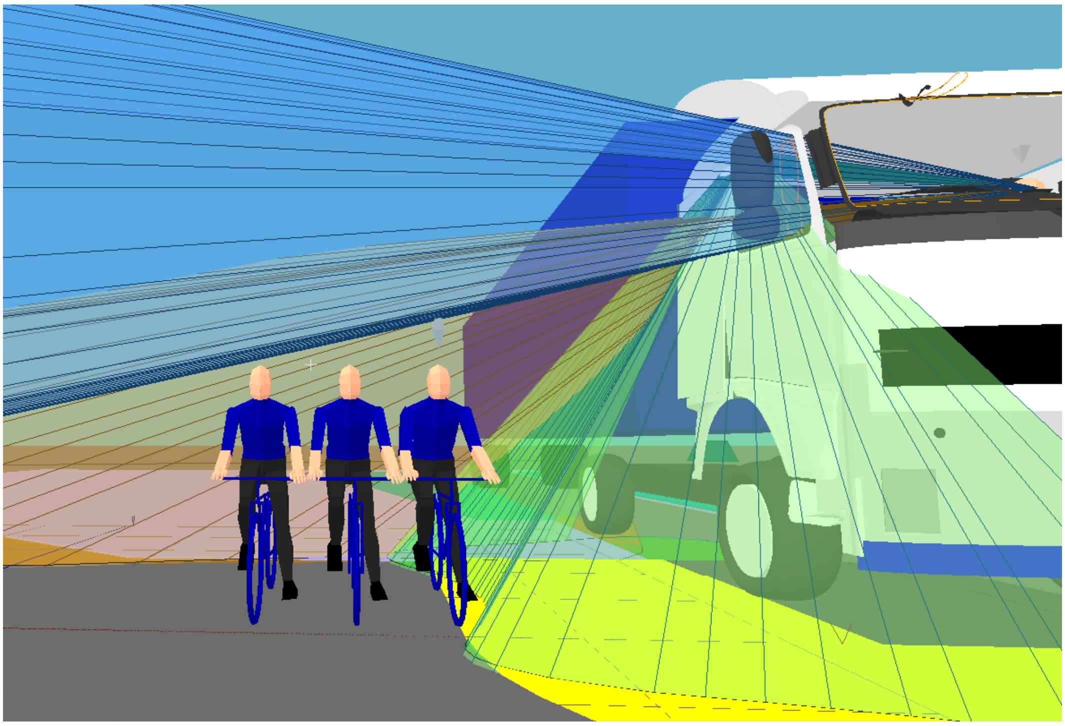

Figure 30. The blind spot between the Class V mirror and the volume that represents the direct vision through the passenger window

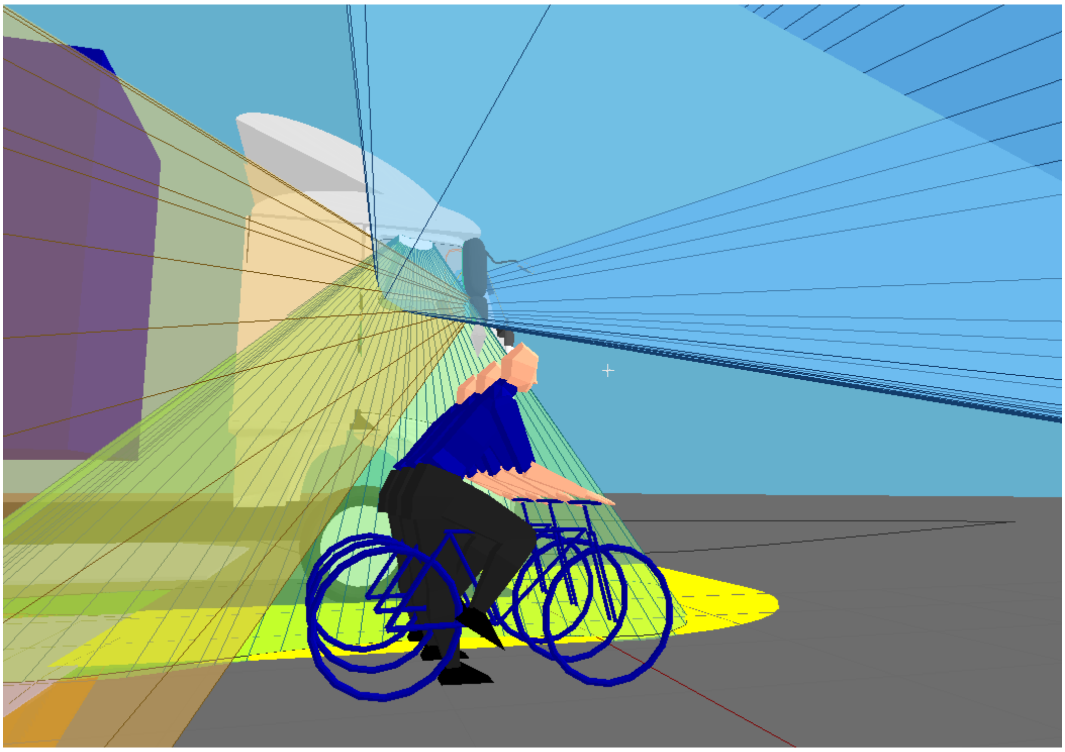

Figure 31. Illustrating that the Class IV mirror projection (yellow semi-transparent object) does not contain any part of the cyclists

Figure 32 shows the blind spot between the volume of space visible through the Class V mirror and the volume of space visible through the window aperture for a 99th%ile UK male driver. This blind spot was able to obscure three cyclists, line abreast with 50%ile female stature (UK data) with 40 mm of the head of the cyclist furthest from the vehicle being visible to the driver through the window. Figure 33 shows that the three cyclists are also not visible within the projected volume for the Class IV mirror.

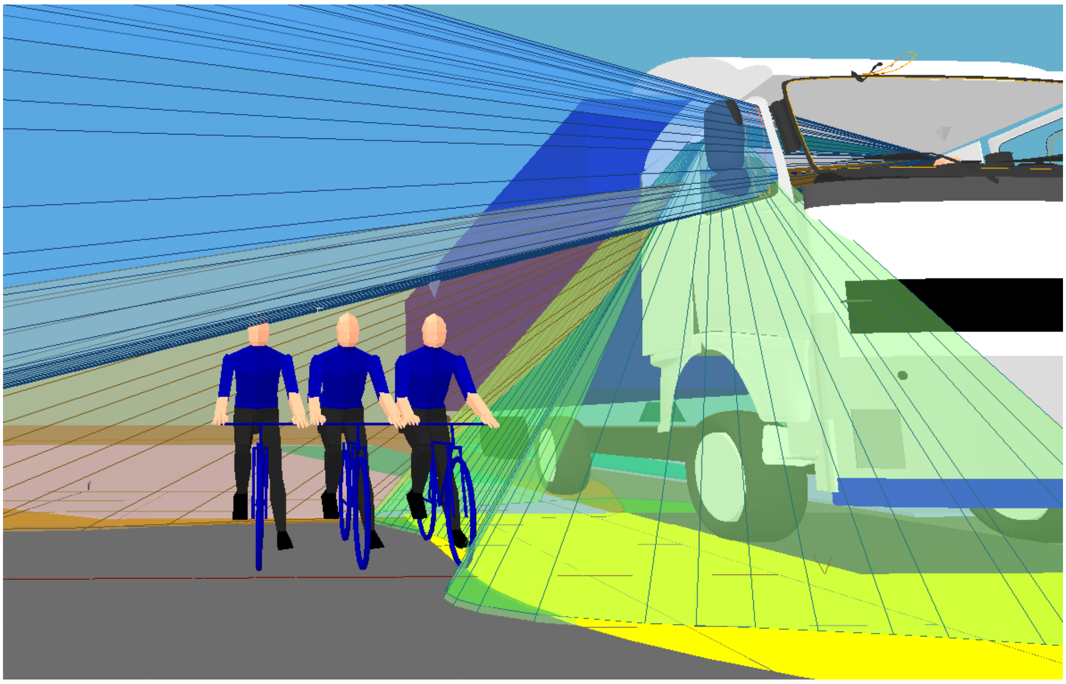

Figure 32. The blind spot between the Class V mirror and the volume that represents the direct vision through the passenger window

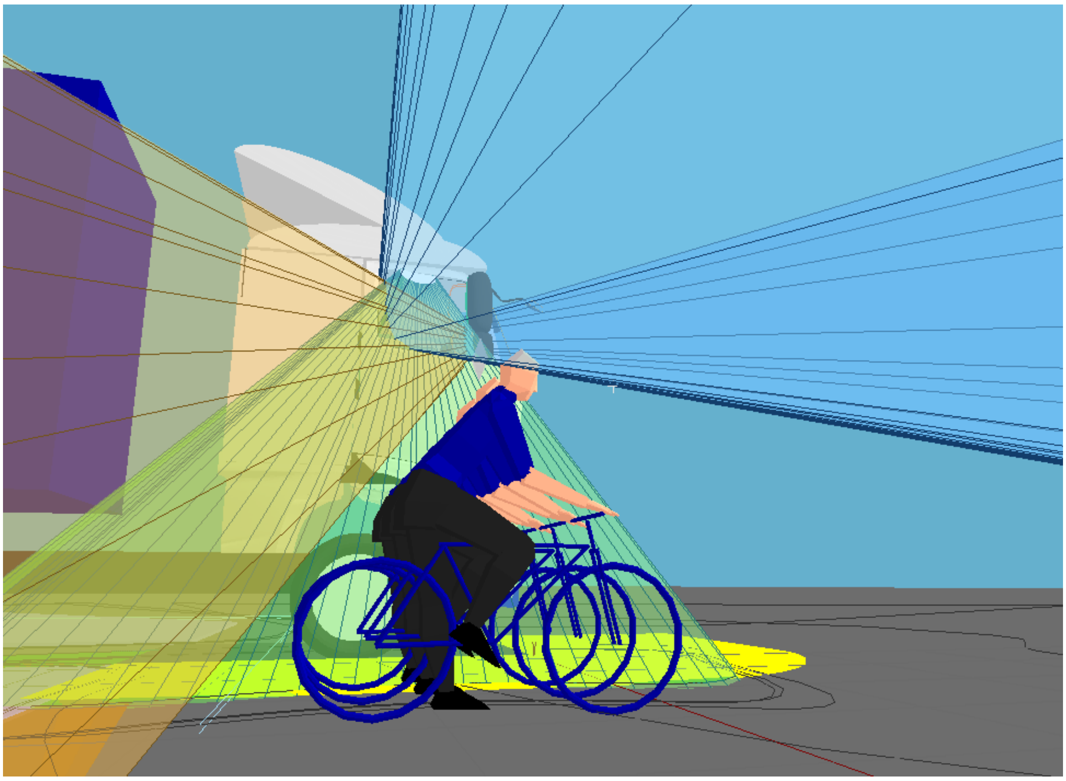

Figure 33. Illustrating that the Class IV mirror projection (yellow semi-transparent object) does not contain any part of the cyclists

2.5.4.3.5 The objects that can be obscured from driver vision by blind spot 2

Figure 34 shows that a 99th%ile UK male can be located adjacent to the driver's door and under the mirrors without being visible to the driver through direct or indirect vision. This occurs for both drivers with 4th%ile and 99th%ile stature.

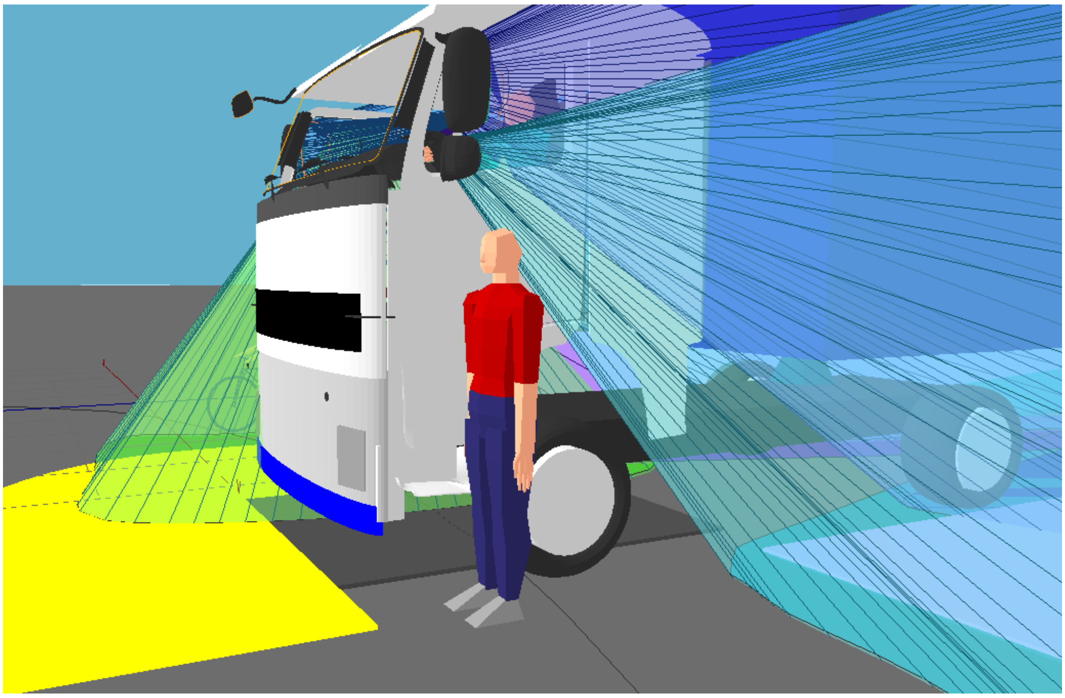

Figure 34. A 99th%ile UK male adjacent to the vehicle without being visible to the driver

Figure 35 shows that a 50th%ile UK female stature cyclist can be located 500mm from the side of the vehicle without being visible to the driver through direct or in-direct vision. This occurs for both drivers with 4th%ile and 99th%ile stature.

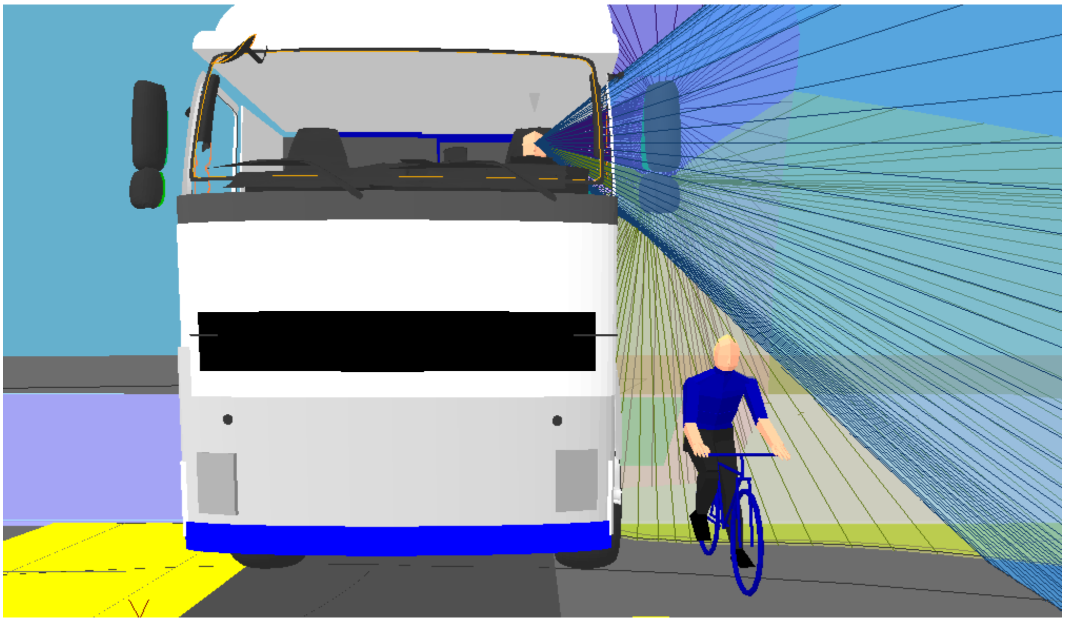

Figure 35. A cyclist 500mm from the side of the vehicle without being visible to the driver

2.5.4.4 Identification of blind spots: SCANIA R420 category N_3 right hand drive LGV

2.5.4.4.1 Mirror and aperture projections for the 4th%ile UK male

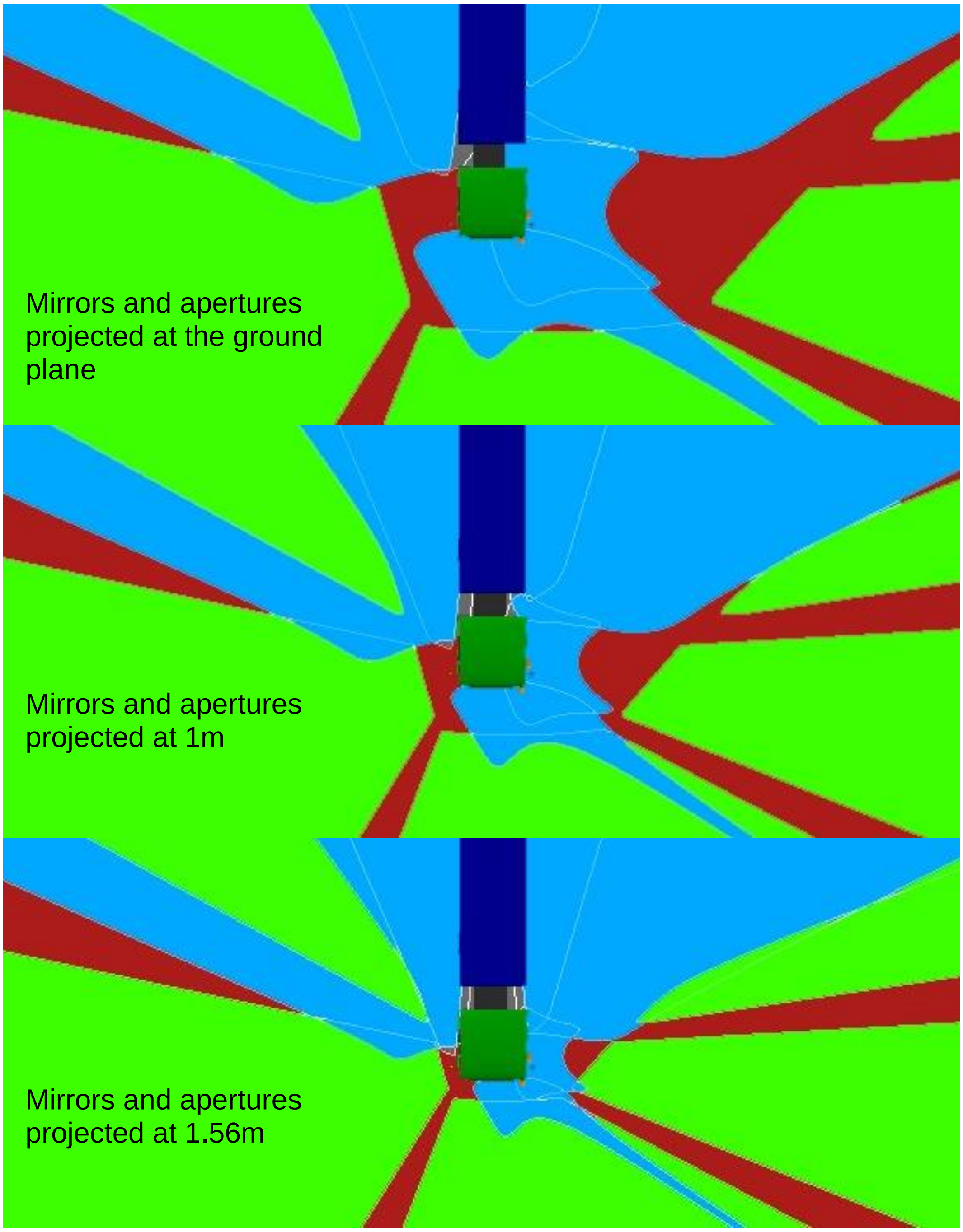

Figure 36. The projection of all mirrors onto the ground plane, 1m above the ground plane and 1.56m above the ground plane using the 4th%ile UK male eye point

2.5.4.4.2 Mirror and aperture projections for the 99th%ile UK male

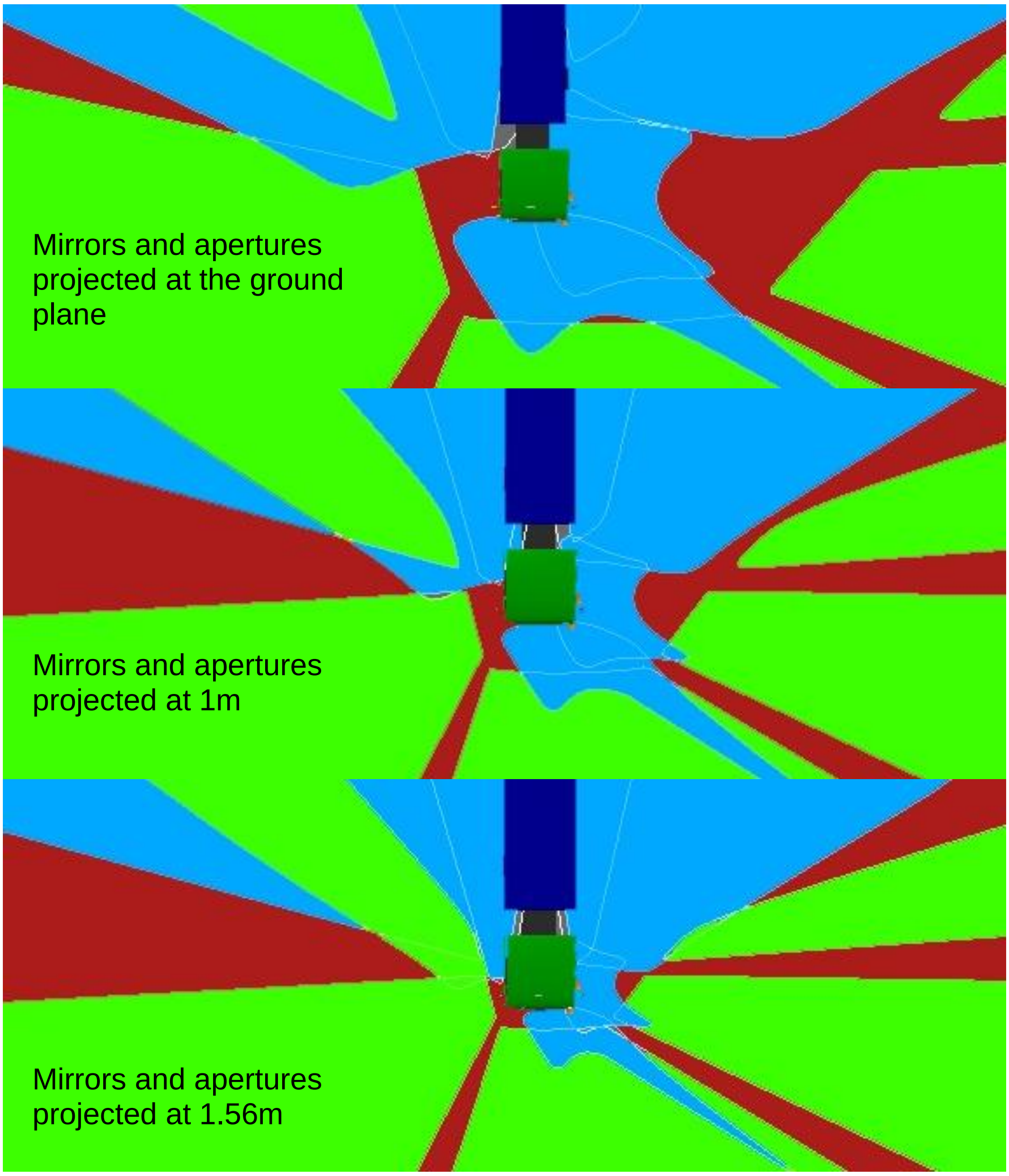

Figure 37. The projection of all mirrors onto the ground plane, 1m above the ground plane and 1.56m above the ground plane using the 99th%ile UK male eye point

2.5.4.4.3 The identified blind spots for the SCANIA R420 right hand drive

Figure 36 and Figure 37 show the projection of all mirrors and apertures onto the ground plane, 1m above the ground plane and 1.56m above the ground plane for the SCANIA R420 category N_3 vehicle for 4th%ile and 99th%ile UK male eye points respectively. Figure 38 shows that this process highlighted two specific blind spot areas of interest, one on either side of the driver's cab. These two blind spot areas are consistent in all of the projected heights used. Blind spot 3 is only present at heights below 1m. The other blind spot areas identified using the technique are associated with the A-pillars and B-pillars of the vehicle.

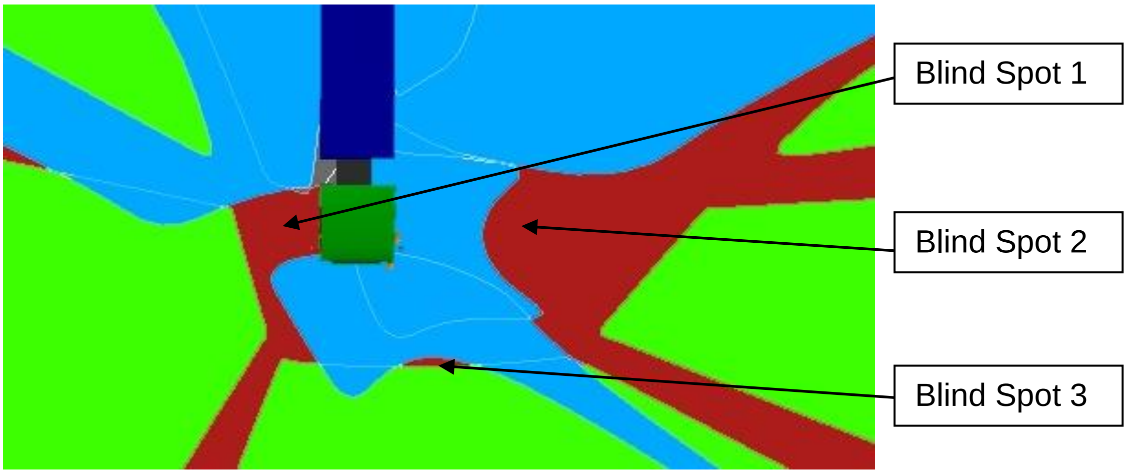

Figure 38. The three blind spot areas that have been identified using the projection of direct and indirect volumes

2.5.4.4.4 The objects that can be obscured from driver vision by blind spot 1

Figure 39 shows the blind spot between the volume of space visible through the Class V mirror and the volume of space visible through the window aperture for a 4^{th}%ile UK male driver. This blind spot was able to obscure three cyclists, line abreast with 50%ile female stature (UK data). Figure 40 shows that the three cyclists are also not visible within the projected volume for the Class IV mirror. Figure 41 shows that a car can be placed in the identified blind spot with only the offside front wing and wheel being visible in the edge of the Class VI mirror for both 4^{th}%ile and 99^{th}%ile driver projections. A four degree rotation of the Class VI mirror in the vertical plane would make the car invisible to the driver of the SCANIA R420. Figure 42 and Figure 43 illustrate the same result for the 99^{th}%ile stature driver projected volumes .

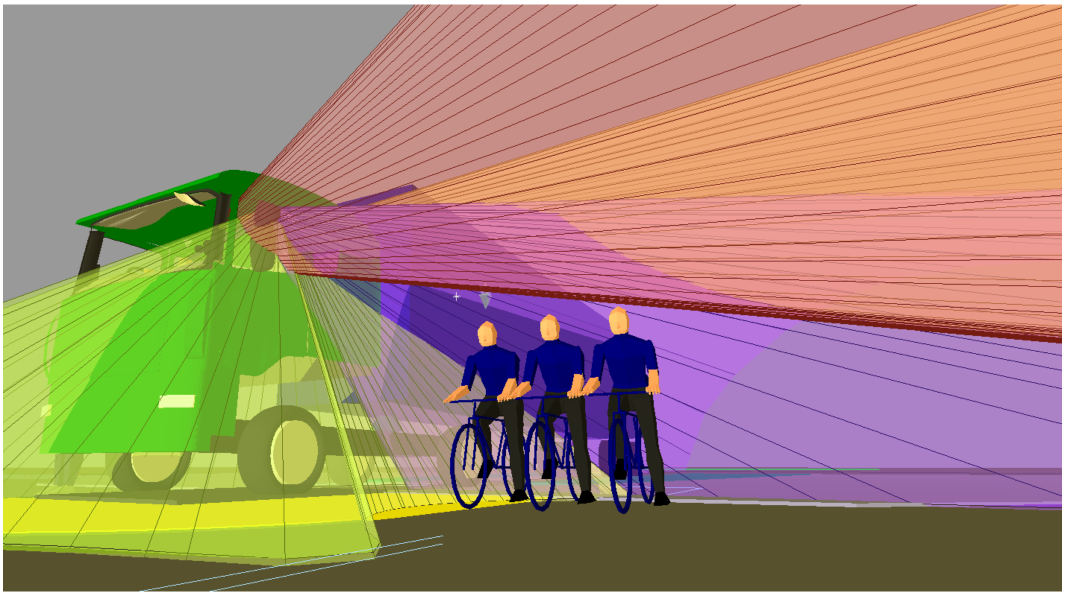

Figure 39. The blind spot between the Class V mirror and the volume that represents the direct vision through the passenger window for 4th%ile driver projections

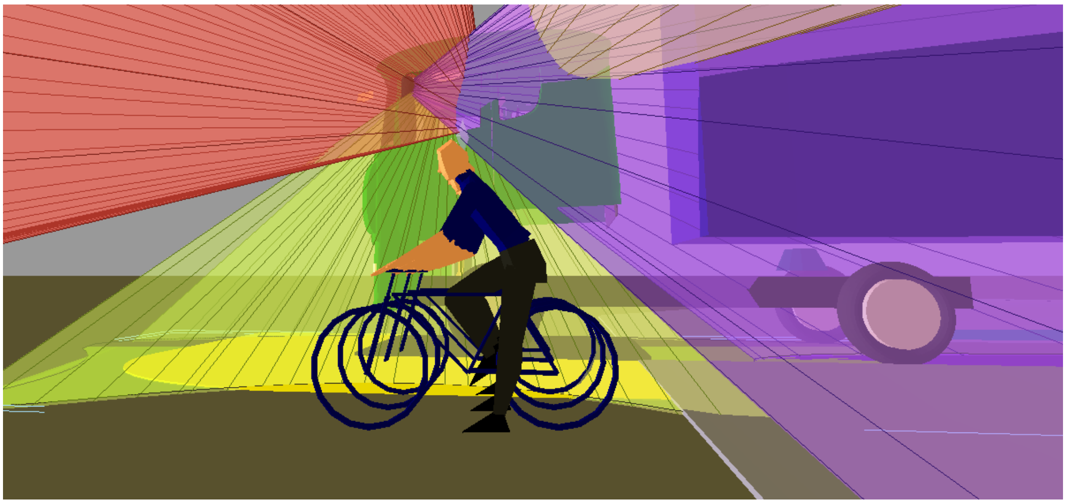

Figure 40. Illustrating that the Class IV mirror projection (purple semi-transparent object) does not contain any part of the cyclists for 4th%ile driver projections

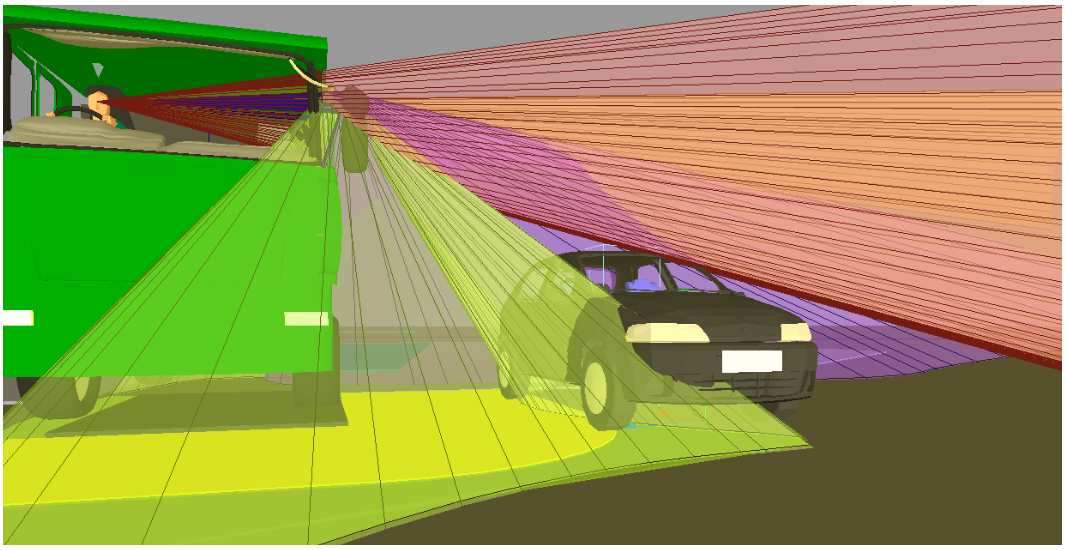

Figure 41. A car can be placed in the identified blind spot with a small portion being visible in the Class VI mirror

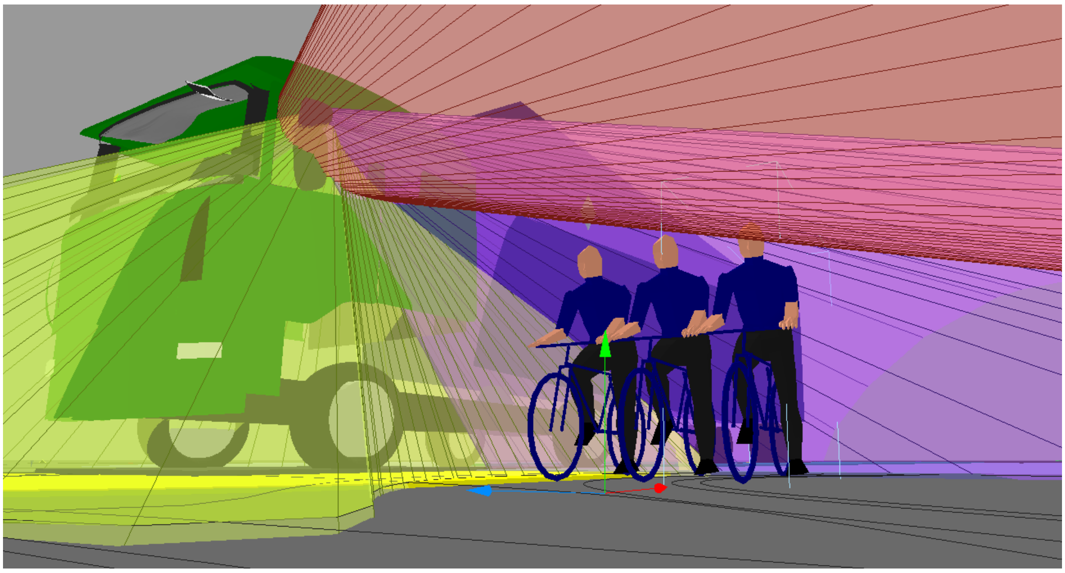

Figure 42. The blind spot between the Class V mirror and the volume that represents the direct vision through the passenger window for 99th%ile driver projections

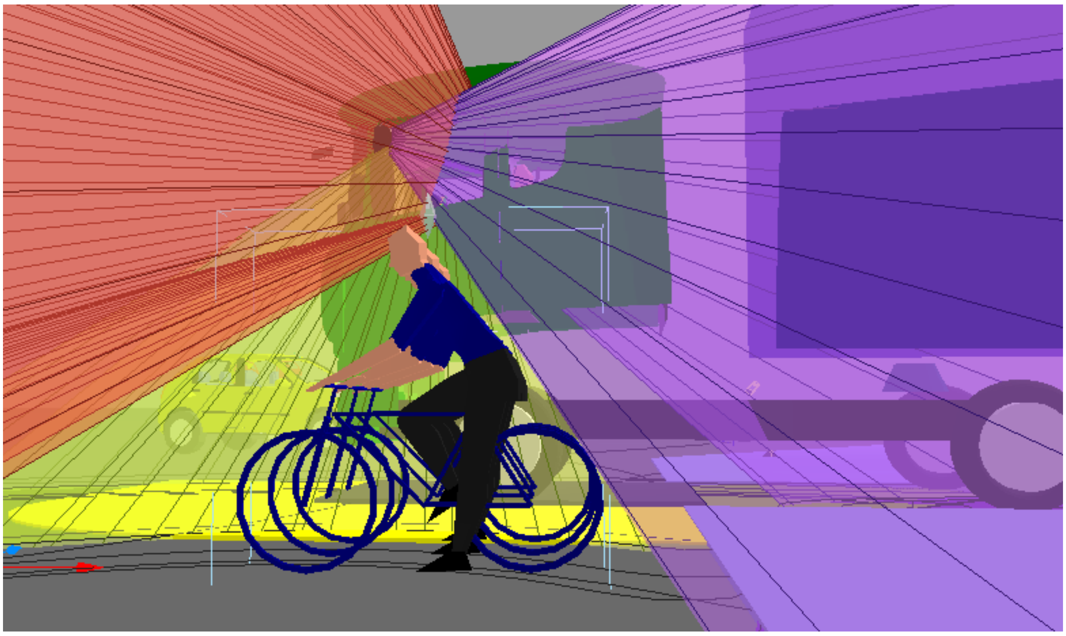

Figure 43. Illustrating that the Class IV mirror projection (purple semi-transparent object) does not contain any part of the cyclists for 99th%ile driver projections

2.5.4.4.5 The objects that can be obscured from driver vision by blind spot 2

Figure 44 shows that a 75th%ile UK male (1801mm tall) can be located adjacent to the driver's door and under the mirrors without being visible to the driver through direct or in-direct vision for the volumes projected from the 4th%ile driver's eye point.

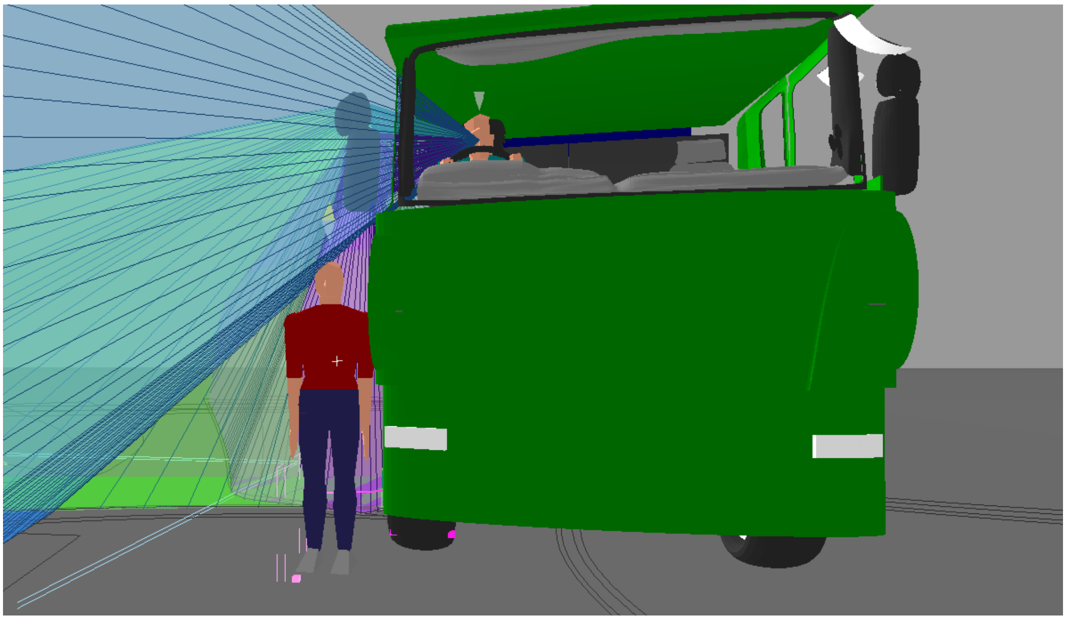

Figure 44. A 75th%ile UK male pedestrian can be obscured from the 4th%ile stature driver

Figure 45 shows that a 18th%ile UK male (1700 mm tall) can be located adjacent to the driver's door and under the mirrors without being visible to the driver through direct or in-direct vision for the volumes projected from the 99th%ile driver's eye point. A taller pedestrian would be visible to the driver through direct vision.

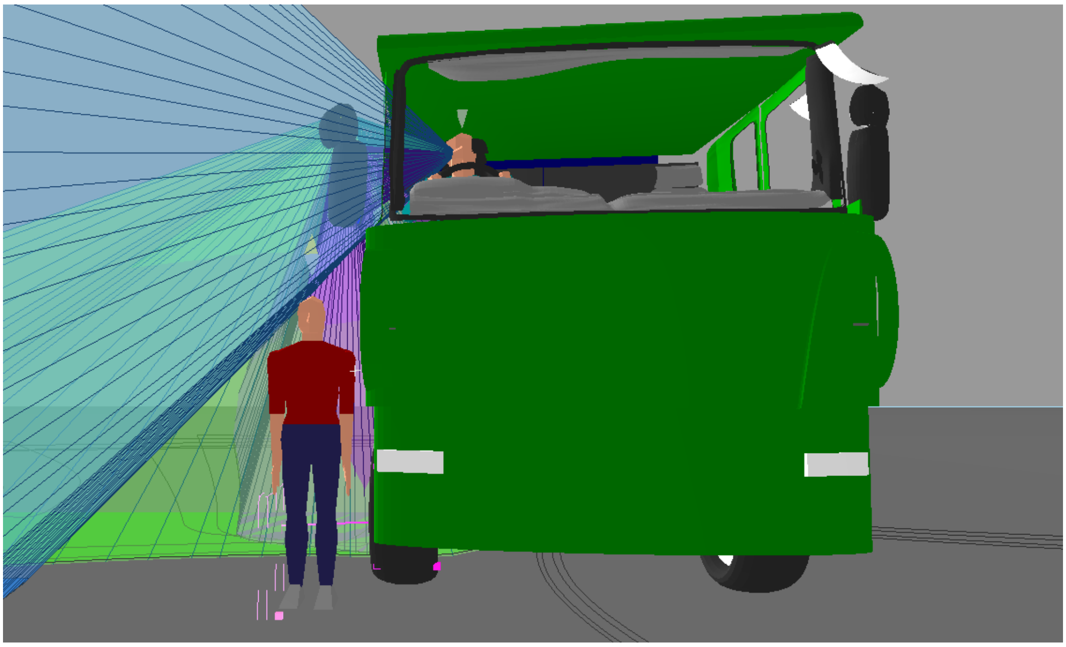

Figure 45. An 18th%ile UK male pedestrian (1700mm tall) can be obscured from the 99th%ile stature driver

Figure 46 shows that a 50th%ile UK female stature cyclist can be located 800mm from the side of the vehicle without being visible to the 4th%ile stature driver through direct or in-direct vision.

Figure 47 shows that a 50th%ile UK female stature cyclist can be located 550mm from the side of the vehicle without being visible to the 99th%ile stature driver through direct or in-direct vision.

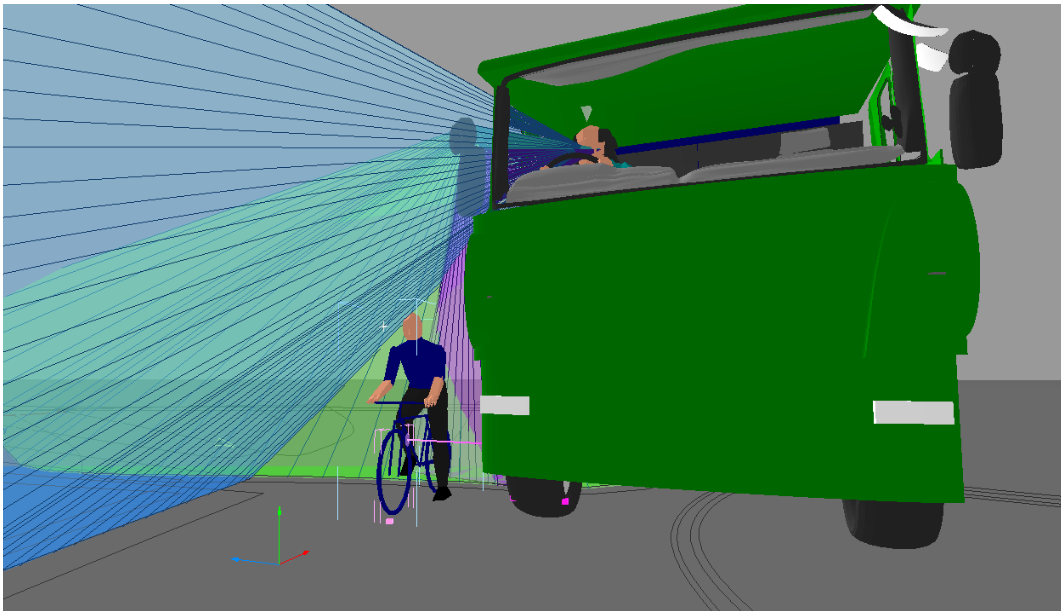

Figure 46. A 50th%ile UK female cyclist that is 800mm from the driver's side of the vehicle can be obscured from the 4th%ile stature driver

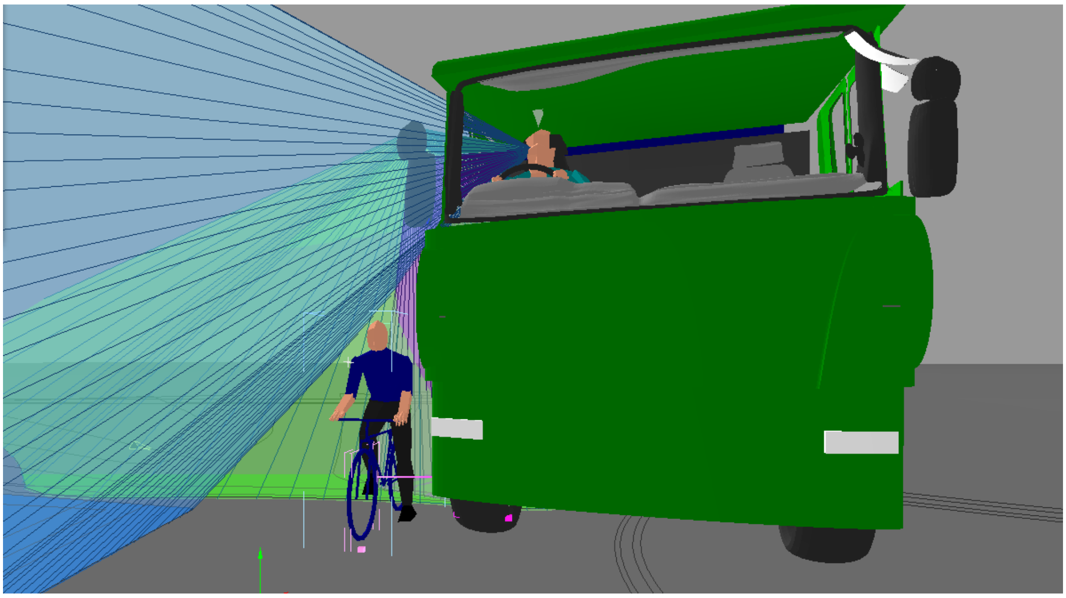

Figure 47. A 50th%ile UK female cyclist that is 550mm from the driver's side of the vehicle can be obscured from the 99th%ile stature driver

2.5.4.5 Identification of blind spots: DAF XF category N_3 right hand drive LGV

2.5.4.5.1 Mirror and aperture projections for the 4th%ile UK male

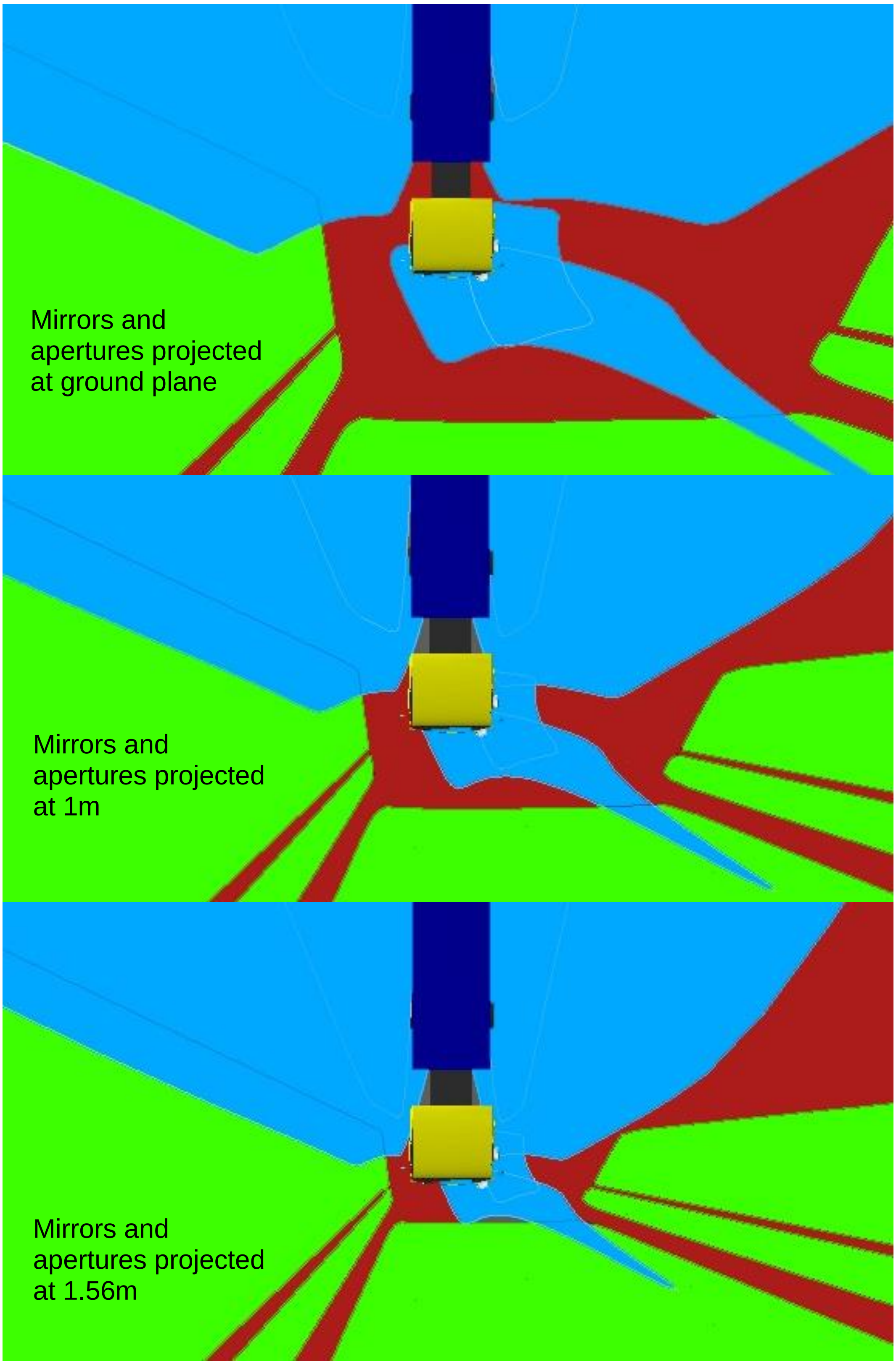

Figure 48. The projection of all mirrors onto the ground plane, 1m above the ground plane and 1.56m above the ground plane using the 4th%ile UK male eye point

2.5.4.5.2 Mirror and aperture projections for the 99th%ile UK male

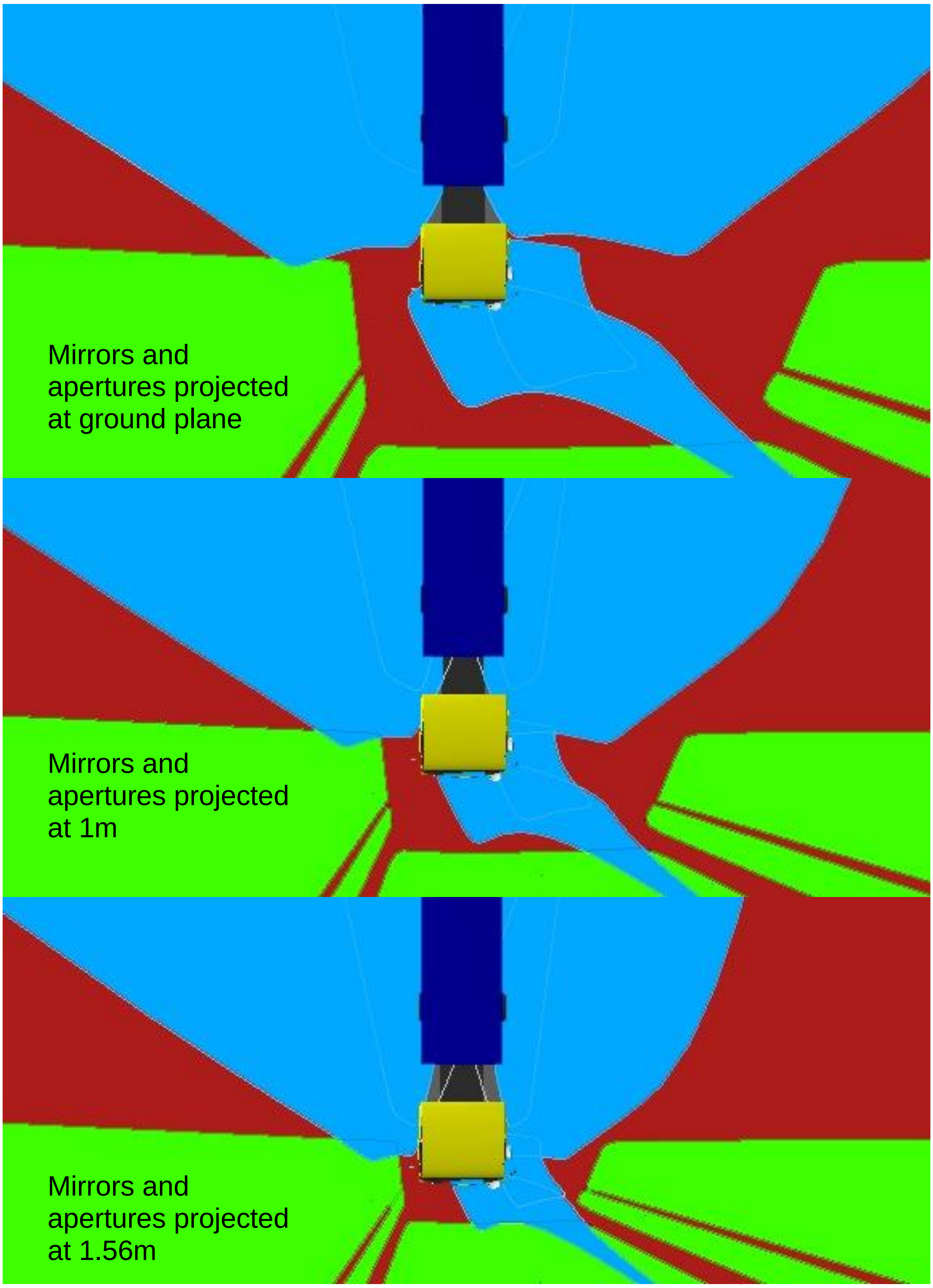

Figure 49. The projection of all mirrors onto the ground plane, 1m above the ground plane and 1.56m above the ground plane using the 99th%ile UK male eye point

Figure 48 and Figure 49 show the projection of all mirrors and apertures onto the ground plane, 1m above the ground plane and 1.56m above the ground plane for the DAF XF category N_3 vehicle for 4th%ile UK male and 99th%ile UK male eye points respectively. Figure 50 shows that this process highlighted two specific blind spot areas of interest, one on either side of the driver's cab. These two blind spot areas are consistent in all of the projected heights used. Blind spot 3 is only present at heights below 1.56m. The other blind spot areas identified using the technique are associated with the A-pillars and B-pillars of the vehicle.

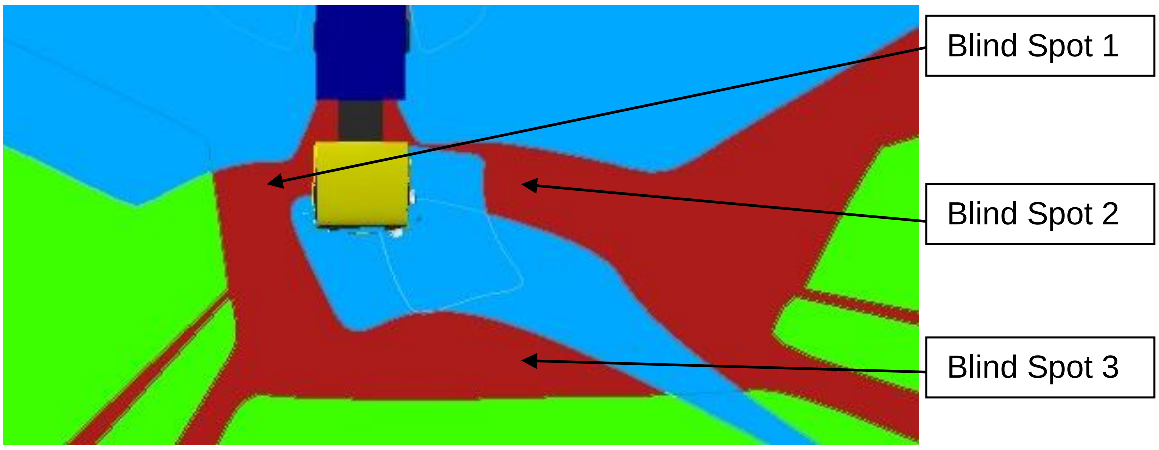

Figure 50. The three blind spot areas that have been identified using the projection of direct and indirect volumes for the DAF XF

2.5.4.5.3 The objects that can be obscured from driver vision by blind spot 1

Figure 51 shows the blind spot between the volume of space visible through the Class V mirror and the volume of space visible through the window aperture for a 4th%ile UK male driver. This blind spot was able to obscure four cyclists, line abreast with 50%ile female stature (UK data). Figure 52 shows that the four cyclists are also not visible within the projected volume for the Class IV mirror. Figure 53 shows that a car can be placed in the identified blind spot with only the offside front wing and wheel being visible in the edge of the Class VI mirror for both 4th%ile and 99th%ile driver projections. A six degree rotation of the Class VI mirror in the vertical plane would make the car invisible to the driver of the DAF XF. Figure 54 and Figure 55 illustrate the same result for the 99th%ile stature driver projected volumes .

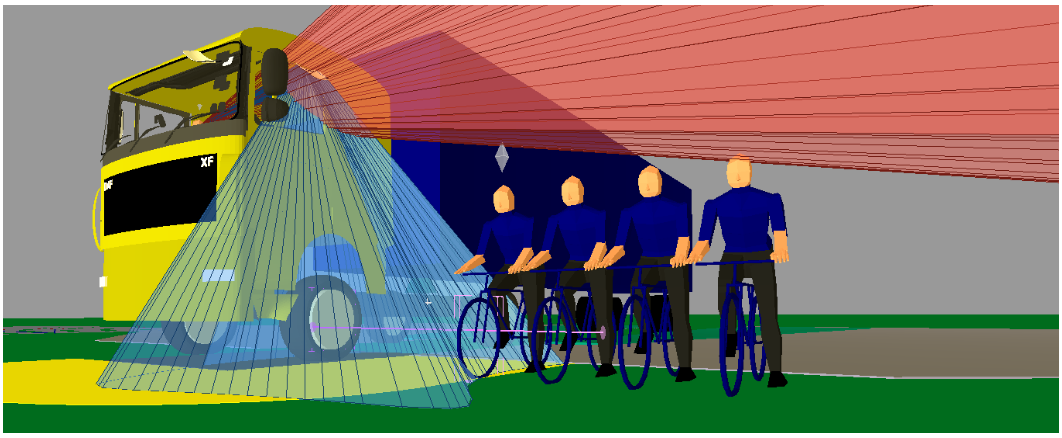

Figure 51. The blind spot between the Class V mirror and the volume that represents the direct vision through the passenger window for 4th%ile driver projections

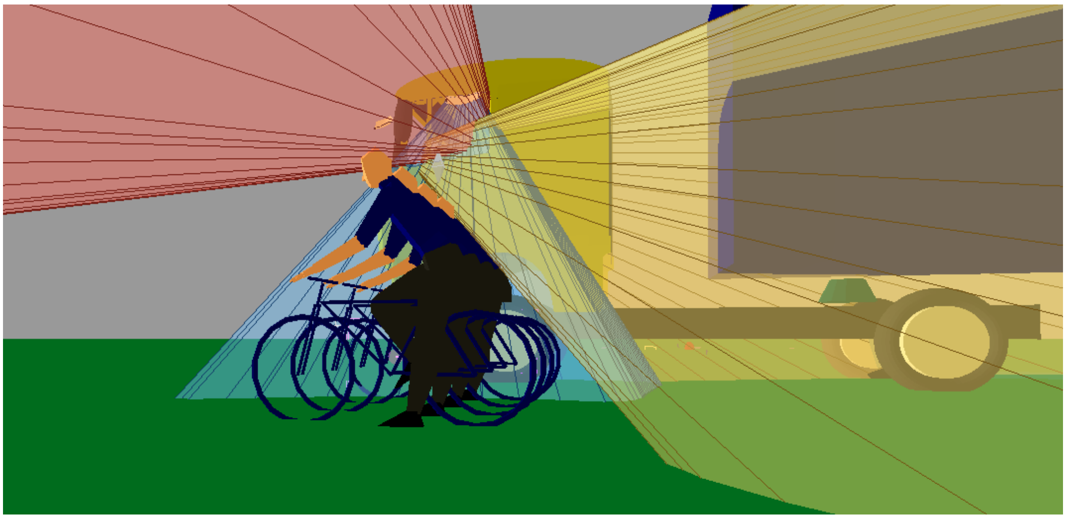

Figure 52. Illustrating that the Class IV mirror projection (yellow semi-transparent object) does not contain any part of the cyclists for 4th%ile driver projections

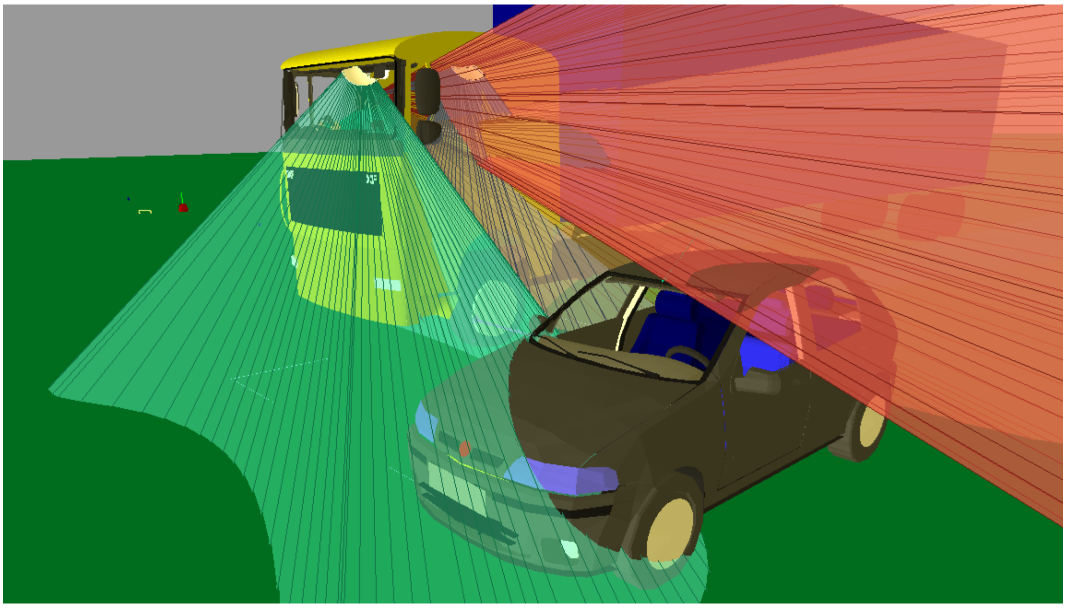

Figure 53. A car can be placed in the identified blind spot with the front wing being visible in the Class VI mirror

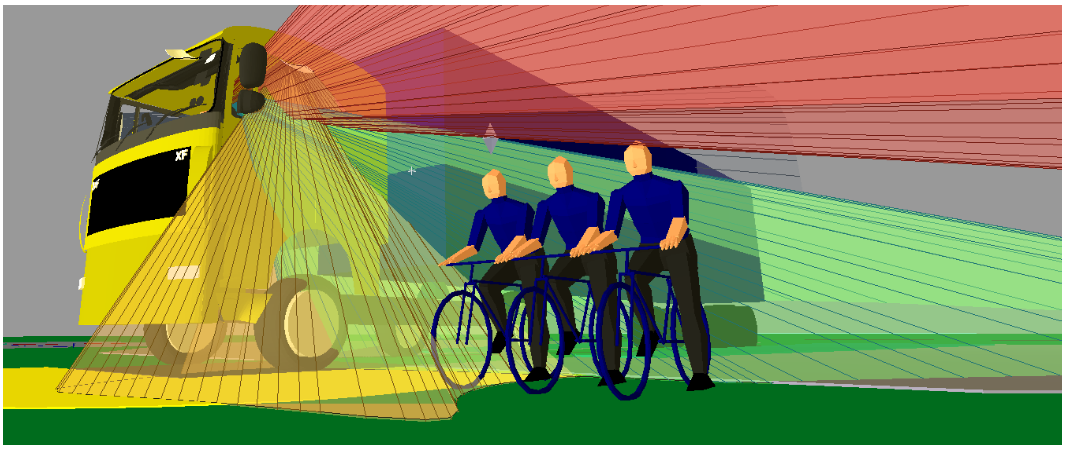

Figure 54. The blind spot between the Class V mirror and the volume that represents the direct vision through the passenger window for 99th%ile driver projections

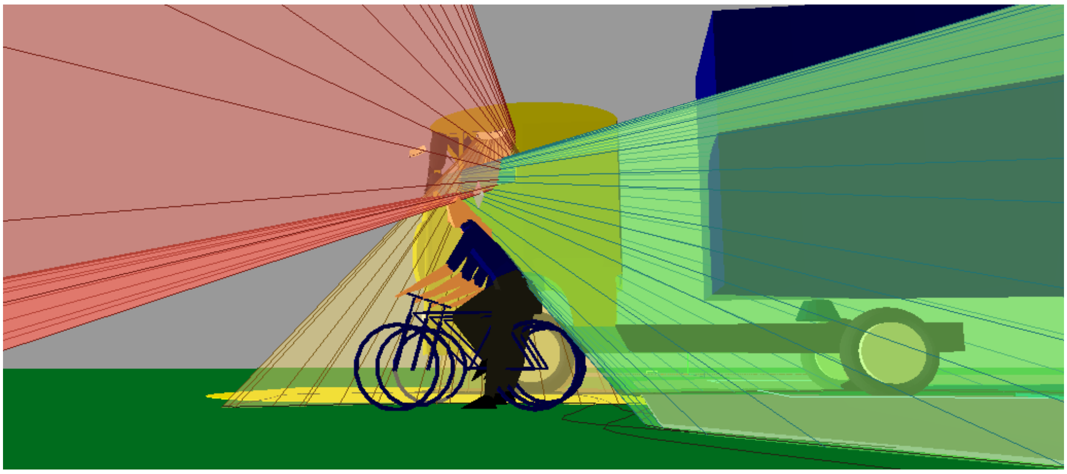

Figure 55. Illustrating that the Class IV mirror projection (yellow semi-transparent object) does not contain any part of the cyclists for 99th%ile driver projections

2.5.4.5.4 The objects that can be obscured from driver vision by blind spot 2

Figure 56 shows that a 75th%ile UK male (1801mm tall) can be located adjacent to the driver's door and under the mirrors without being visible to the driver through direct or in-direct vision for the volumes projected from the 4th%ile driver's eye point.

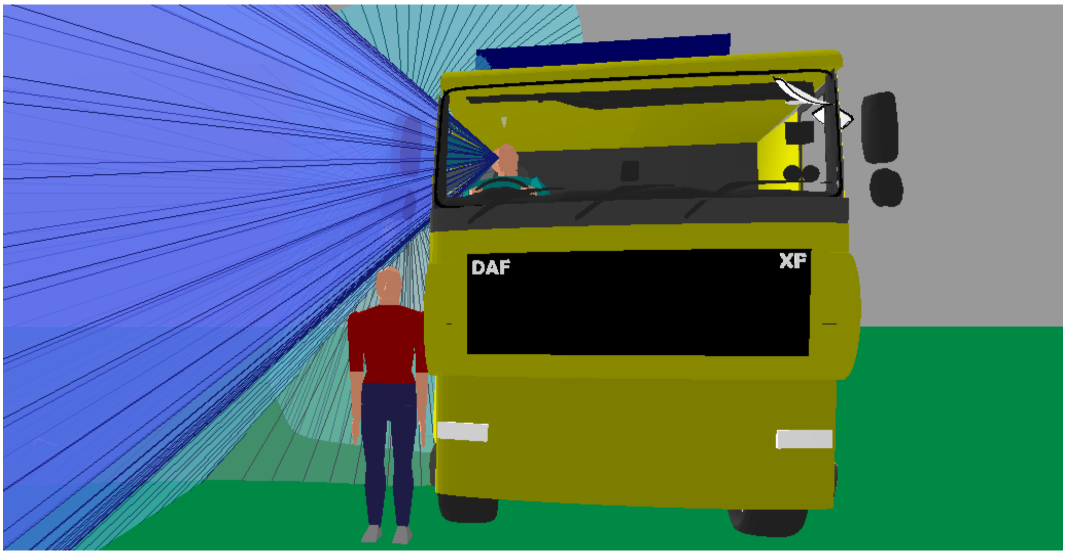

Figure 56. A 95th%ile UK male pedestrian can be obscured from the 4th%ile stature driver

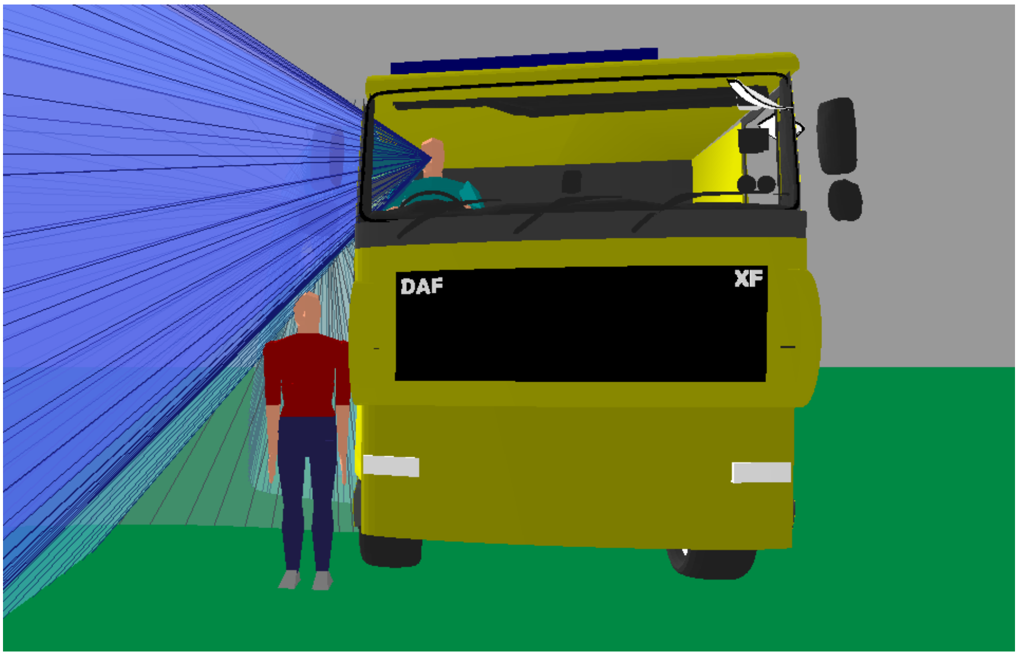

Figure 57. A 92nd%ile UK male pedestrian can be obscured from the 99th%ile stature driver

Figure 57 shows that a 92th%ile UK male (1840 mm tall) can be located adjacent to the driver's door and under the mirrors without being visible to the driver through direct or in-direct vision for the volumes projected from the 99th%ile driver's eye point. A taller pedestrian would be visible to the driver through direct vision.

Figure 58 shows that a 50th%ile UK female stature cyclist can be located 950mm from the side of the vehicle without being visible to the 4th%ile stature driver through direct or in-direct vision.

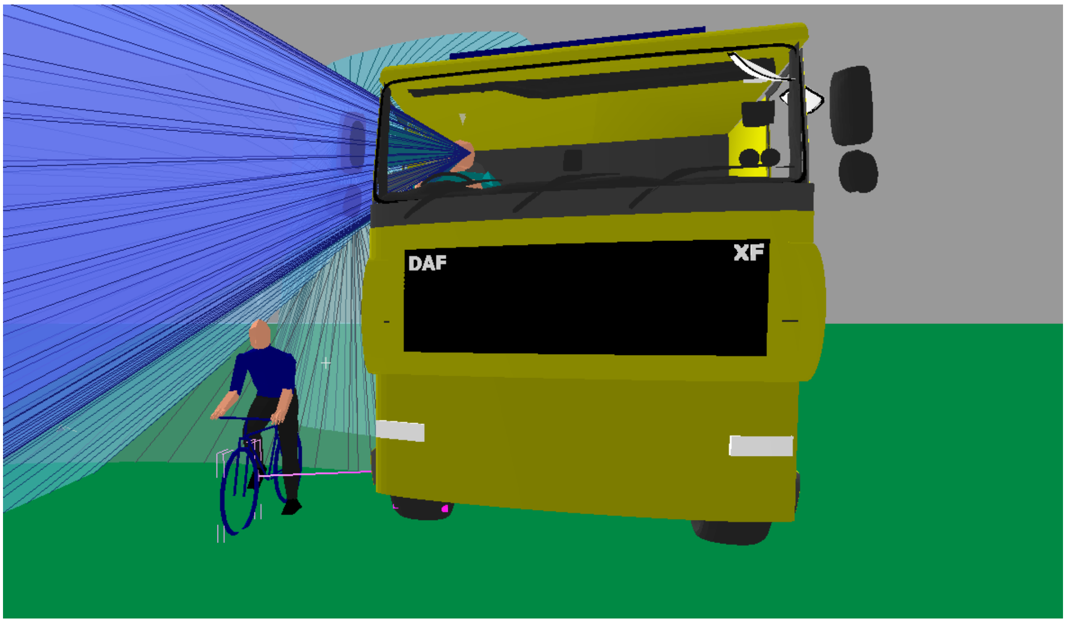

Figure 58. A 50th%ile UK female cyclist that is 950mm from the driver's side of the vehicle can be obscured from the 4th%ile stature driver

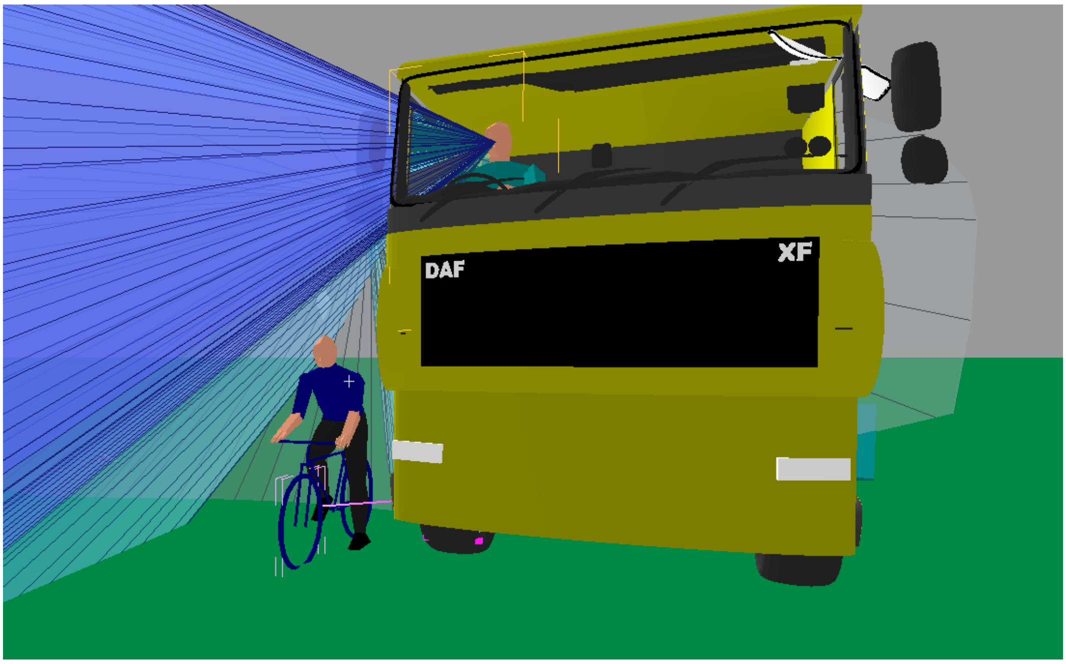

Figure 59. A 50th%ile UK female cyclist that is 625mm from the driver's side of the vehicle can be obscured from the 99th%ile stature driver

Figure 59 shows that a 50th%ile UK female stature cyclist can be located 625mm from the side of the vehicle without being visible to the 99th%ile stature driver through direct or in-direct vision.

2.5.4.6 Summary for analysis stage 1 for category N_3 vehicles

The analysis of blind spots for three category N_3 vehicles has highlighted consistent blind spots for both direct and indirect vision. The blind spot on the passenger side of the vehicle is the most substantial, with the ability to hide up to four cyclists line a breast with mirrors adjusted to cover the standard areas of the ground plane prescribed by Directive 2003/97/EC. The blind spot is also capable of hiding a car with visibility only possible in the Class VI mirror. A small mal-adjustment of the Class VI mirror can result in complete obscuration of the car from the driver of the category N_3 vehicle.

2.5.4.7 OTS scenarios

2.5.4.7.1 OTS scenario setup: Scenario 1. Cyclist collides with the side of a category N_3 vehicle

This scenario involved a category N_3 vehicle pulling away from a junction and making a left turn. The driver of the category N_3 vehicle was unaware that a cyclist, who was attempting to go straight on, was next to the passenger side of the N_3 vehicle. As the category N_3 vehicle made its left turn the cyclist collided with the left hand side of the category N_3 vehicle trailer and was knocked off the bicycle. The junction where this accident occurred was modelled using aerial photographs and map data. Figure 60 shows the road junction that was associated with the accident scenario modelled in the DHM system.

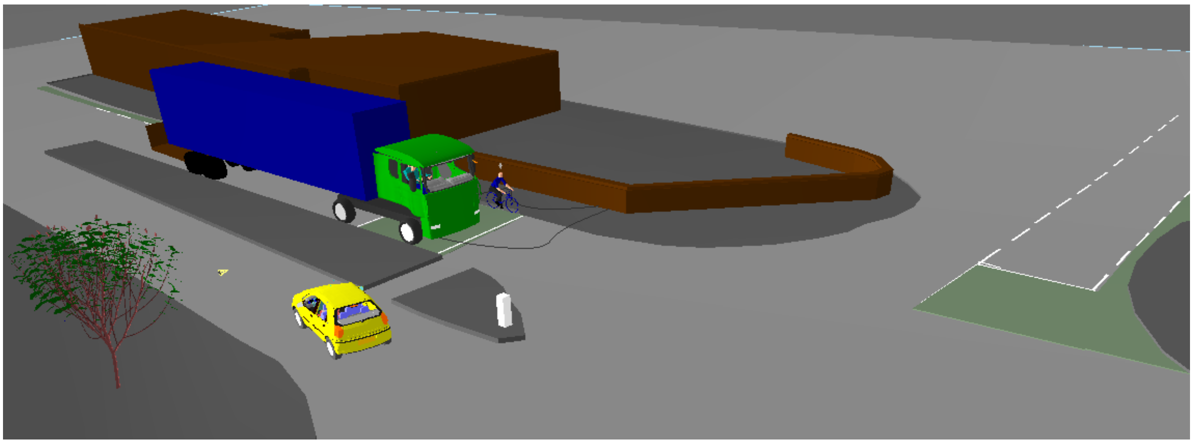

Figure 60. The road junction associated with accident scenario 1 modelled in the DHM system

The key stage in the accident scenario was assumed to be the point at which the category N_3 vehicle pulled away from the junction without being aware of the presence of the cyclists. Therefore the analysis of scenario 1 focused on the potential of the category N_3 driver to see cyclist in a position to the left of the driver's cab before setting off.

2.5.4.7.2 Scenario 1: Left hand drive Volvo 480

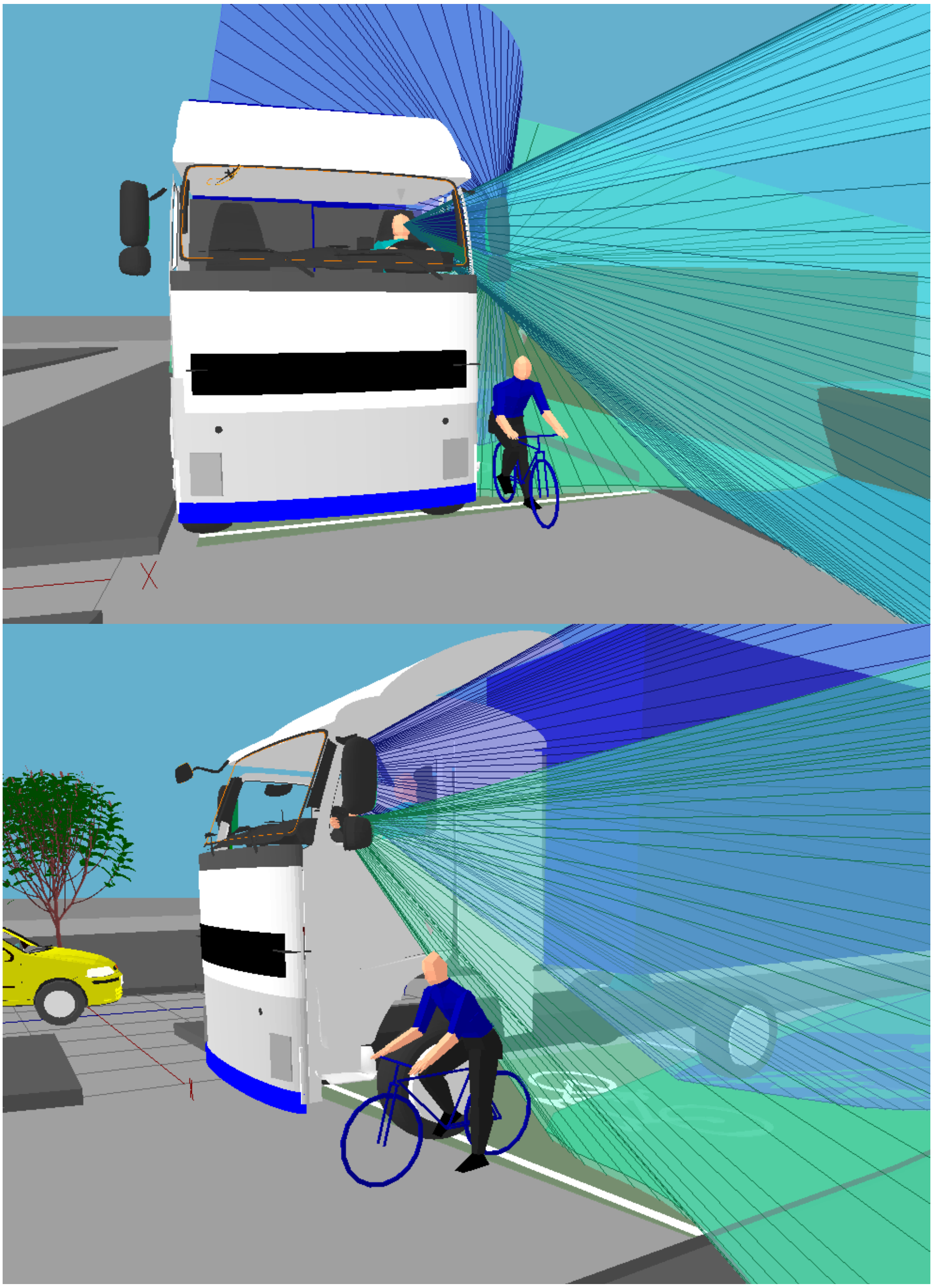

Figure 61. The 50th%ile UK female on a bicycle can be obscured from the driver of the left hand drive Volvo 480

Figure 61 shows that the driver of the Volvo 480 would not be able to see the cyclist in a location that is 550mm from the side of the vehicle. The top of the head of the cyclist is 1450mm above the ground plane.

2.5.4.7.3 Scenario 1: Scania R420 and DAF XF

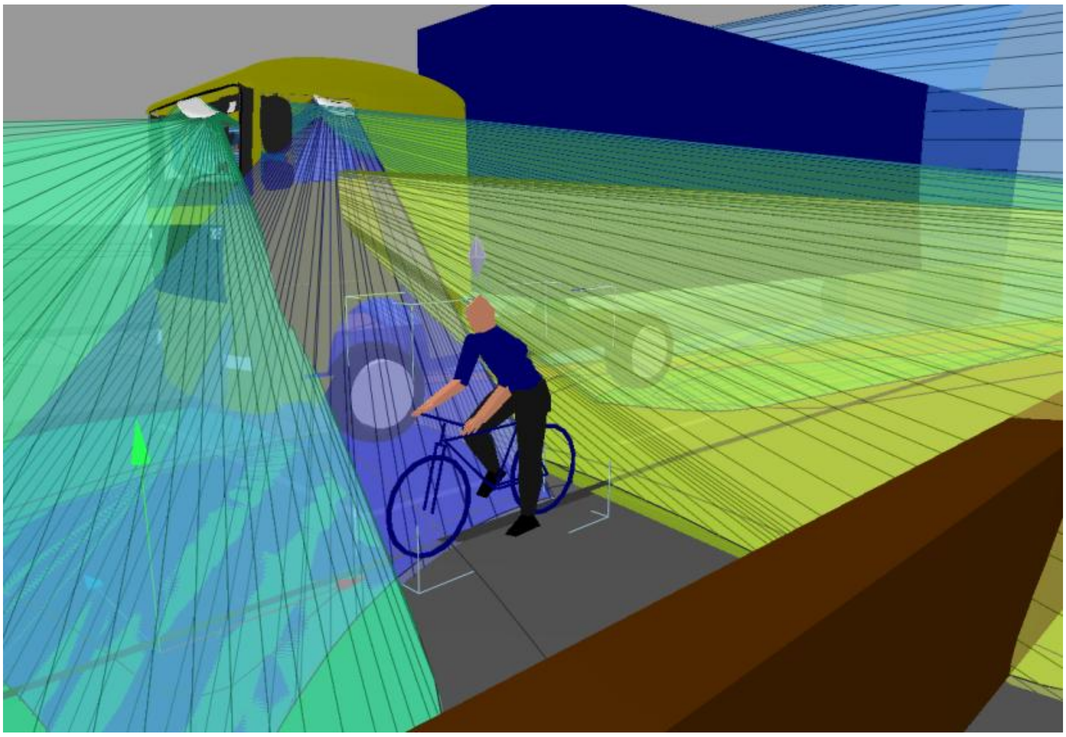

Figure 62. The cyclist can be obscured from the vision of the DAF XF driver in a blind spot that exists between the Class IV and Class V mirrors and the projection for direct vision through the passenger window

The width of the road at the junction shown in Figure 62 and Figure 63is 4.9m wide. It is presumed that the driver of the LGV would orientate the vehicle to the right hand side of the lane to facilitate the left hand turn at the cross roads. In this situation it is possible for the cyclist to adopt a location at the far left hand side of the road, and to be obscured from the LGV driver by the passenger door of the vehicle. The cyclist would be not be visible to the LGV driver in the either the Class IV, V or VI mirrors in this position for both the DAF XF and SCANIA R420 vehicles as shown in Figure 62 and Figure 63 respectively.

2.5.4.7.4 Summary for scenario 1

The results from the analysis of the scenario above confirm the findings found in Sections 2.5.4.4 and 2.5.4.5 in that the blind spot between the direct vision from windows and the indirect vision from the Class V mirror have the potential to mask a cyclist. This leads to the conclusion that this was potentially the cause of the accident in Scenario 1.

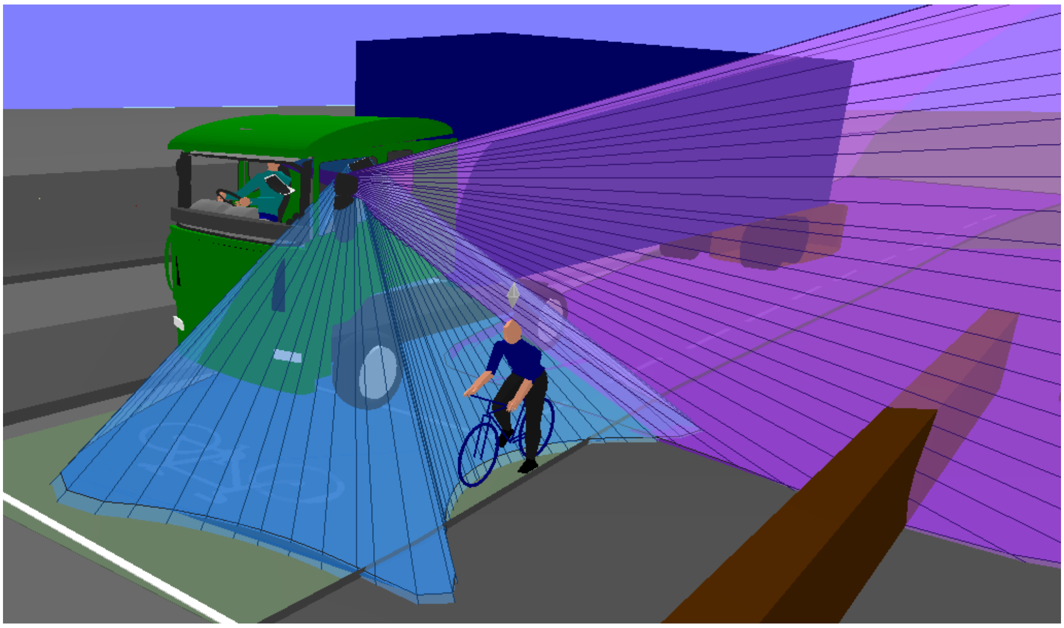

Figure 63. The cyclist can be obscured from the vision of the DAF XF driver in a blind spot that exists between the Class IV and Class V mirrors and the projection for direct vision through the passenger window

2.5.4.7.5 OTS scenario setup: Scenario 2: category N_3 vehicle changes lane on a motorway without being aware that another vehicle is adjacent to the cab

Multiple OTS cases were identified where an LGV changed lane without being aware that another vehicle was adjacent to the cab for category N_3 vehicles. This scenario was modelled using standard motorway lane widths to simulate the positioning of the category N_3 vehicles and the vehicles with which they collided. Figure 64 shows the environment that was modelled in the DHM system for scenario 2. The left hand drive and right hand drive category N_3 vehicles were analysed for lane change manoeuvres to both the left and right hand lanes, in each case the a car with a width of 1.9m, a length of 3.6m and a height of 1.45m was positioned forward of the coverage of the Class IV mirror, on both the left hand side and right hand side of the LGV cab. It was then determined if the vehicle could be visible to the driver.

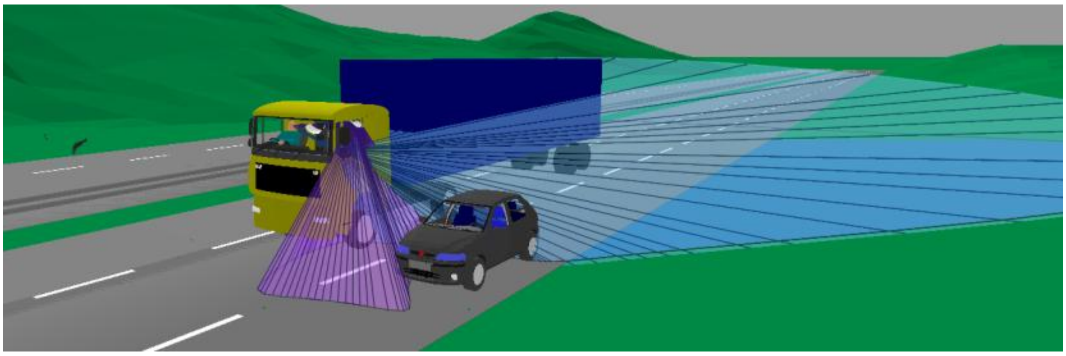

Figure 64. The motorway scenario associated with side swipe accidents modelled in the DHM system

2.5.4.7.6 DAF XF: Manoeuvre into left lane from middle lane

Figure 65 shows that the car can be positioned in the left hand lane of the motorway in a position that is forwards of the volume of space that is visible through the Class IV mirror, and outside of the volume of space that is visible through direct vision through the passenger window. In this situation the two parts of the car that are visible to the driver of the LGV include a small portion of the driver's door in the bottom left hand corner of the Class V mirror, and the front wing of the vehicle through the Class VI mirror. Figure 65 shows the intersection of the driver's door with the volume of space visible through the Class V mirror with a 4th%ile stature driver's eye point. Figure 66 shows the intersection of the volume of space visible in the Class VI mirror and the front quarter of the car with a 4th%ile stature driver's eye point. Figure 67 shows the intersection of the driver's door with the volume of space visible through the Class V mirror with a 99th%ile stature driver's eye point. Figure 68 shows the intersection of the volume of space visible in the Class VI mirror and the front quarter of the car with a 99th%ile stature driver's eye point.

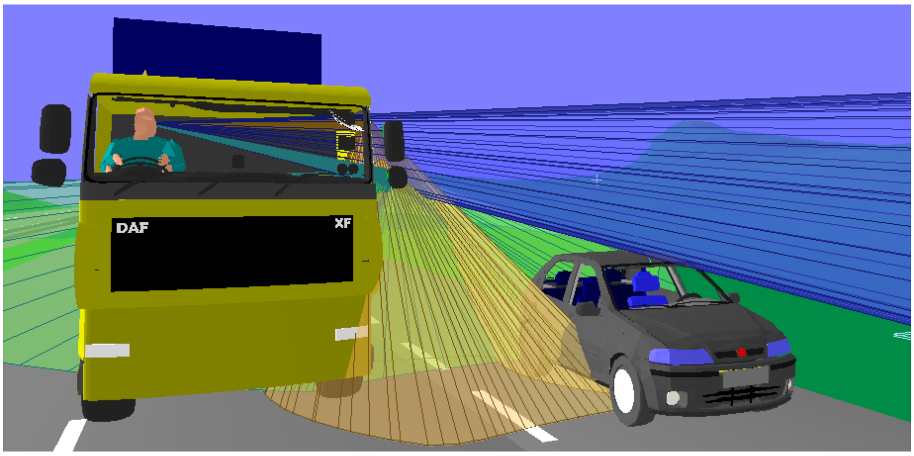

Figure 65. The intersection of the driver's door with the volume of space visible through the Class V mirror with a 4th%ile stature driver's eye point

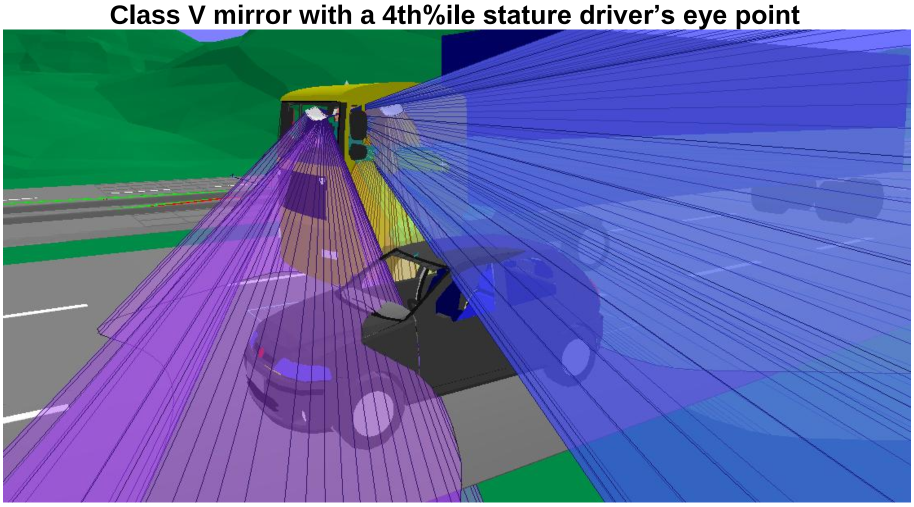

Figure 66. The intersection of the volume of space visible in the Class VI mirror and the front quarter of the car with a 4th%ile stature driver's eye point

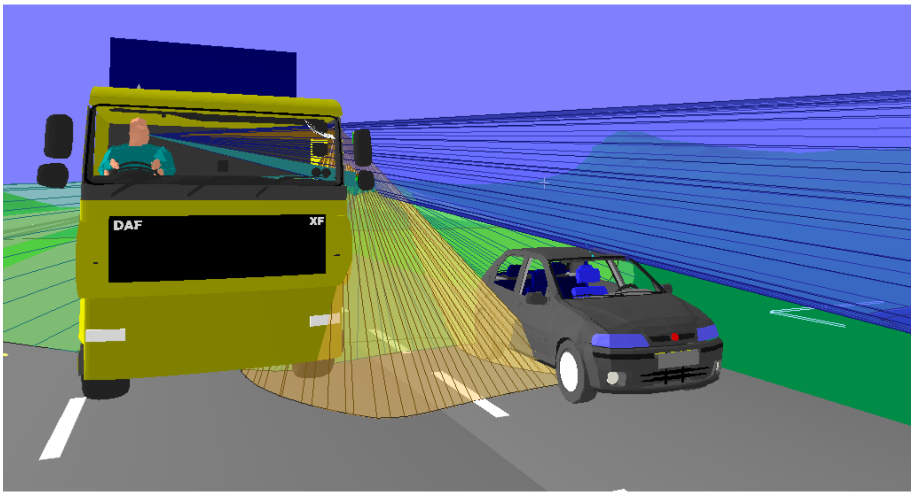

Figure 67. The intersection of the driver's door with the volume of space visible through the Class V mirror with a 99th%ile stature driver's eye point

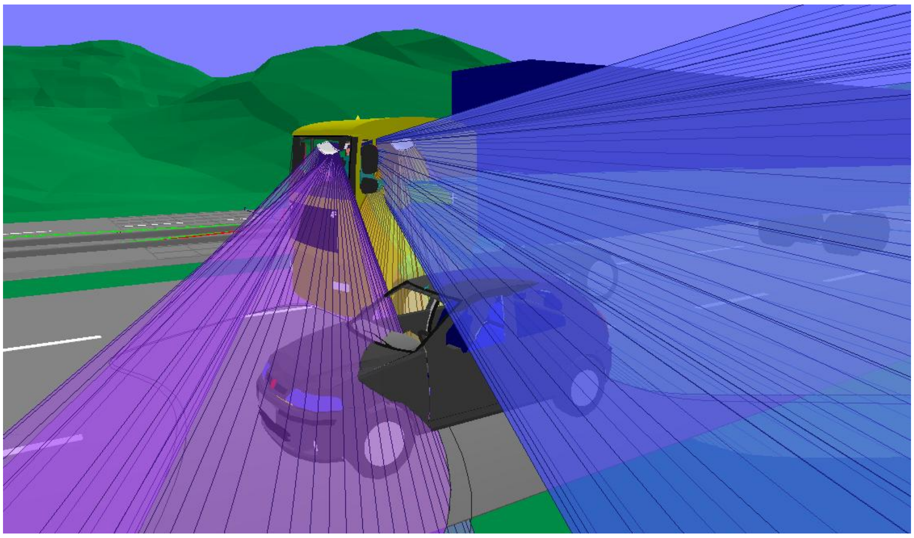

Figure 68. The intersection of the volume of space visible in the Class VI mirror and the front quarter of the car with a 99th%ile stature driver's eye point

2.5.4.7.7 DAF XF: Manoeuvre into the right lane from left lane

Figure 69 and Figure 70 show that when a car is positioned to the right of the DAF XF in a position that is forwards of the volume of space that is visible through the Class IV the car should be visible with direct vision through the driver's side window.

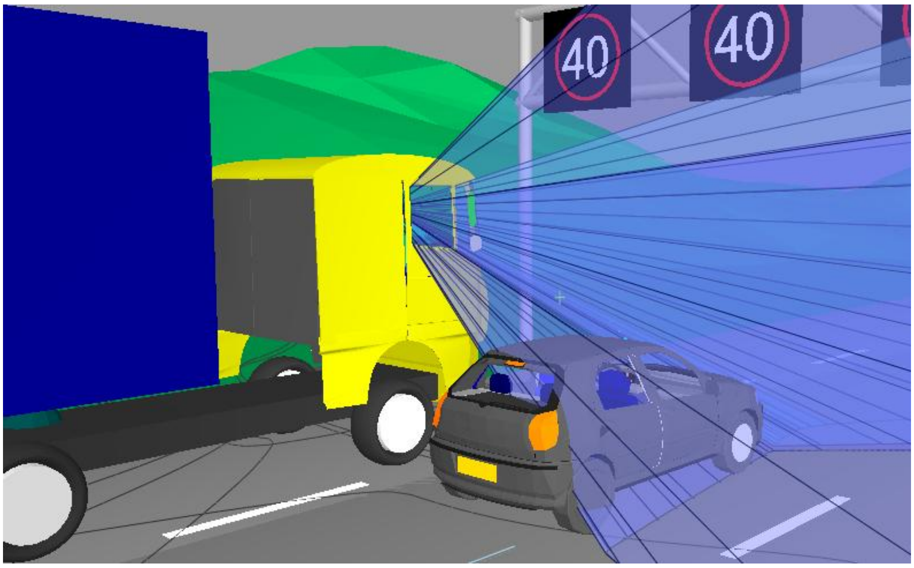

Figure 69. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 4th%ile stature LGV driver

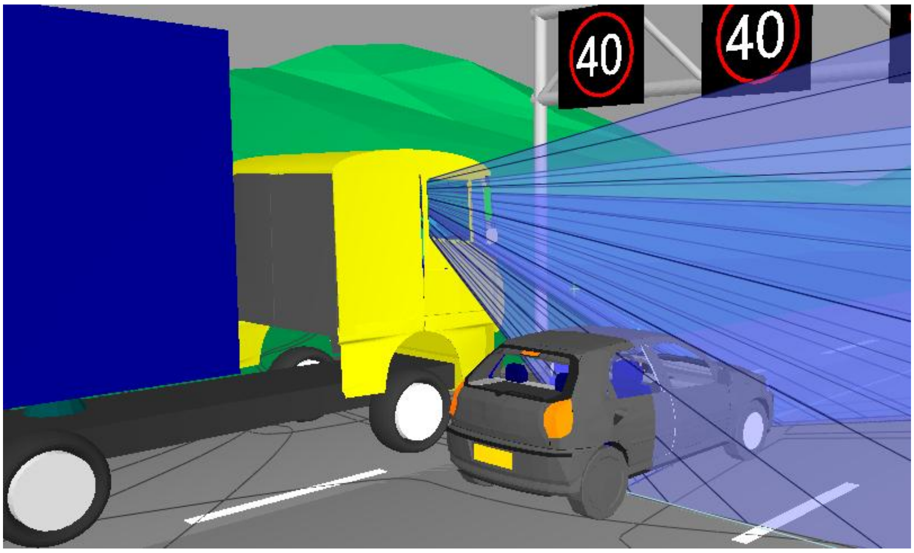

Figure 70. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 99th%ile stature LGV driver

2.5.4.7.8 Volvo 480 Left hand drive: Manoeuvre into middle lane from left hand lane

Figure 71 and Figure 73 show that the car can be positioned in the middle lane of the motorway in a position that is forwards of the volume of space that is visible through the Class IV mirror, and outside of the volume of space that is visible through direct vision through the passenger window. In this situation the car is only visible to the LGV driver through the Class VI mirror. Figure 72 shows the intersection of the volume of space visible in the Class VI mirror and the front quarter of the car with a 4th%ile stature driver's eye point. Figure 74 shows the intersection of the volume of space visible in the Class VI mirror and the front quarter of the car with a 99th%ile stature driver's eye point.

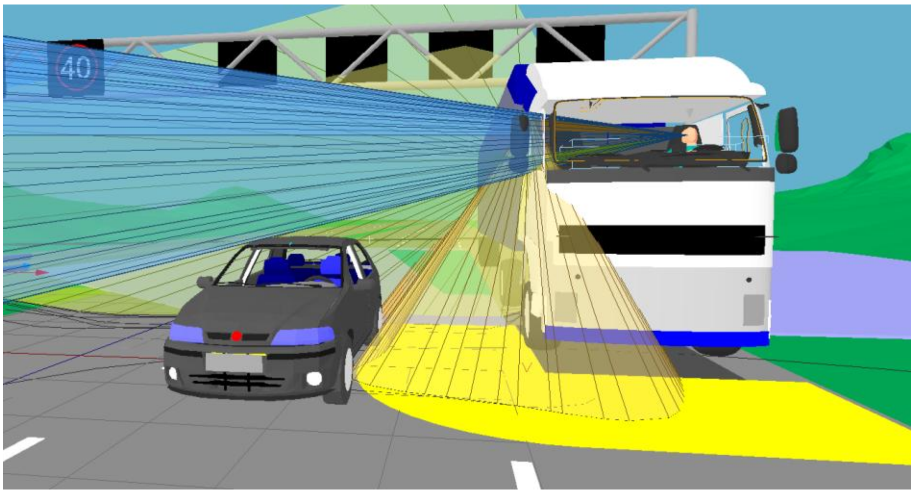

Figure 71. The car is not visible to the driver of the LGV using direct vision or the Class V Mirror with a 4th%ile stature driver's eye point

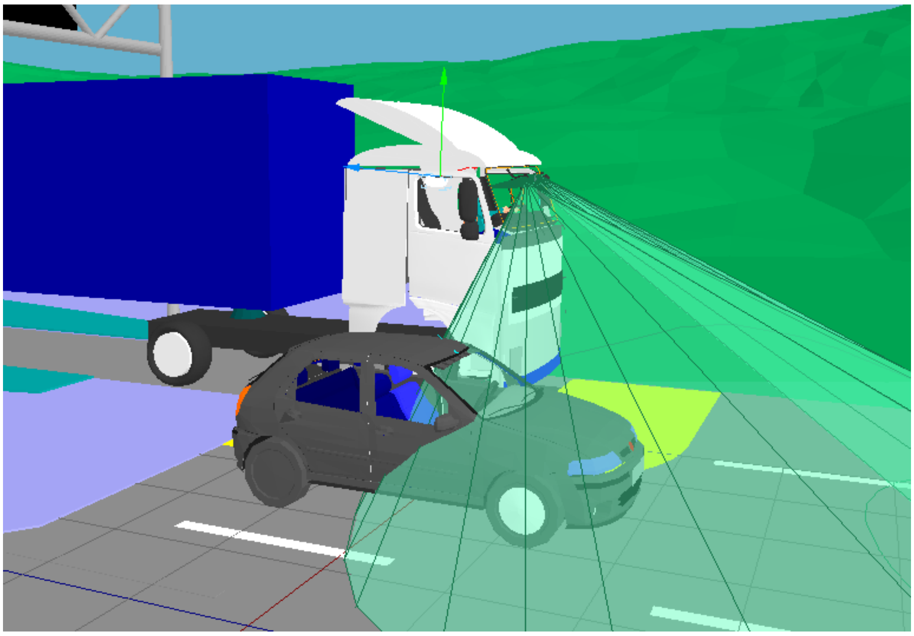

Figure 72. The intersection of the volume of space visible in the Class VI mirror and the front quarter of the car with a 4th%ile stature driver's eye point

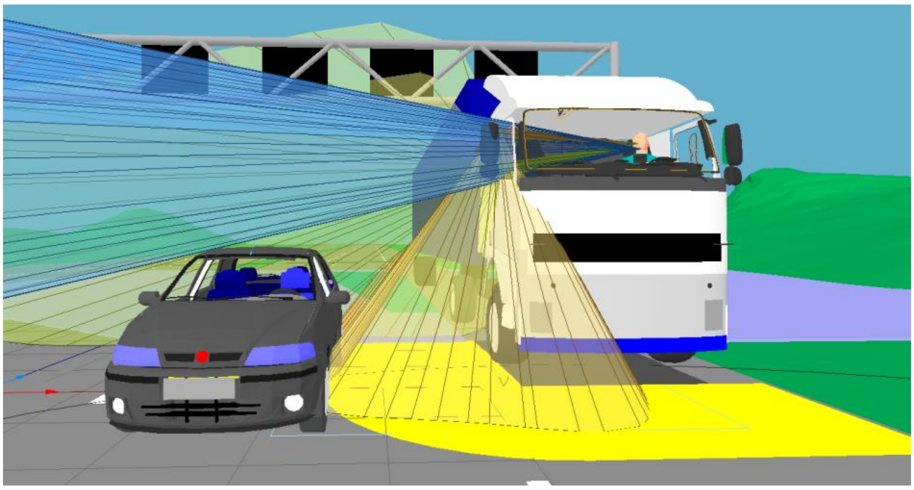

Figure 73. The car is not visible to the driver of the LGV using direct vision or the Class V mirror with a 99th%ile stature driver's eye point

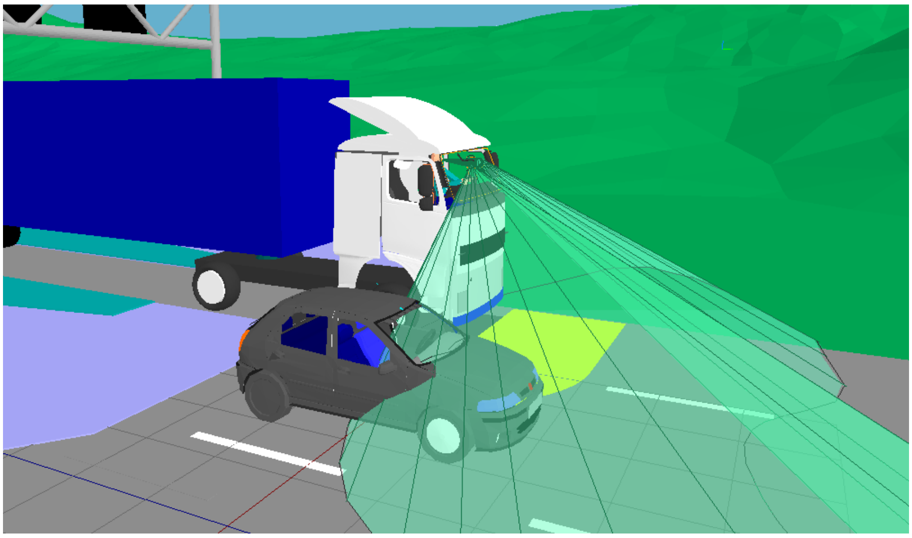

Figure 74. The intersection of the volume of space visible in the Class VI mirror and the front quarter of the car with a 99th%ile stature driver's eye point

2.5.4.7.9 Volvo 480 left hand drive: Manoeuvre into the left lane from the middle lane

Figure 75 and Figure 76 show that when a car is positioned to the left of the left hand drive Volvo 480 in a position that is forwards of the volume of space that is visible through the Class IV the car should be visible with direct vision through the driver's side window for both the 4th%ile and 99th%ile drivers.

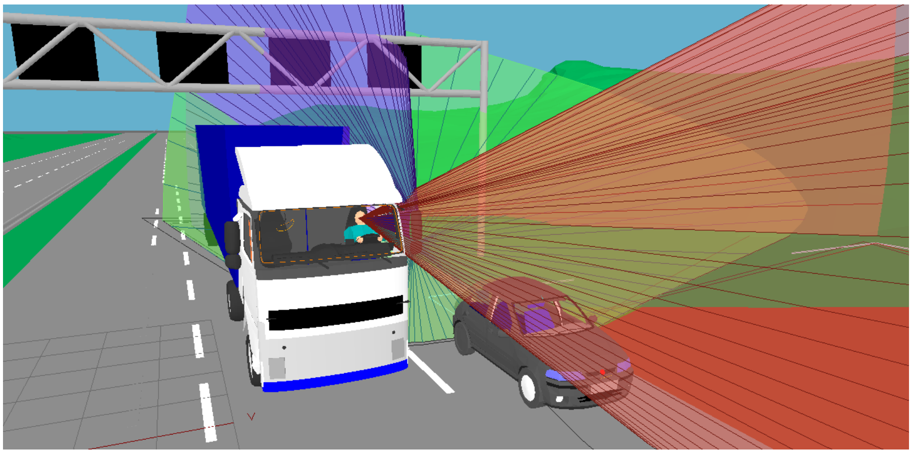

Figure 75. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror should be directly visible to a 4th%ile stature LGV driver

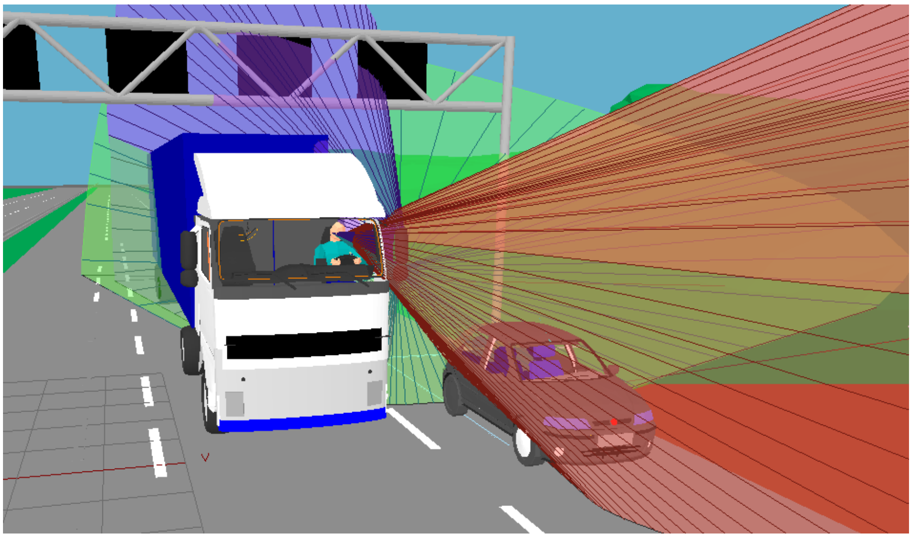

Figure 76. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror should be directly visible to a 99th%ile stature LGV driver

2.5.4.7.10 SCANIA R420: Manoeuvre into left lane from middle lane

Figure 77 and Figure 79 show that the car can be positioned in the left hand lane of the motorway in a position that is forwards of the volume of space that is visible through the Class IV mirror. In this position the car is partially visible through direct vision through the passenger window for both the 4th%ile and 99th%ile driver eye points . The car is also partially visible in the Class V and Class VI mirrors for the 4th%ile and 99th%ile driver eye points as shown in Figure 78 and Figure 80.

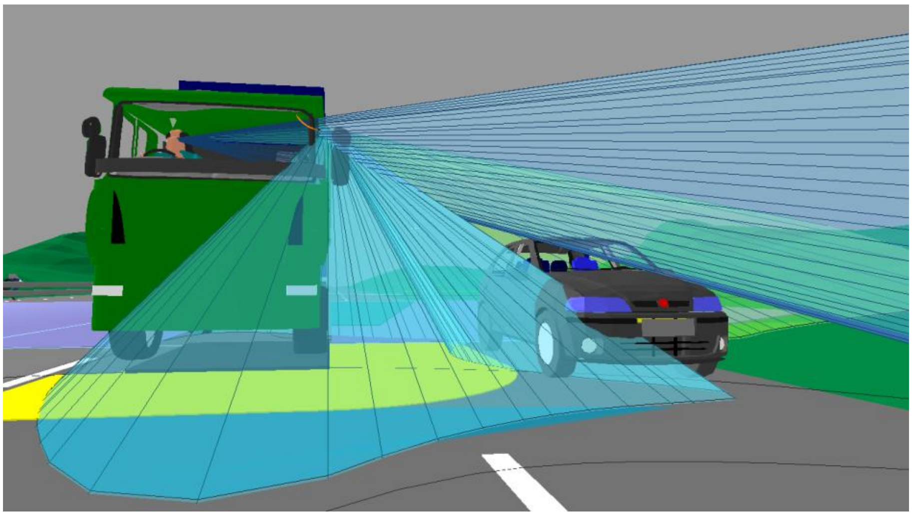

Figure 77. The car is partially visible to the driver through direct vision and the use of the Class V mirror from the 4th%ile stature driver eye point

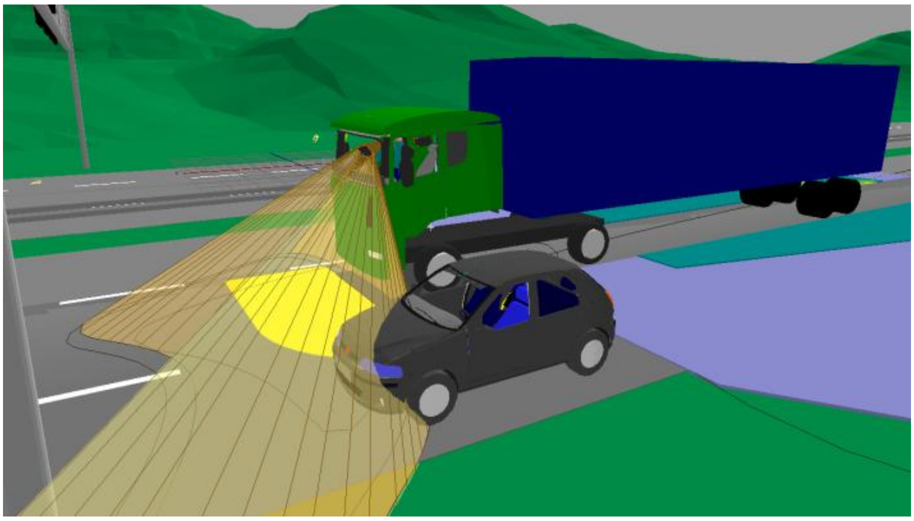

Figure 78. The car is partially visible to the driver through the use of the Class VI mirror from the 4th%ile stature driver eye point

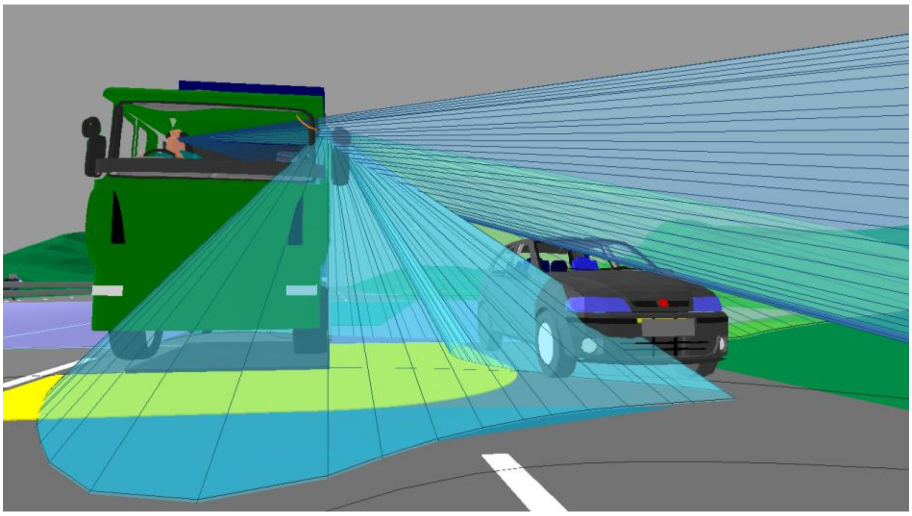

Figure 79. The car is partially visible to the driver through direct vision and the use of the Class V mirror from the 99th%ile stature driver eye point

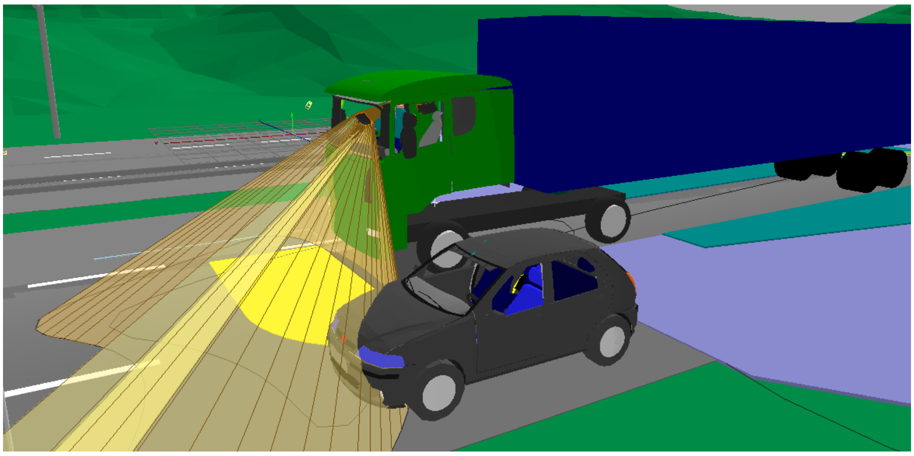

Figure 80. The car is partially visible to the driver through the use of the Class VI mirror from the 99th%ile stature driver eye point

2.5.4.7.11 SCANIA R420: Manoeuvre into the middle lane from the left lane

Figure 81 and Figure 82 show that when a car is positioned to the right of the SCANIA R420 in a position that is forwards of the volume of space that is visible through the Class IV the car should be visible with direct vision through the driver's side window for both the 4th%ile and 99th%ile drivers.

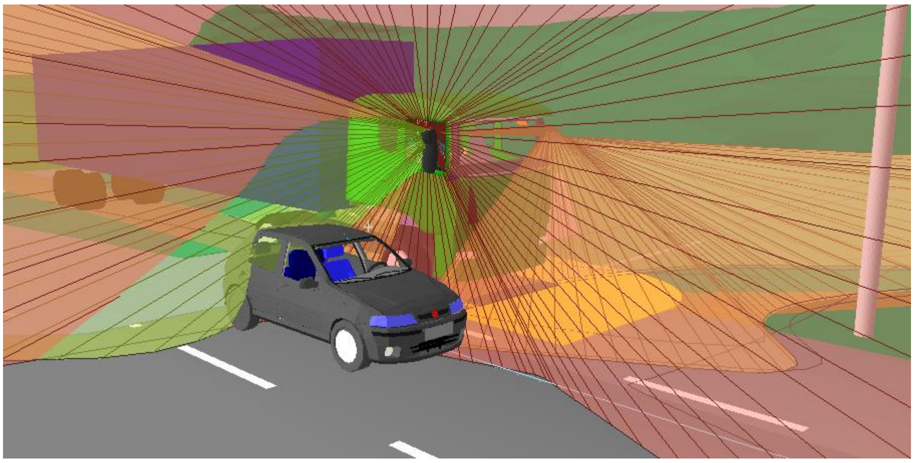

Figure 81. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 4th%ile stature LGV driver

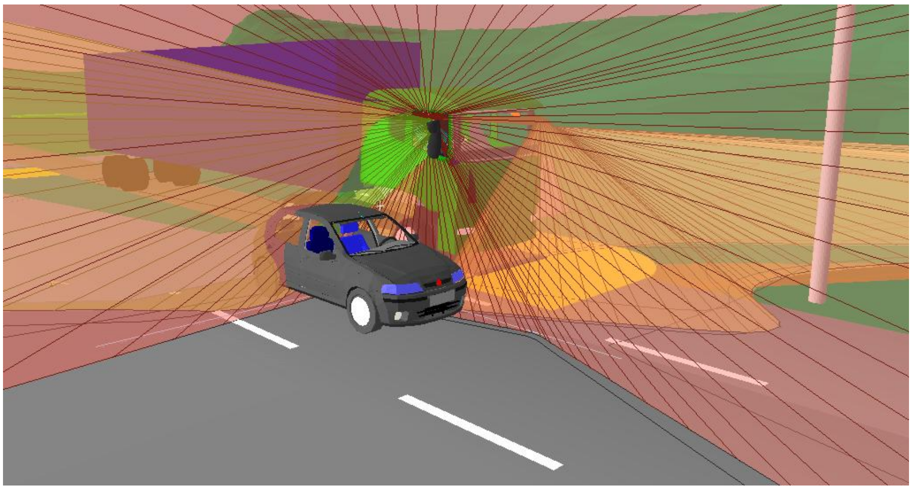

Figure 82. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 99th%ile stature LGV driver

2.5.5 Discussion of the results found for category N_3 vehicles

The analysis of direct and indirect visibility from three category N_3 vehicles has shown that consistent blind spots exist across all three vehicles. The blind spot that exists between the direct vision through the passenger window and volume of space that is visible using the Class V mirror has been shown to have the potential to mask pedestrians, cyclists and vehicles from the drivers of LGVs.

The work has also highlighted an issue with the current method for describing the required coverage for Class V mirrors. Directive 2003/97/EC only specifies visible areas for mirror coverage at the ground plane which has the potential to be misinterpreted by users. For example, it is presumed that the design intent of current Class V mirrors is to cover areas larger than that defined in Directive 2003/97/EC. However, if the standards are followed to the letter, it is possible to adjust the Class V mirror (as shown in Figure 83) so that the corners of the prescribed area are visible as described in the VOSA recommended field of view check[9]. However, the curved nature of the mirror projection on the ground plane results in less than full coverage of the required area. The driver's view through the Class V mirror would show that the four corners of prescribed area are covered by the mirror, and yet a cyclist, who is within the prescribed area, would be not be visible to the driver. Figure 84 shows that approximately half of the volume covered by the Class V mirror is focused on the side of the vehicle if the mirror is adjusted in this way. This is not an optimum usage of the mirror design. It is therefore recommended that a volumetric approach is taken when defining standards which defines a height above the floor that should be visible to the user, combined with a larger area of coverage. This will be discussed further in the solutions section.

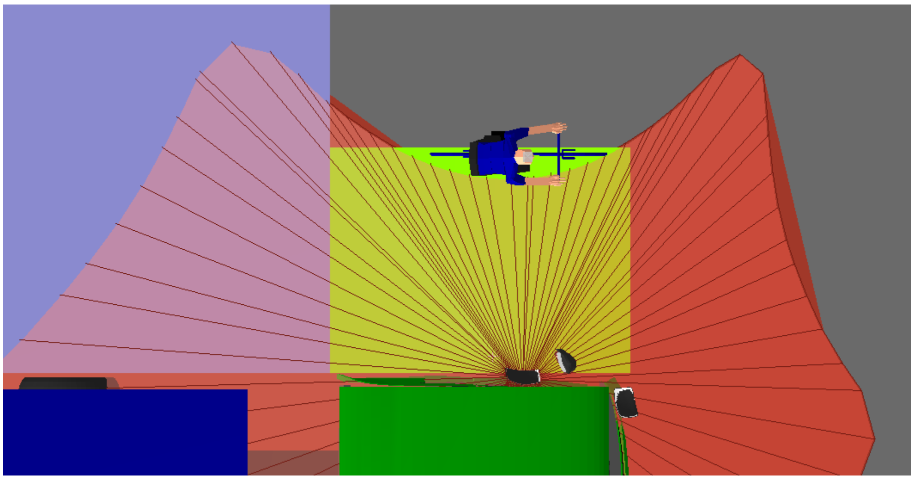

Figure 83. The potentially poor adjustment of a Class V mirror based upon current standards descriptions

[9] VOSA 2008: Compliance Guide for the retrofitting of mirrors to lorries. Directive 2007/38/EC

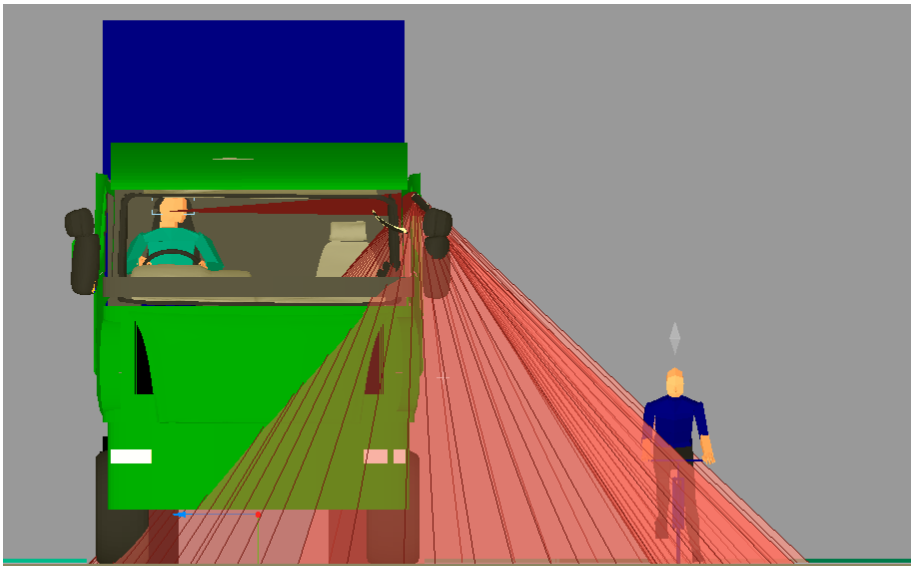

Figure 84. The potentially poor adjustment of a Class V mirror based upon current standards descriptions

In addition, the analysis for the category N_3 vehicles has been performed using correctly adjusted mirrors. Dodd (2009)[10] 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 their own, to ensure that they have 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)[11] stated that "a badly adjusted mirror may be worse than no mirror at all". The accident scenarios that have been examined have the potential to be caused by the identified blind spots, but these blind spots could easily be increased in size by poor adjustment of the Class IV, Class V and Class VI mirrors.

2.5.6 Analysis results for category N_2 vehicles

2.5.6.1 An analysis of the compliance with EC directives on mirror coverage at the ground plane level

The following section illustrates the compliance of each vehicle with the EC directives on mirror coverage at the ground plane for Class II, IV, V and VI mirrors using the mirror projection technique in the Digital Human Modelling software.

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

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

2.5.6.1.1 The compliance of the Renault Midlum category N_2 LGV

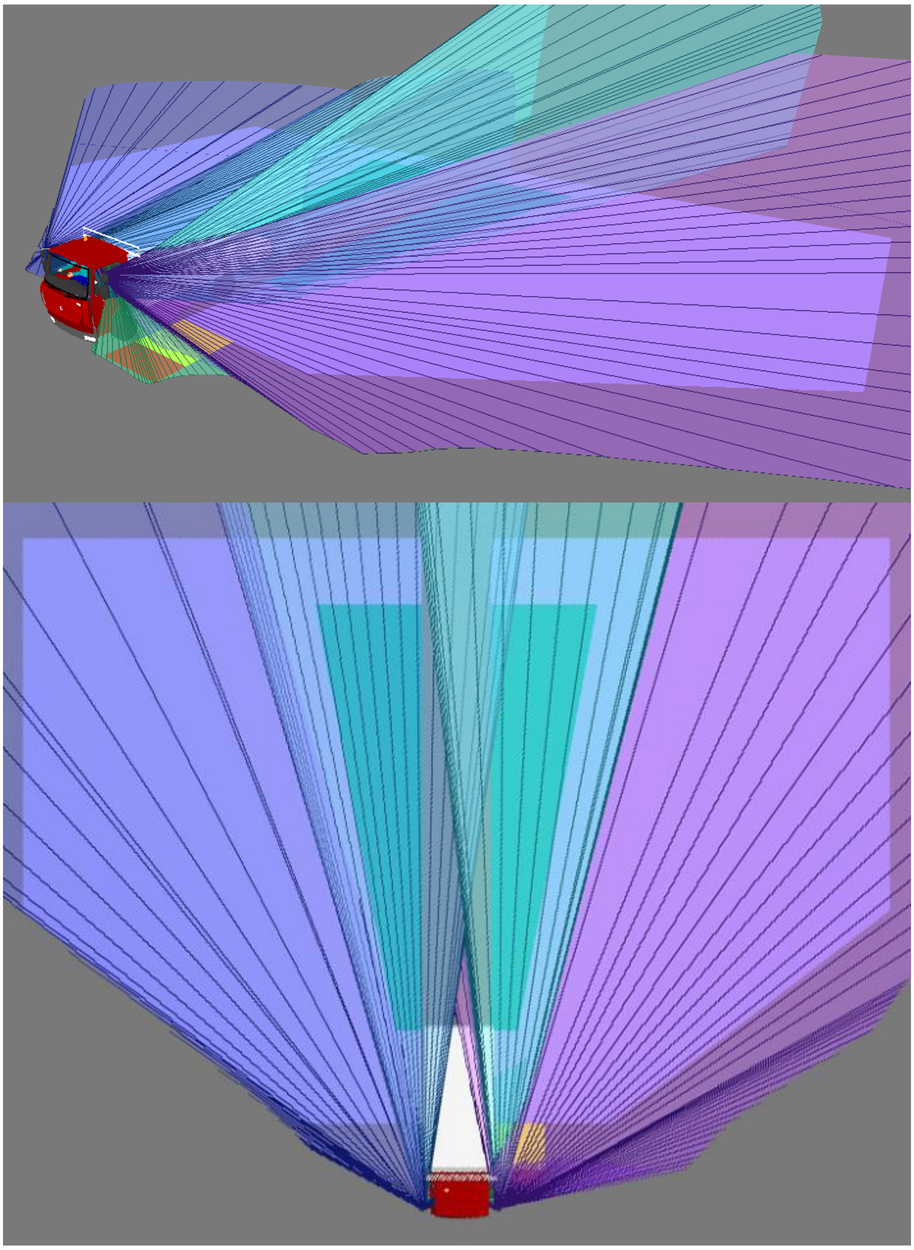

Figure 85. The compliance of the Renault Midlum category N_2 vehicle with the recommended area of visibility at the ground plane

Figure 85 shows that the mirrors mounted on the Renault Midlum were able to be adjusted to comply with the standard templates for the areas to be visible using mirrors found in Directive 2003/97/EC.

2.5.6.1.2 The compliance of the IVECO Euromaster category N_2 LGV

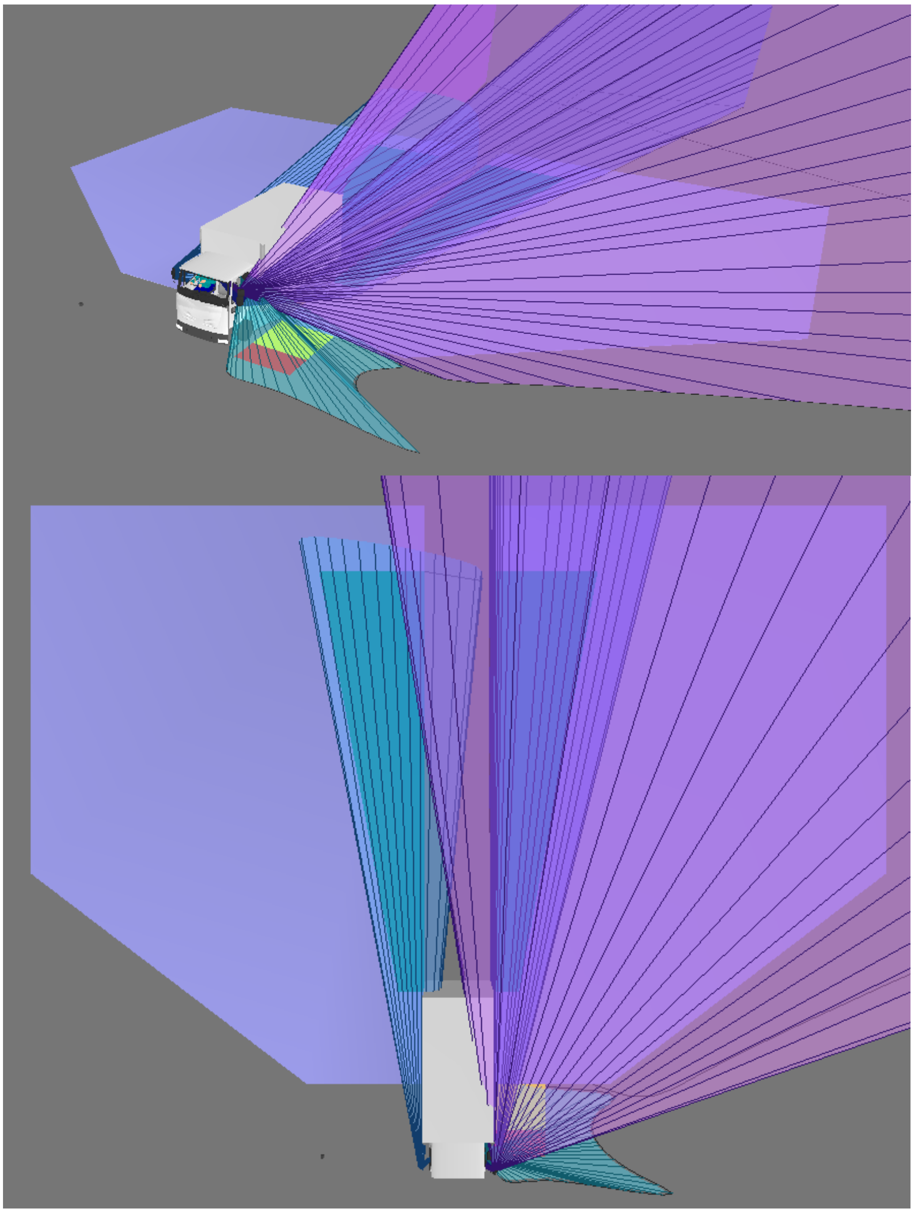

Figure 86. The compliance of the Iveco Eurocargo category N_2 vehicle with the recommended area of visibility at the ground plane

Figure 86 shows that the mirrors mounted on the 2003 Iveco Eurocargo are partially compliant with the standard templates for the areas to be visible using mirrors found in Directive 2003/97/EC. This vehicle was built before it was mandatory to fit Class IV mirrors to both sides of the vehicle. The vehicle was selected for analysis as it includes small additional windows in the passenger and driver's doors, which was seen as an interesting feature that was worth exploring in more detail.

2.5.6.1.3 The compliance of the DAF 45 category N_2 LGV

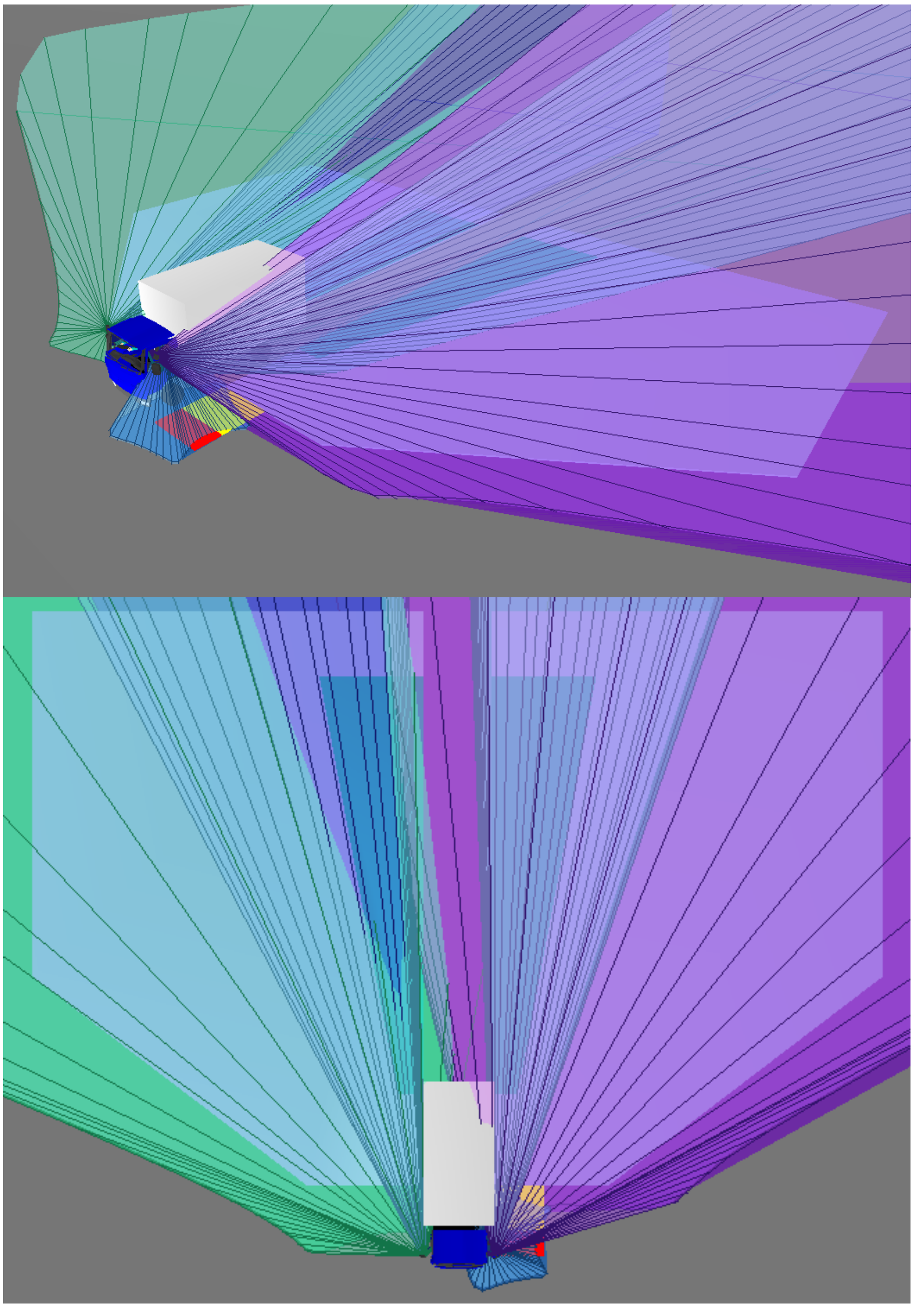

Figure 87. The compliance of the DAF LF 45 category N_2 vehicle with the recommended area of visibility at the ground plane

Figure 87 shows that the mirrors mounted on the DAF LF 45 were able to be adjusted to comply with the standard templates for the areas to be visible using mirrors found in Directive 2003/97/EC.

2.5.6.2 Identification of blind spots: Renault Midlum category N_2 LGV

2.5.6.2.1 Mirror and aperture projections for the 4th%ile UK male

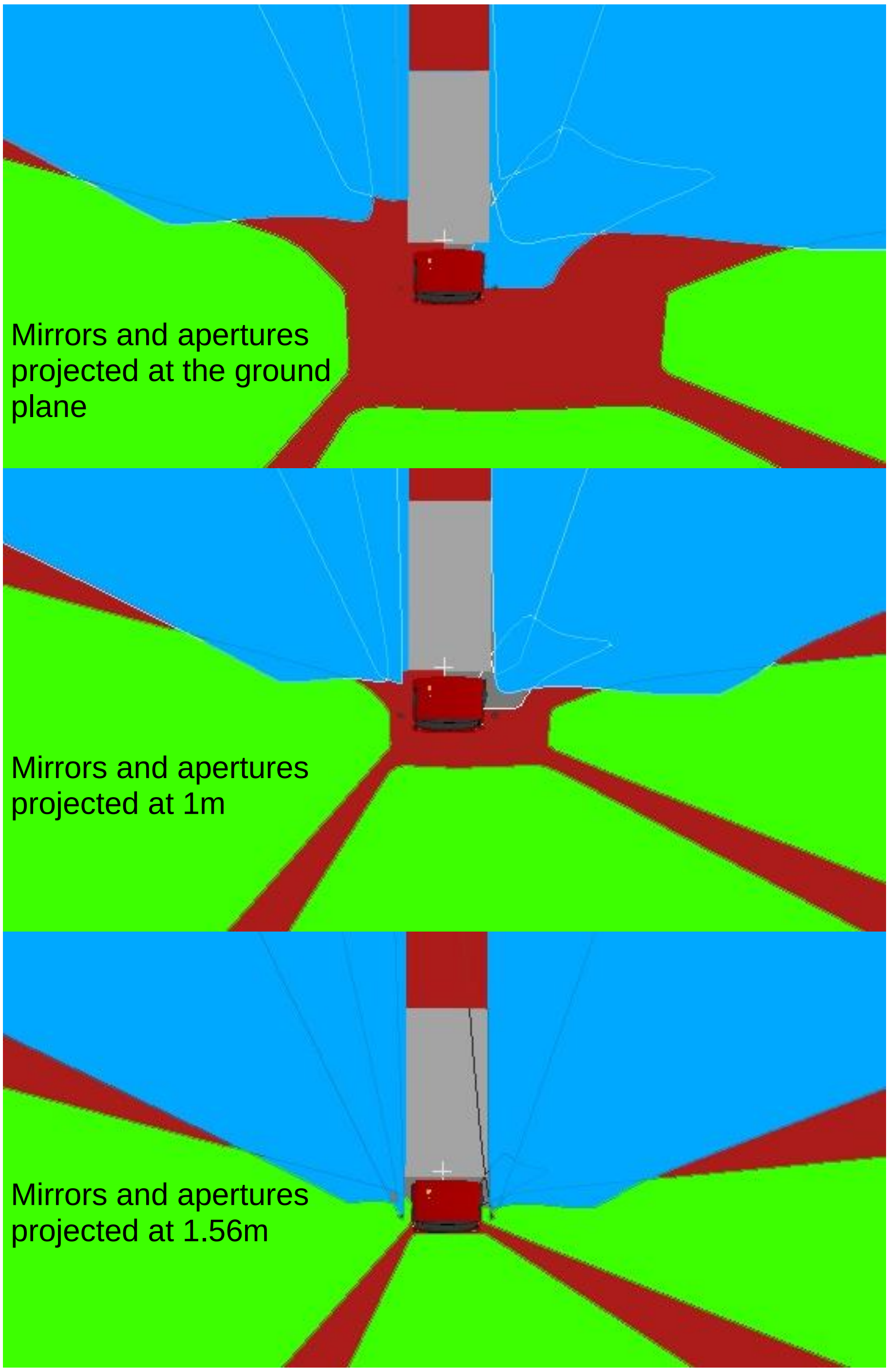

Figure 88. The projection of all mirrors onto the ground plane, 1m above the ground plane and 1.56m above the ground plane using the 4th%ile UK male eye point

2.5.6.2.2 Mirror and aperture projections for the 99th%ile UK male

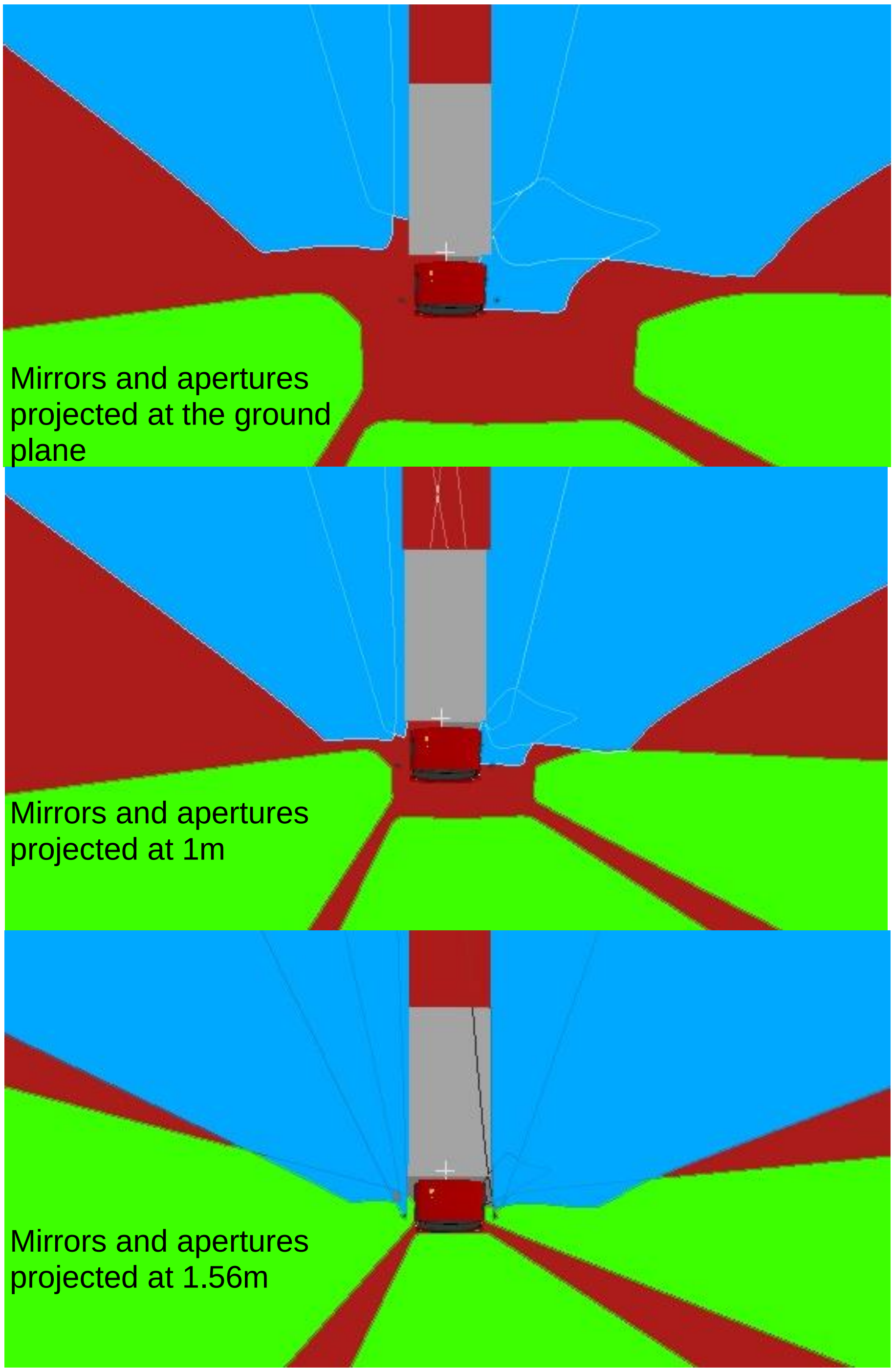

Figure 89. The projection of all mirrors onto the ground plane, 1m above the ground plane and 1.56m above the ground plane using the 99th%ile UK male eye point

Figure 88 and Figure 89 show the projection of all mirrors and apertures onto the ground plane, 1m above the ground plane and 1.56m above the ground plane for the Renault Midlum category N_2 vehicle for 4th%ile UK male and 99th%ile UK male eye points respectively. Figure 90 shows that the projection of the visible volumes of space using direct and indirect methods for the Renault Midlum has highlighted three blind spot areas, one on either side of the driver's cab and one in front of the driver's cab. These two blind spot areas are consistent in all of the projected heights used.

Blind spot 3 is only present at heights below 1.56m, but is adjacent to the vehicle. The other blind spot areas identified using the technique are associated with the A-pillars and B-pillars of the vehicle.

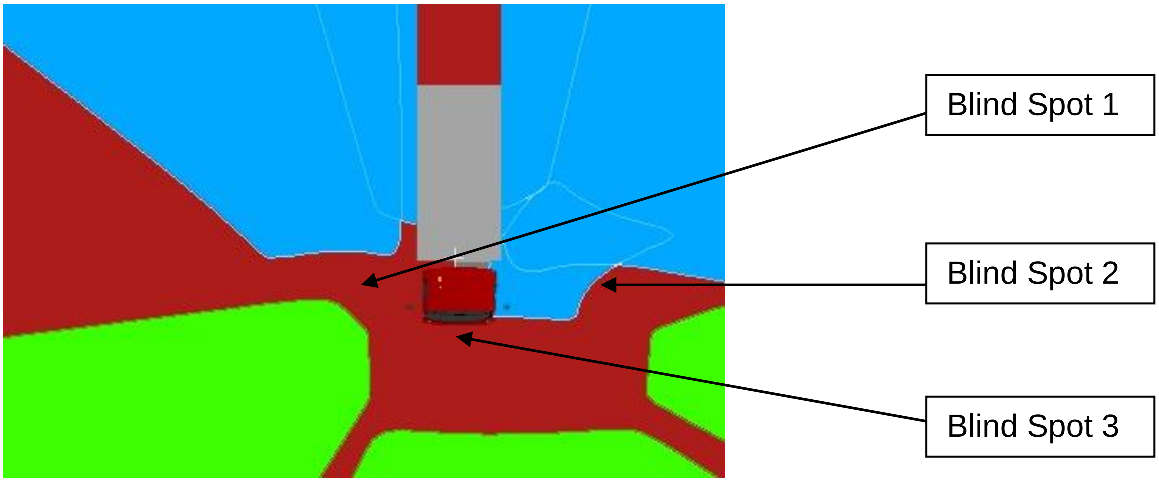

Figure 90. The three blind spot areas that have been identified using the projection of direct and indirect volumes for the Renault Midlum

2.5.6.2.3 The objects that can be obscured from driver vision by blind spot 1

Figure 91 and Figure 92 show the height of a person that can be obscured by the driver's door for the 4th%ile driver and 99th%ile driver respectively. The results show that children can be obscured from the driver's view.

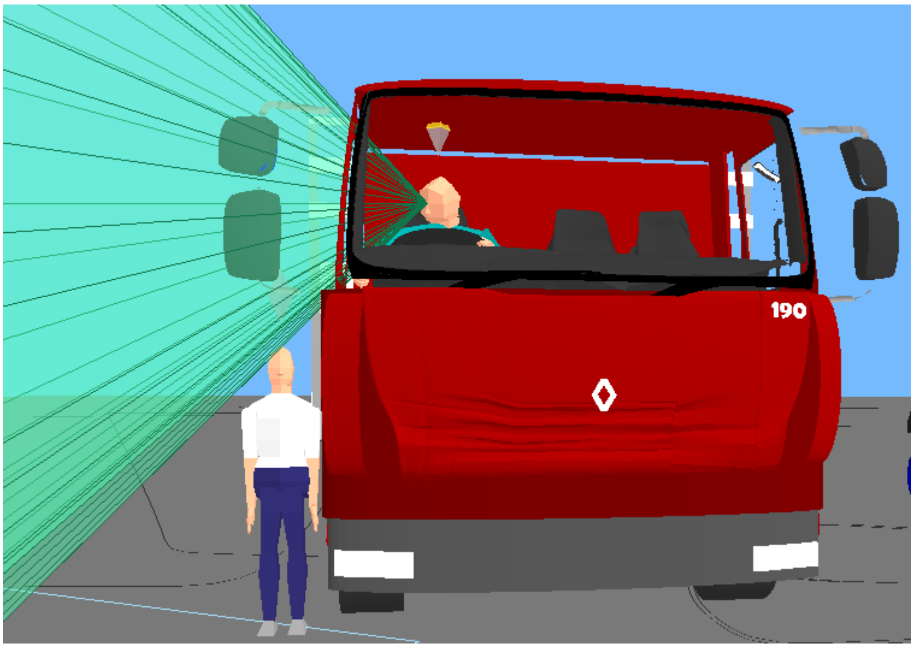

Figure 91. A 1400mm stature person (5th%ile 13yr old UK male) can be obscured from the 4th%ile stature driver

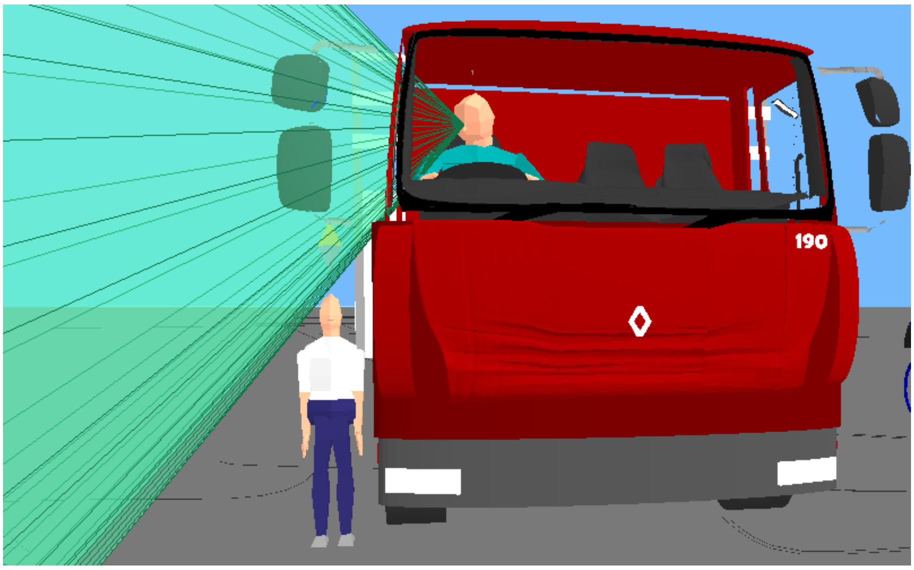

Figure 92. A 1220mm stature person (5th%ile 9yr old UK male) can be obscured from the 99th%ile stature driver

2.5.6.2.4 The objects that can be obscured from driver vision by blind spot 2

Figure 93 and Figure 94 show a cyclist that is positioned forwards of the volume of space that is visible through the Class IV mirror. In this position the cyclist is visible to the driver through direct vision for both driver sizes.

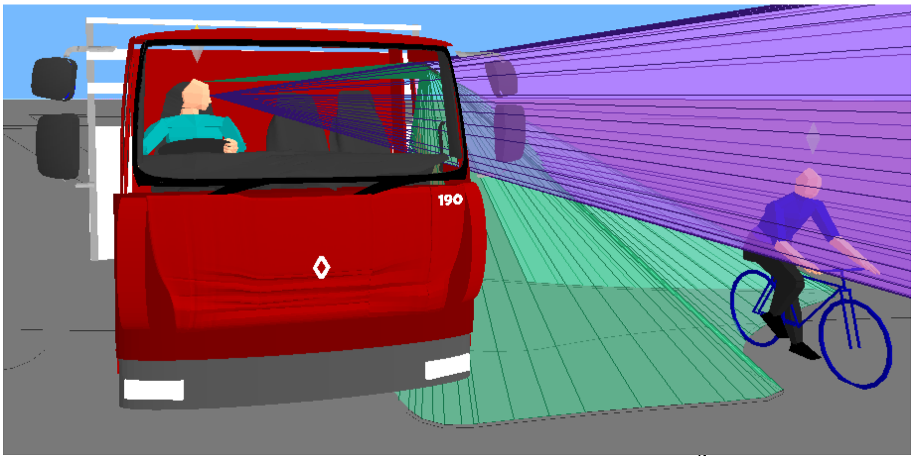

Figure 93. A cyclist located in blind spot zone 2 is visible to the 4th%ile driver through direct vision

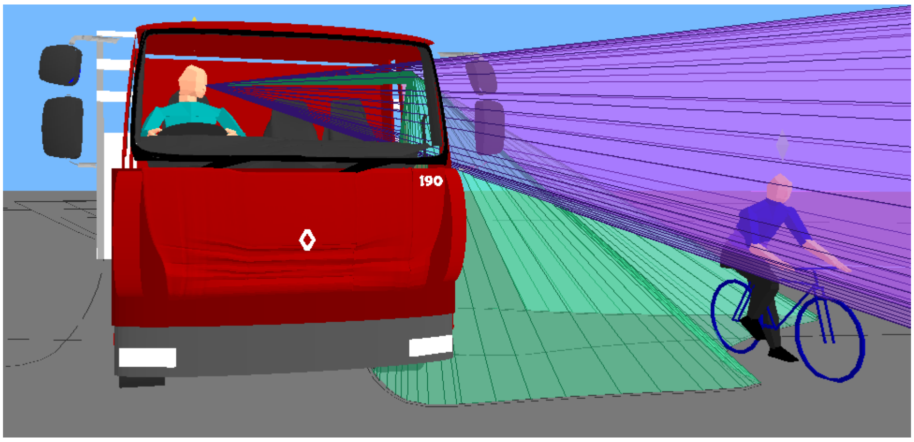

Figure 94. A cyclist located in blind spot zone 2 is visible to the 99th%ile driver through direct vision

2.5.6.2.5 The objects that can be obscured from driver vision by blind spot 3

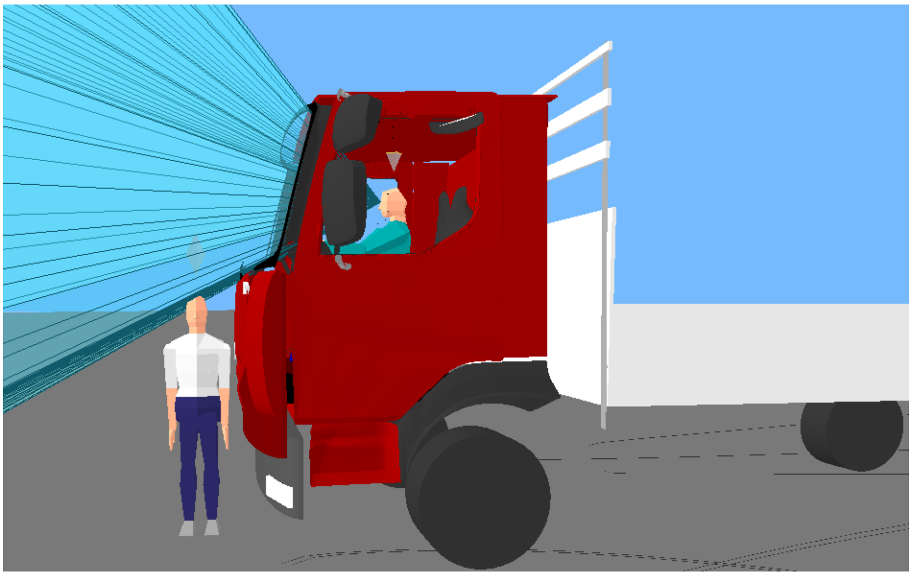

Figure 95. A 1350mm stature person (approx. 5th%ile 12yr old UK male (1360mm)) can be obscured from the 4th%ile stature driver

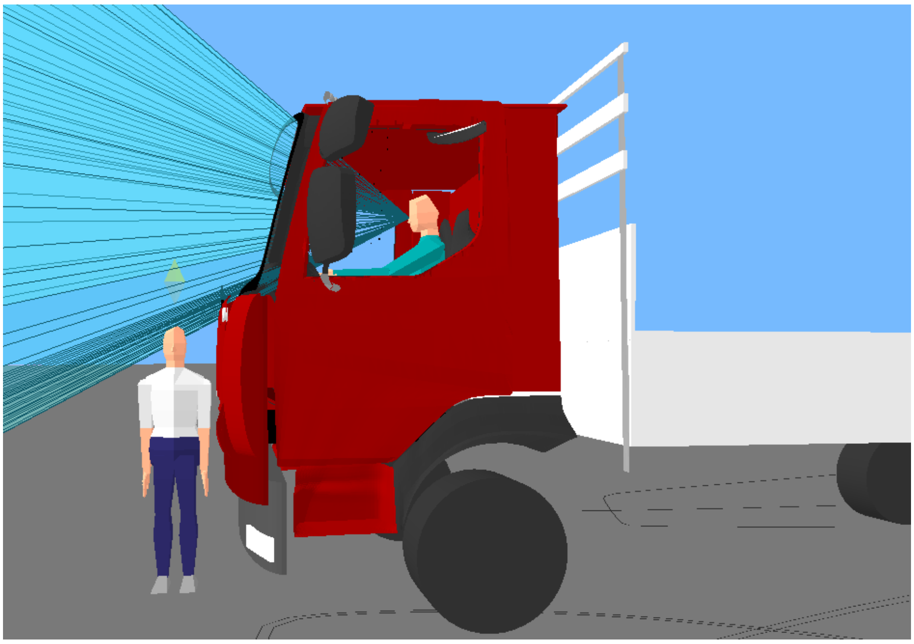

Figure 96. A 1450mm stature person (approx. 5th%ile 14yr old UK male(1480mm)) can be obscured from the 99th%ile stature driver

Figure 95 and Figure 96 show the height of a person that can be obscured in front of the vehicle, below the windscreen, for the 4th%ile driver and 99th%ile driver respectively. The results show that children can be obscured from the driver's view.

2.5.6.3 Identification of blind spots: IVECO Eurocargo category N_2 LGV

2.5.6.3.1 Mirror and aperture projections for the 4th%ile UK male

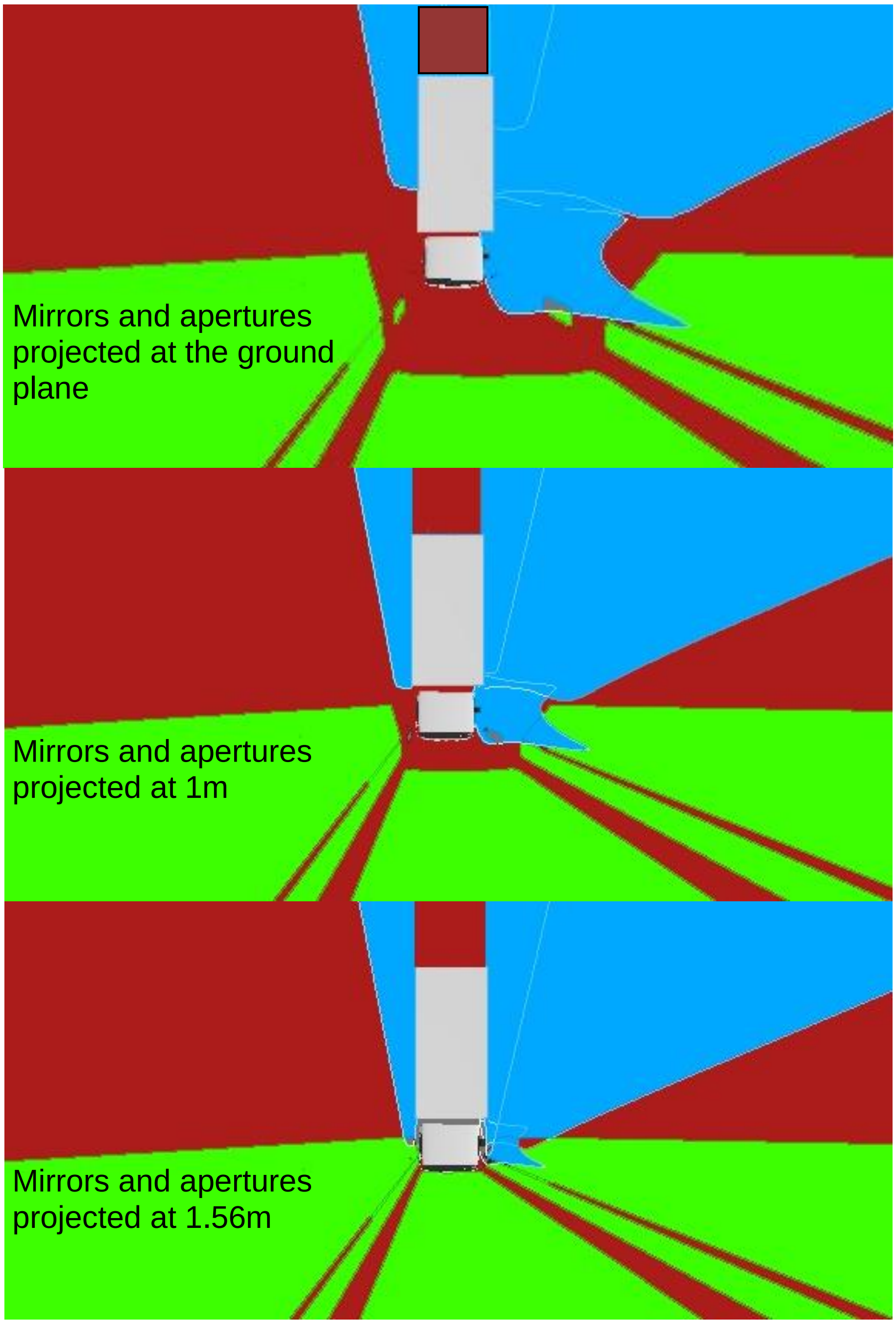

Figure 97. The projection of all mirrors onto the ground plane, 1m above the ground plane and 1.56m above the ground plane using the 4th%ile UK male eye point

2.5.6.3.2 Mirror and aperture projections for the 99th%ile UK male

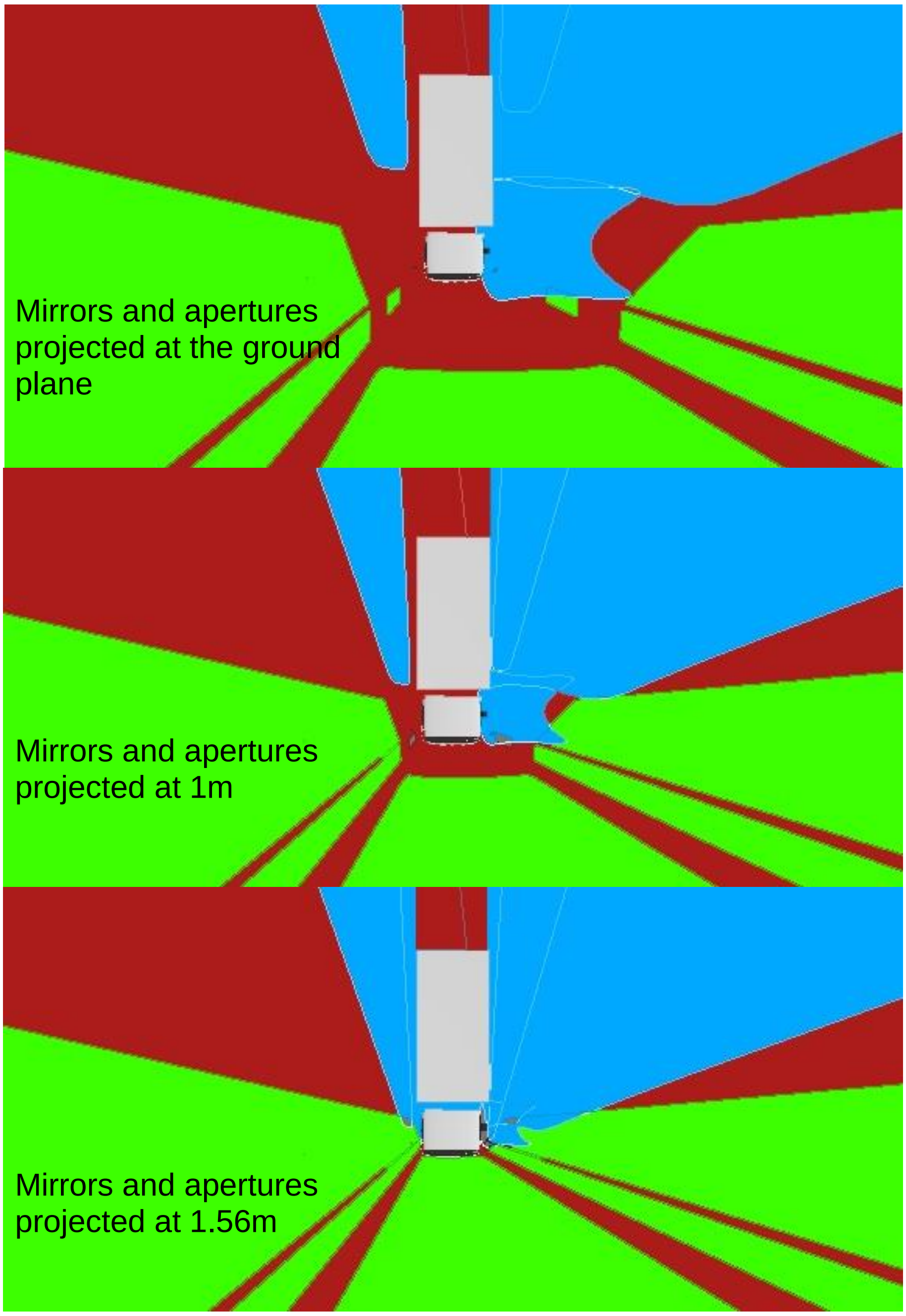

Figure 98. The projection of all mirrors onto the ground plane, 1m above the ground plane and 1.56m above the ground plane using the 99th%ile UK male eye point

Figure 98 and Figure 97 show the projection of all mirrors and apertures onto the ground plane, 1m above the ground plane and 1.56m above the ground plane for the IVECO Eurocargo category N_2 vehicle for 4th%ile UK and 99th%ile UK male eye points respectively. Figure 99 shows that the projection of the visible volumes of space using direct and indirect methods for the Iveco Eurocargo has highlighted three blind spot areas, one on either side of the driver's cab and one in front of the driver's cab. These two blind spot areas are consistent in all of the projected heights used. Blind spot 3 is only present at heights below 1.56m, but is adjacent to the vehicle. The other blind spot areas identified using the technique are associated with the A-pillars and B-pillars of the vehicle.

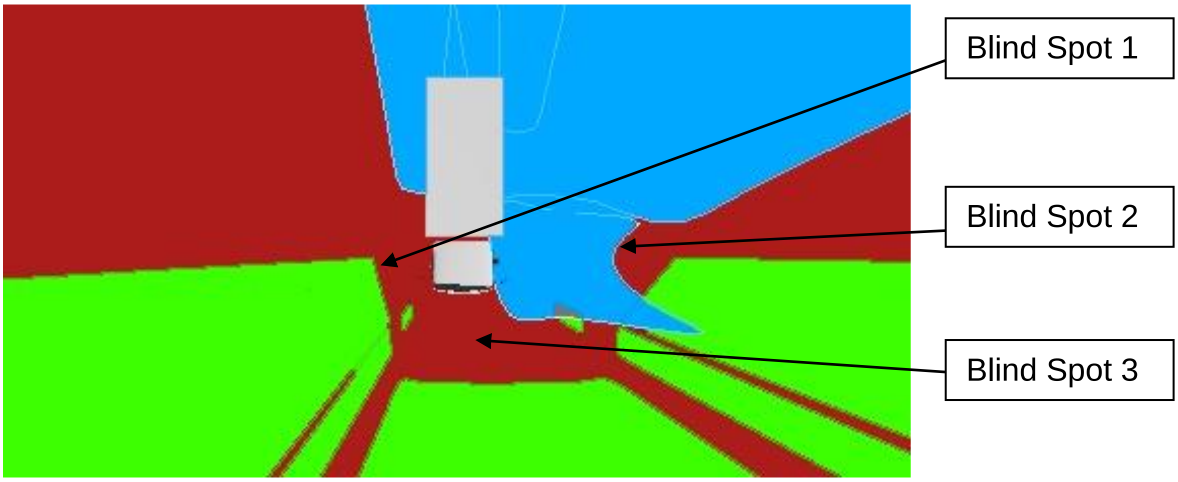

Figure 99. The three blind spot areas that have been identified using the projection of direct and indirect volumes for the Iveco Eurocargo

2.5.6.3.3 The objects that can be obscured from driver vision by blind spot 1

Figure 100 and Figure 101 show the height of a person that can be obscured by the driver's door for the 4th%ile driver and 99th%ile driver respectively. The results show that children can be obscured from the driver's view.

Figure 100. A 1365mm stature person (5th%ile 12yr old UK male) can be obscured from the 4th%ile stature driver

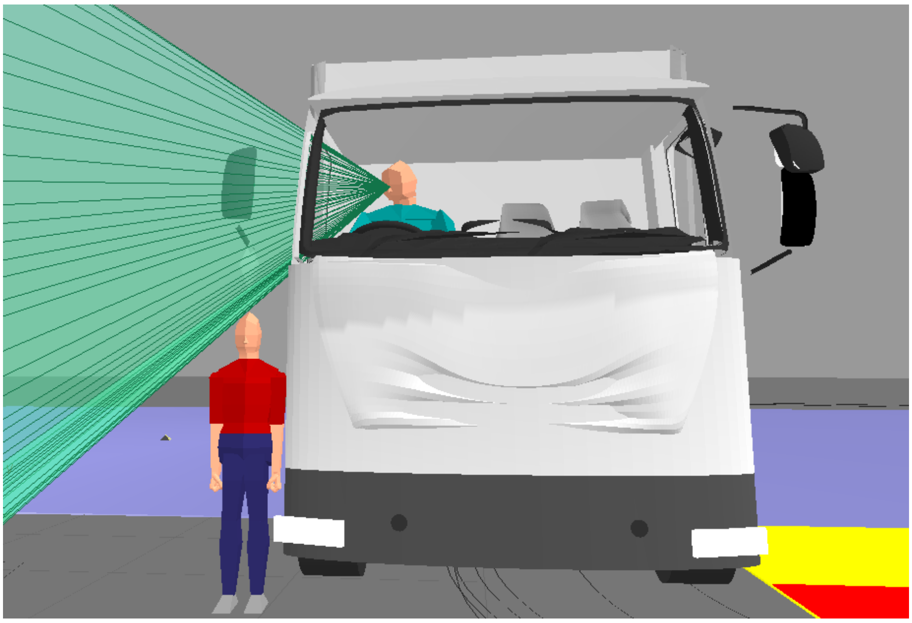

Figure 101. A 1340mm stature person (approx. 5th%ile 11yr old UK male (1325mm)) can be obscured from the 99th%ile stature driver

Figure 102 illustrates that the small window in the driver's door that was considered during the selection of N_2 vehicles has little effect in improving visibility for the driver on the off side of the vehicle. The window shows the potential to be blocked by the arm of the driver when in the driving position.

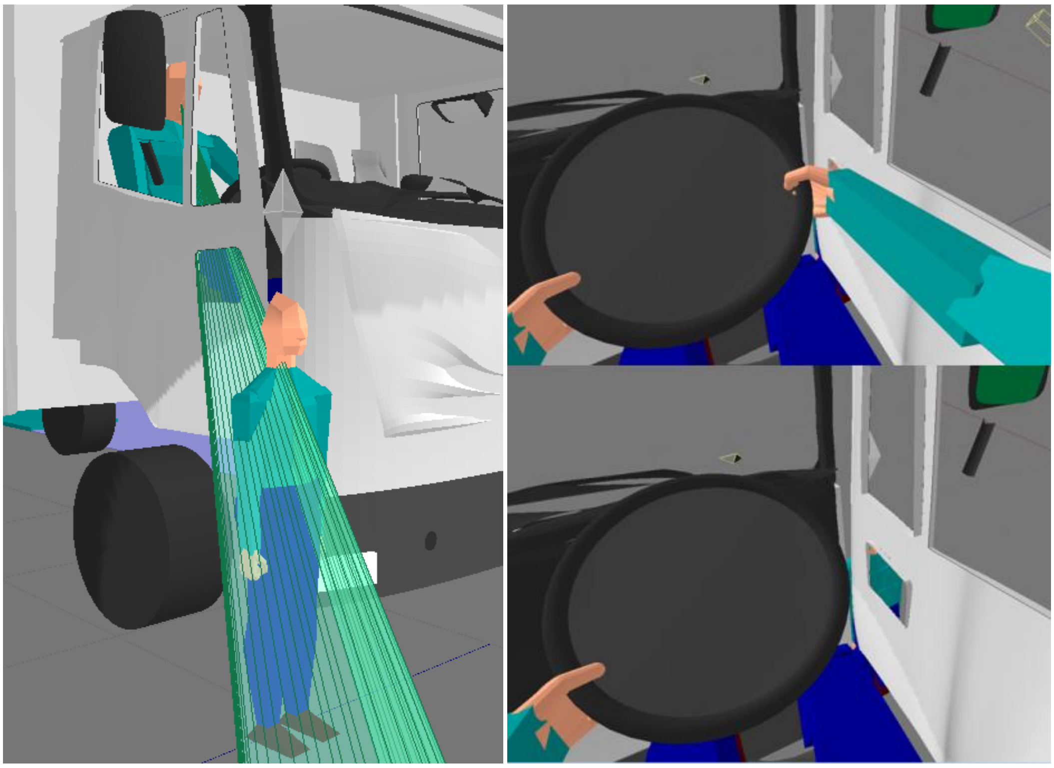

Figure 102. The small window in the driver's door has little potential to improve visibility to the offside of the vehicle

2.5.6.3.4 The objects that can be obscured from driver vision by blind spot 2

Figure 103 and Figure 104 show a cyclist that is positioned forwards of the volume of space that is visible through the Class IV mirror. In this position the cyclist is visible to the driver through direct vision for both driver sizes.

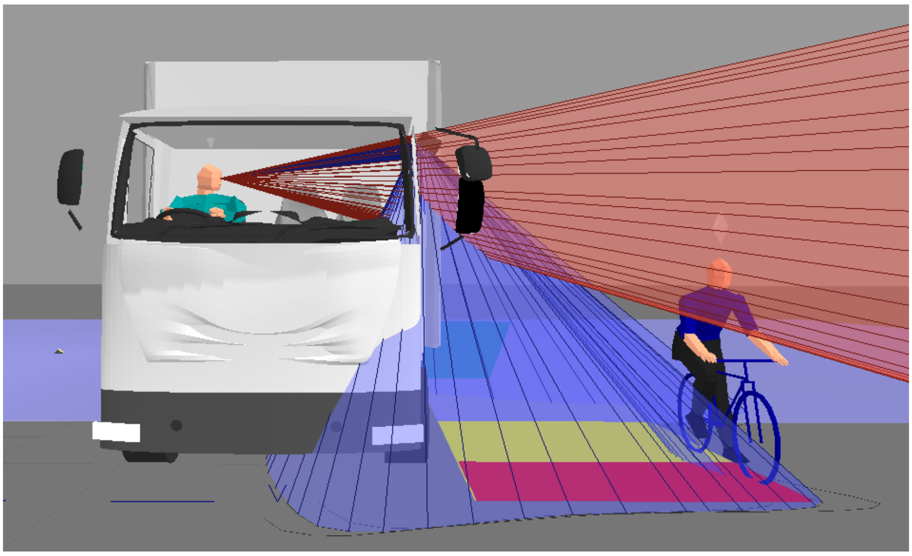

Figure 103. A cyclist located in blind spot zone 2 is visible to the 4th%ile driver through direct vision

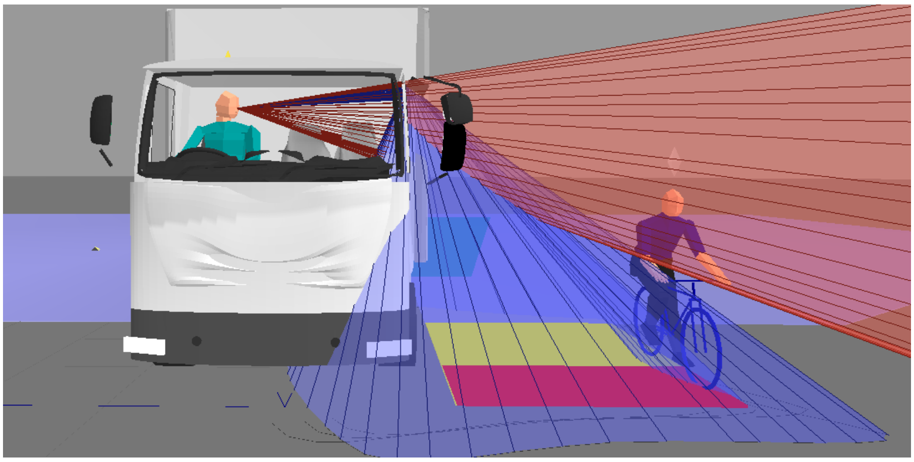

Figure 104. A cyclist located in blind spot zone 2 is visible to the 99th%ile driver through direct vision

2.5.6.3.5 The objects that can be obscured from driver vision by blind spot 3

Figure 105 and Figure 106 show the height of a person that can be obscured in front of the vehicle, below the windscreen, for the 4th%ile driver and 99th%ile driver respectively. The results show that children can be obscured from the driver's view.

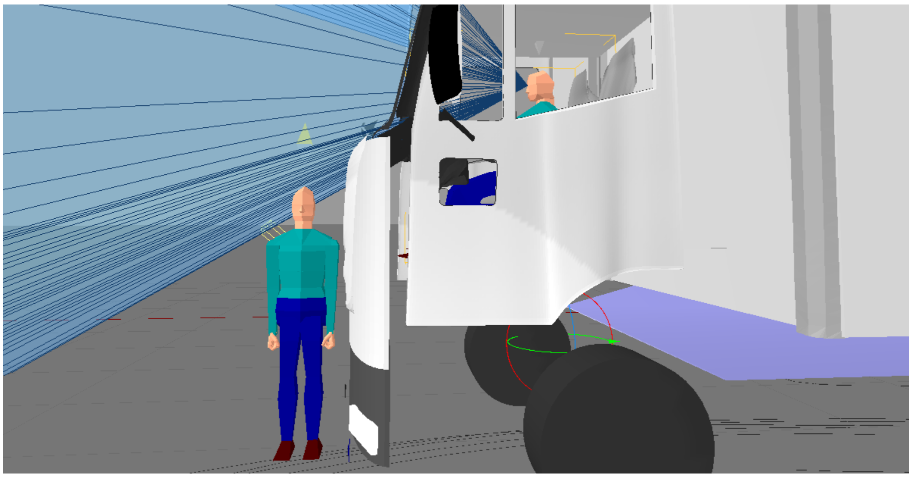

Figure 105. A 1400mm stature person (5th%ile 13yr old UK male) can be obscured from the 4th%ile stature driver

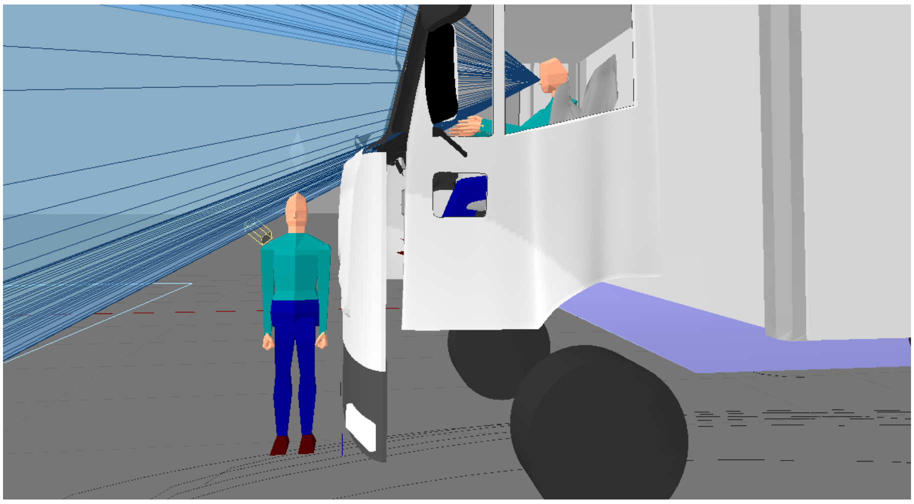

Figure 106. A 1400mm stature person (5th%ile 13yr old UK male) can be obscured from the 99th%ile stature driver

2.5.6.4 Identification of blind spots: DAF 45 category N_2 LGV

2.5.6.4.1 Mirror and aperture projections for the 4th%ile UK male

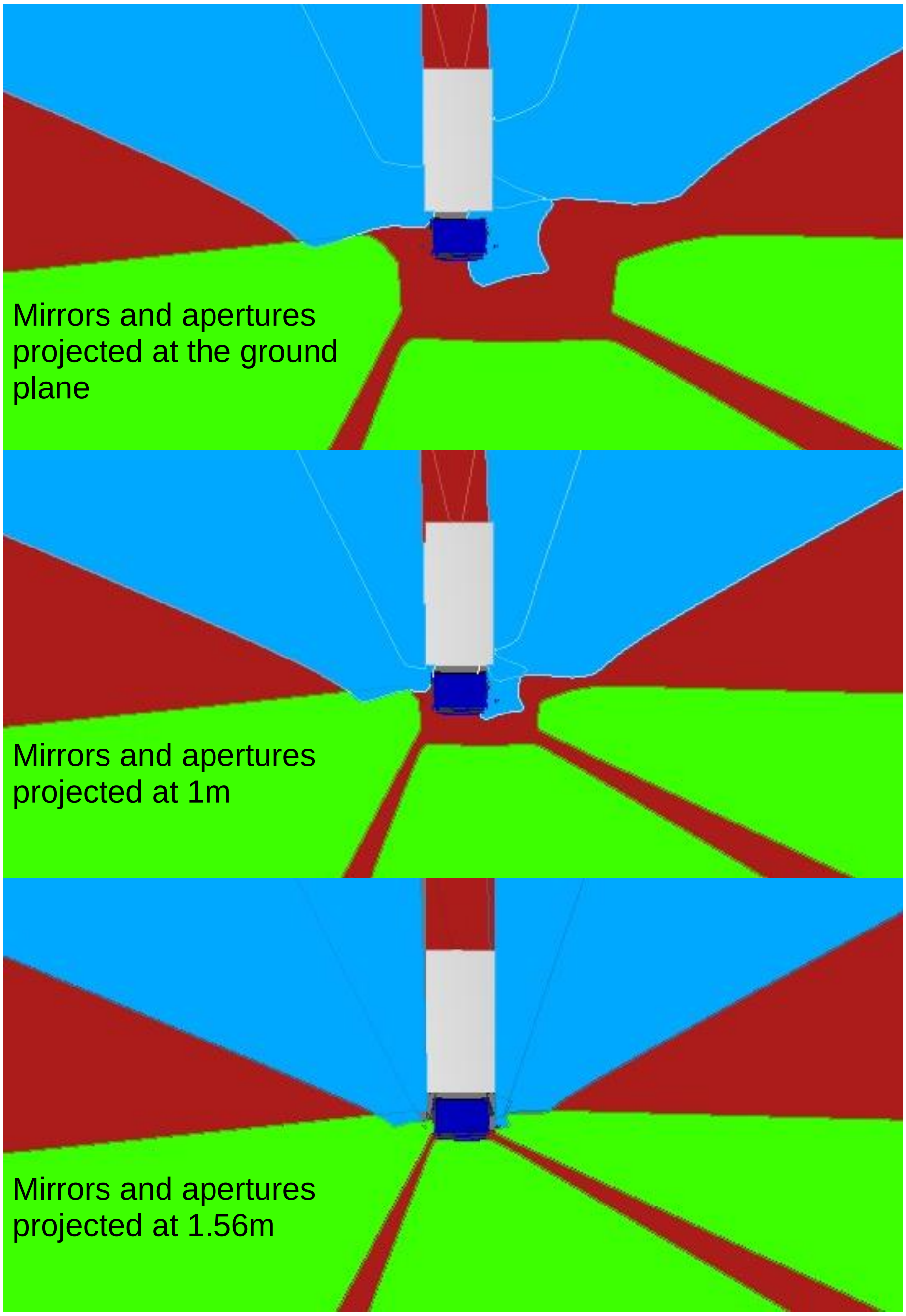

Figure 107. The projection of all mirrors onto the ground plane, 1m above the ground plane and 1.56m above the ground plane using the 4th%ile UK male eye point

2.5.6.4.2 Mirror and aperture projections for the 99th%ile UK male

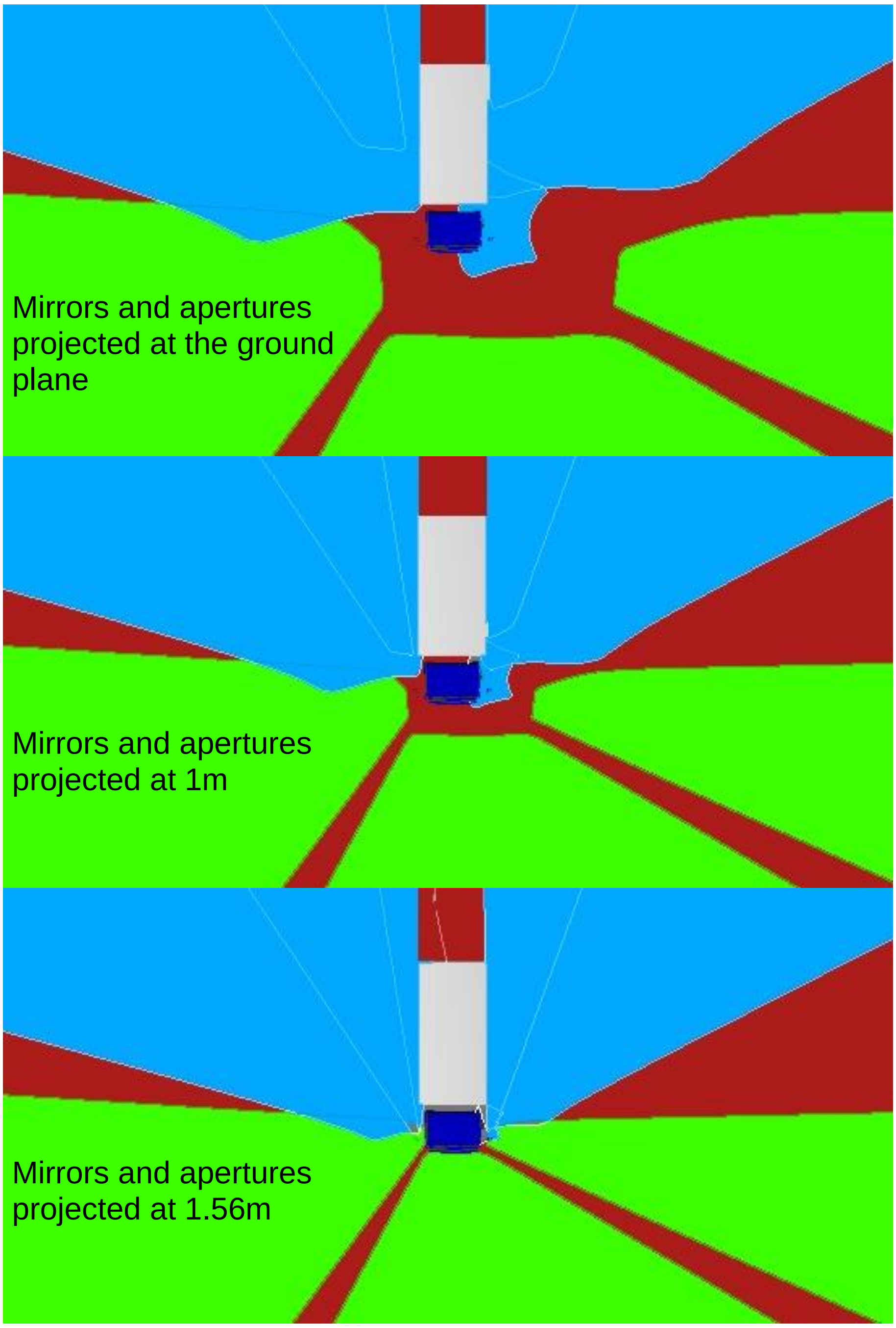

Figure 108. The projection of all mirrors onto the ground plane, 1m above the ground plane and 1.56m above the ground plane using the 99th%ile UK male eye point

Figure 108 and Figure 107 show the projection of all mirrors and apertures onto the ground plane, 1m above the ground plane and 1.56m above the ground plane for the DAF 45 category N_2 vehicle for 4^{th}%ile and 99^{th}%ile UK male eye points respectively. Figure 109 shows that the projection of the visible volumes of space using direct and indirect methods for the DAF LF 45 has highlighted three blind spot areas, one on either side of the driver's cab and one in front of the driver's cab. These two blind spot areas are consistent in all of the projected heights used. Blind spot 3 is only present at heights below 1.56m, but is adjacent to the vehicle. The other blind spot areas identified using the technique are associated with the A-pillars and B-pillars of the vehicle.

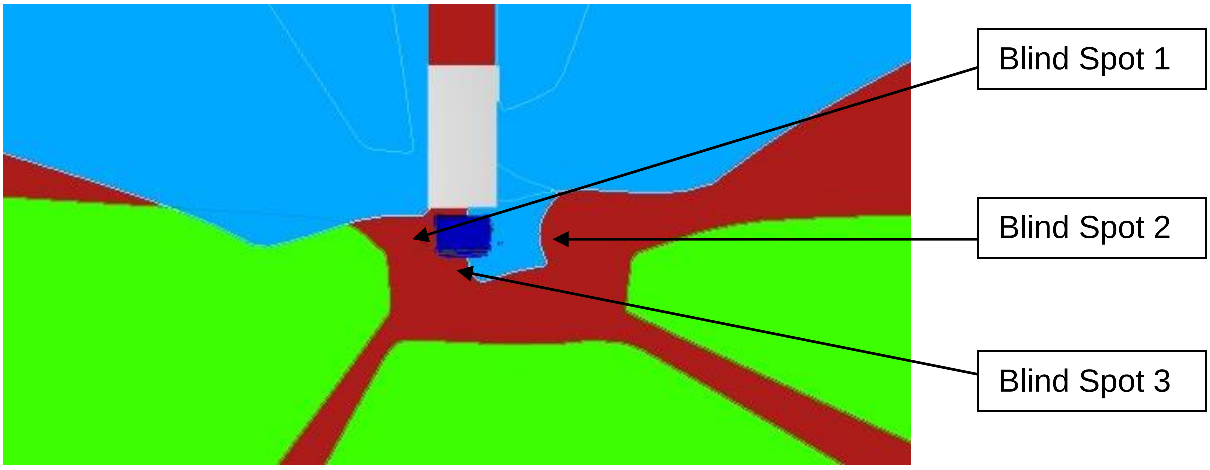

Figure 109. The three blind spot areas that have been identified using the projection of direct and indirect volumes for the DAF LF 45

2.5.6.4.3 The objects that can be obscured from driver vision by blind spot 1

Figure 110 and Figure 111 show the height of a person that can be obscured by the driver's door for the 4th%ile driver and 99th%ile driver respectively. The results show that children can be obscured from the driver's view.

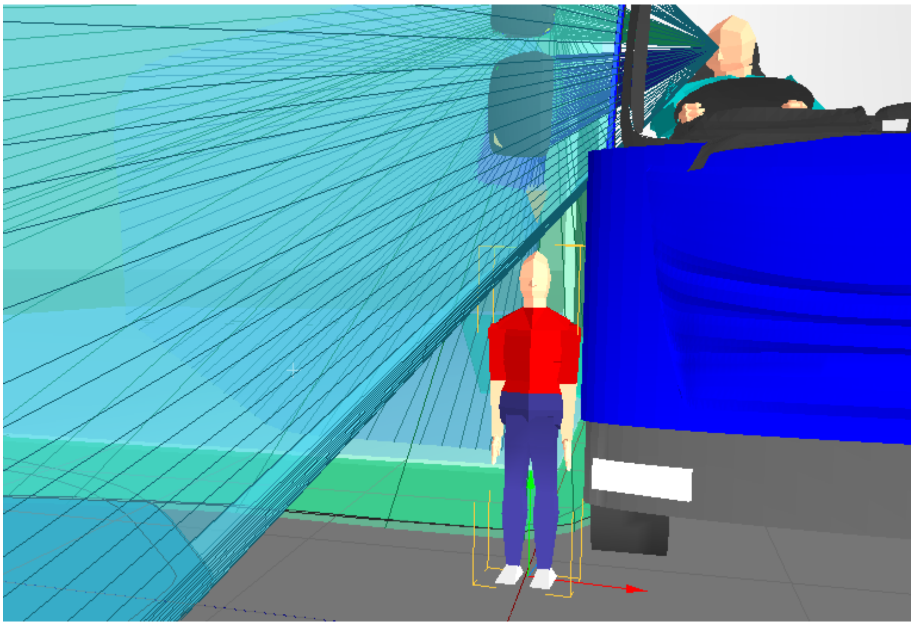

Figure 110. A 1220mm stature person (5th%ile 9yr old UK male) can be obscured from the 4th%ile stature driver

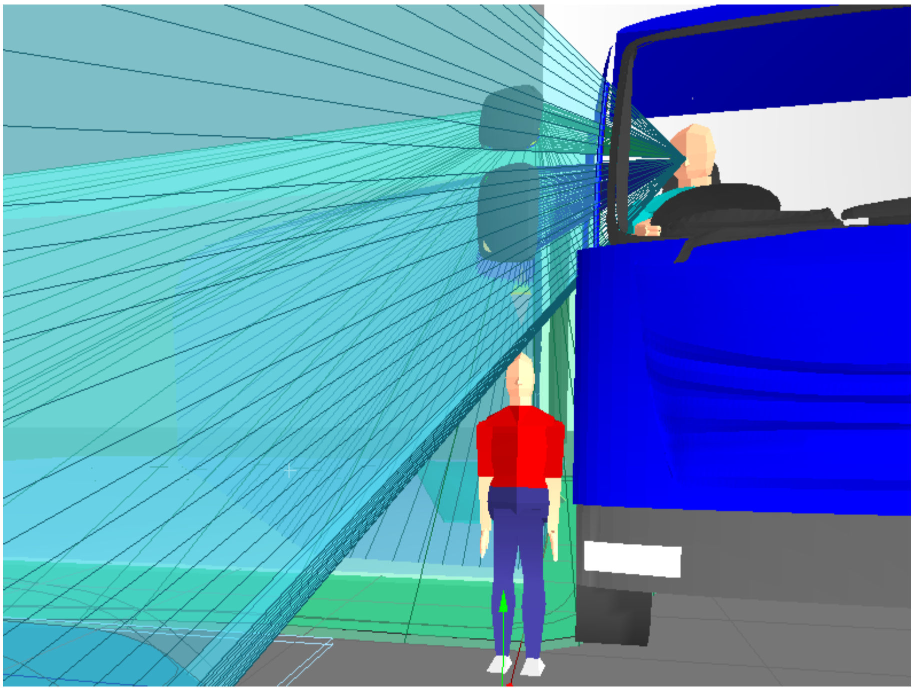

Figure 111. A 1280mm stature person (5th%ile 10yr old UK male) can be obscured from the 99th%ile stature driver

2.5.6.4.4 The objects that can be obscured from driver vision by blind spot 2

Figure 112 and Figure 113 show a cyclist that is positioned forwards of the volume of space that is visible through the Class IV mirror. In this position the cyclist is not visible to the driver through direct vision for the 4th%ile driver, and the head of the cyclist only is visible to the 99th%ile driver.

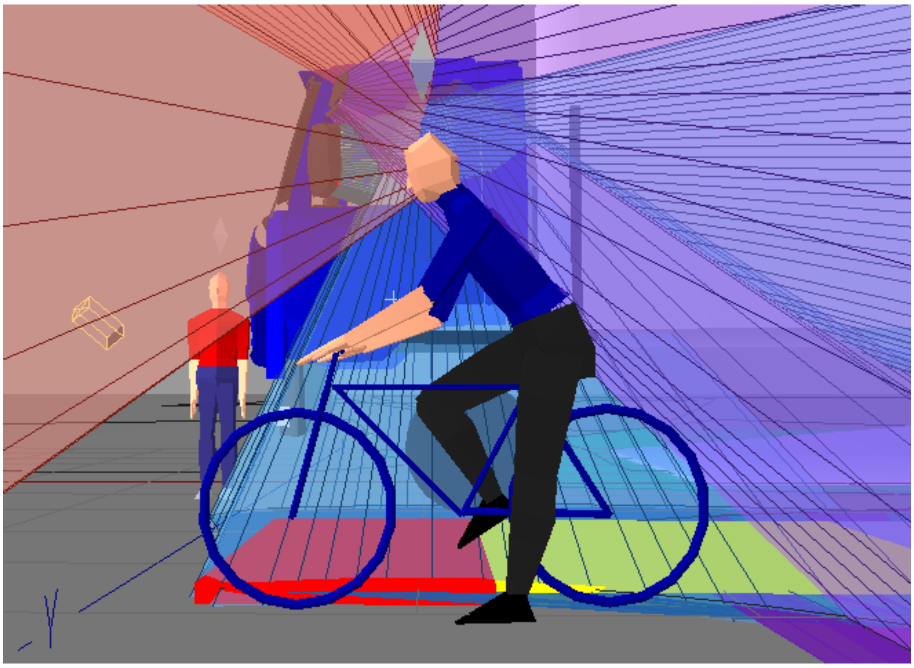

Figure 112. A cyclist located in blind spot zone 2 is not visible to the 4th%ile driver through direct vision or the use of mirrors

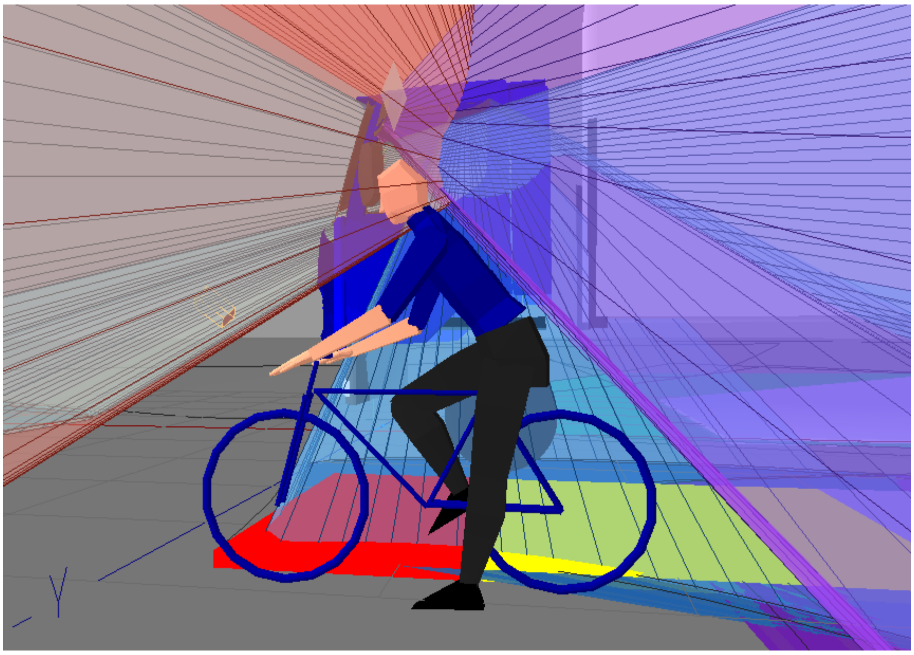

Figure 113. A cyclist located in blind spot zone 2 is only partially visible (the head only) to the 4th%ile driver through direct vision and the use of mirrors

2.5.6.4.5 The objects that can be obscured from driver vision by blind spot 3

Figure 114 shows the height of a person that can be obscured in front of the vehicle, below the windscreen, forthe 4th%ile driver and 99th%ile driver. The results show that children can be obscured from the driver's view.

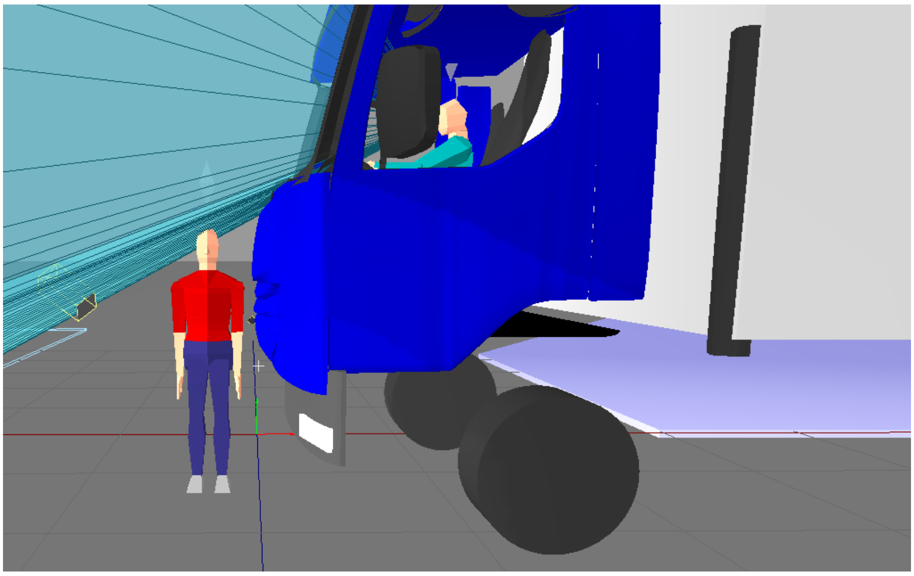

Figure 114. A 1450mm stature person (approx. 5th%ile 14yr old UK male (1480mm) can be obscured from the 4th%ile and 99th%ile stature drivers

2.5.6.5 OTS Scenarios

2.5.6.5.1 OTS scenario setup: Scenario 1. A category N_2 vehicle pulls out of a T-Junction to join the main carriage way and fails to notice a vehicle travelling down the main carriage way

This scenario is based upon a specific OTS case where a category N_2 vehicle pulled out of T-Junction and turned right without seeing a vehicle approaching from the left. A collision then occurred. Figure 115 shows the analysis environment modelled in the DHM system.

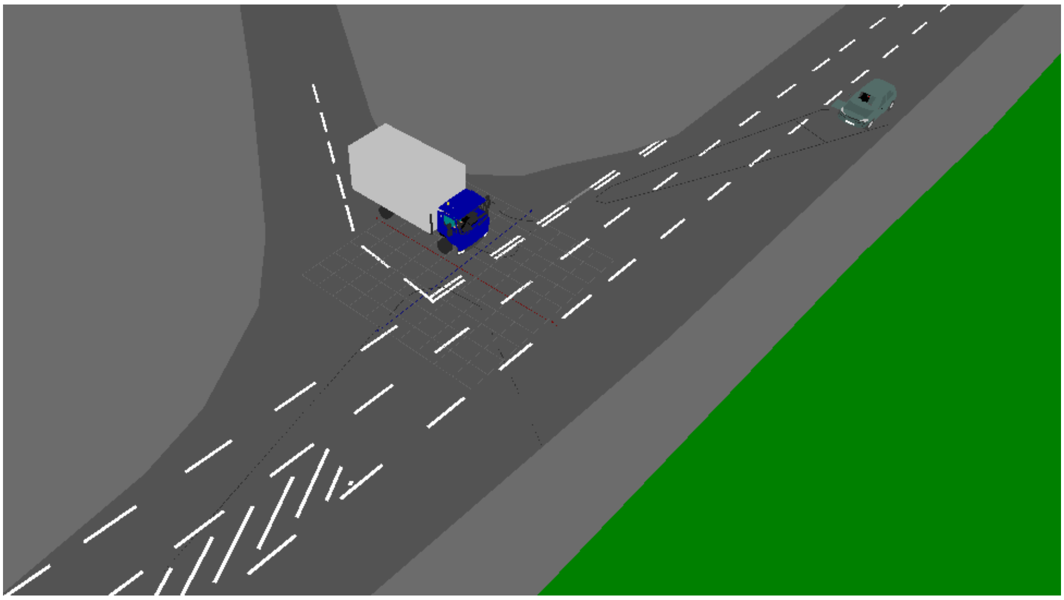

Figure 115. The road junction associated with accident scenario 3

The kerb to kerb turning circle data was gathered for each category N_2 vehicle that was tested in the scenario. This allowed the likely positioning of the vehicle at the mouth of the T-Junction to be considered during the scenario setup for each vehicle. The length of the skid marks shown in the OTS case report indicated that the approaching vehicle was travelling at speed. It has been assumed that the driver of the category N_2 vehicle 'looked but did not see' the vehicle approaching from the left.

2.5.6.5.2 Scenario setup

The scenario was modelled using the map data provided in the OTS case report (see Figure 116). The vehicle CAD model that represents the category M_1 vehicle has the same dimensions as the model of vehicle that was involved in the incident. The rationale for the scenario modelling is as follows. The angle of the T-Junction to the main carriageway has the potential to cause difficulty for the category N_2 driver in terms of positioning for optimum visibility to the left of the cab in order to observe oncoming traffic. Ideally the N_2 vehicle should be perpendicular to the main carriageway to allow visibility to the left and right of the cab. There is potential for the trailer to partially block the lane entering the T-Junction when the N_2 vehicle is positioned perpendicularly to the main carriageway. Therefore, depending upon the length of the vehicle, there is potential for the driver to position the N_2 vehicle at an angle to the main carriageway reducing visibility to the left hand side.

Figure 116. The road layout recreated from the OTS case report

The kerb to kerb turning circle data was gathered for each category N_2 vehicle that is tested in the scenario. The manufacturer's data reports that the Renault Midlum 190 has a kerb to kerb radius of 6.77m, the DAF LF 45 has a radius of 5.52m, and the Iveco Eurocargo has a radius of 6.41m. It was found that the turning circle of the category N_2 vehicles would not hinder the ability to make the turn to the right, allowing all vehicles to placed perpendicularly to the main carriage way. An example of this can be seen in Figure 117.

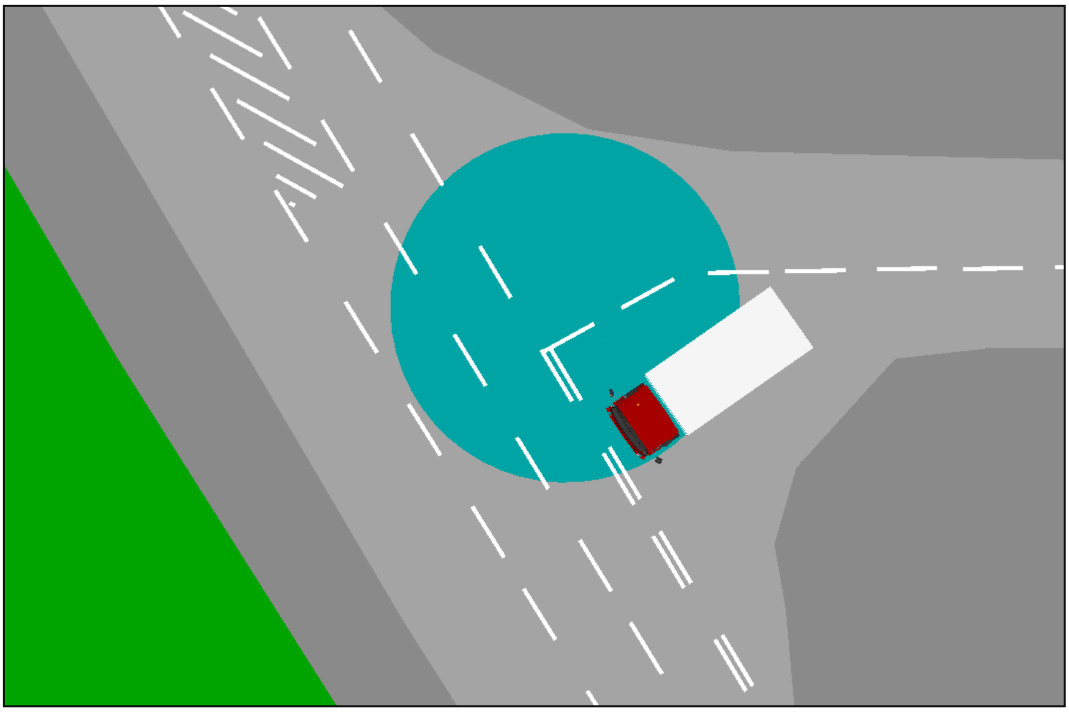

Figure 117. Plan view: The selected location for the Renault Midlum 190 with a orientation that is perpendicular to the main carriageway. The blue circle shows the kerb to kerb turning radius of the Renault Midlum

2.5.6.5.3 Visibility of the oncoming vehicle from the Renault Midlum 190 cab for a 4th%ile UK Male Driver

With the approaching car placed in the centre of the left hand lane, obscuration occurs as the car approaches the LGV due to the passenger side Class II mirror surround. This occurs at a distance of between 40m and 31m from the N_2 driver's eyes. Figure 118 shows a view of the obscuration of the approaching vehicle where the volume enclosed by the red projection cannot be seen by the driver. Figure 119 shows the driver's eye view with the car being obscured by the Class II mirror surround.

If the approaching vehicle is obscured from the category N_2 vehicle driver for a travel distance of 9m, then the car will be obscured for 0.7seconds if travelling at 30mph. It is therefore possible for the driver of the N_2 vehicle to glance left, and not see the approaching car and then pull out. The accident could therefore have been caused by obscuration of the approaching car by the Class II mirror surround.

Figure 120 shows that the car could also have been partially obscured by the A-pillar of the vehicle.

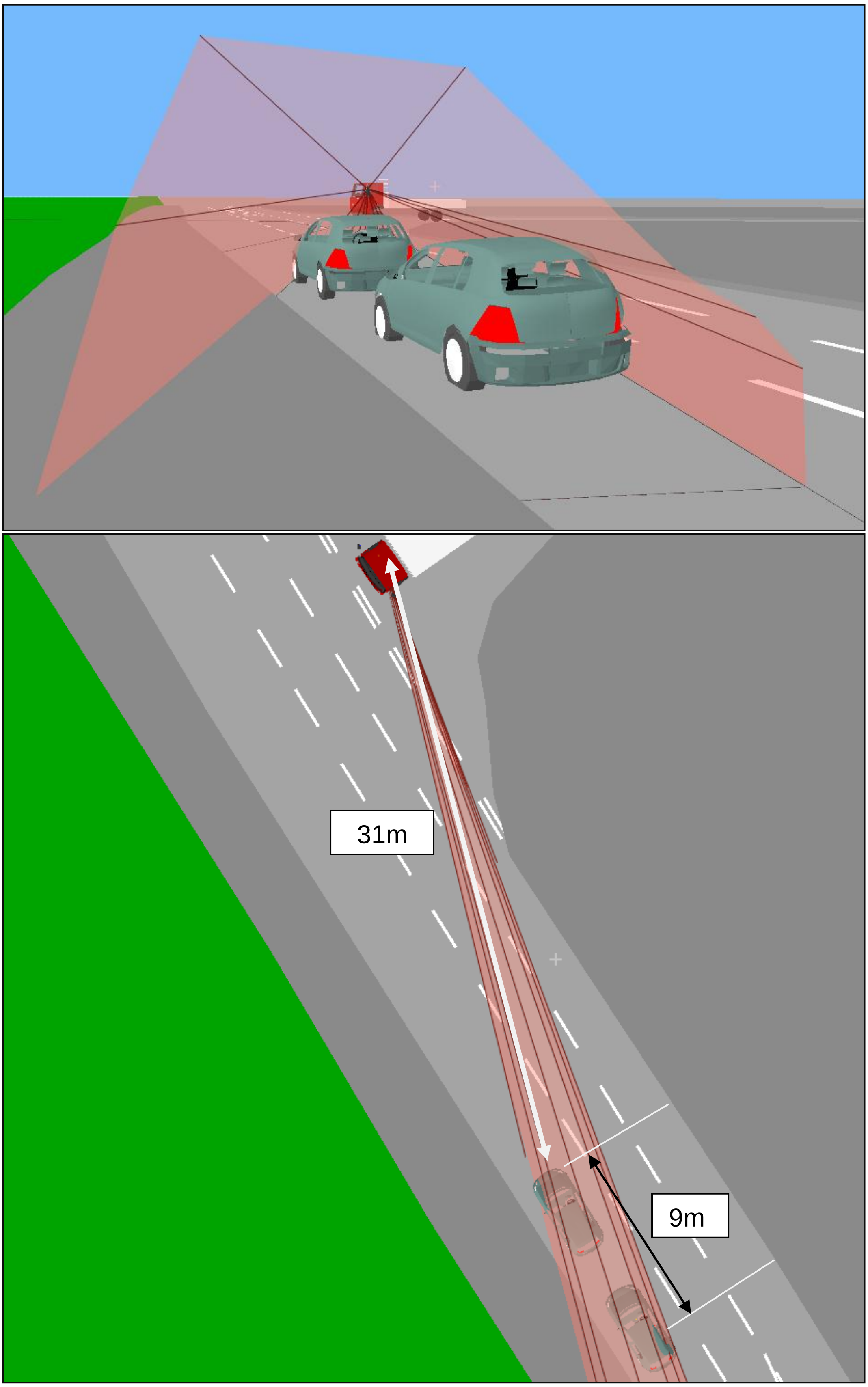

Figure 118. At a distance of 31m from the driver's ocular point the two cars, with a distance of 9m between the front bumper of one, and the rear bumper of the other, can be obscured by the passenger side Class II mirror surround

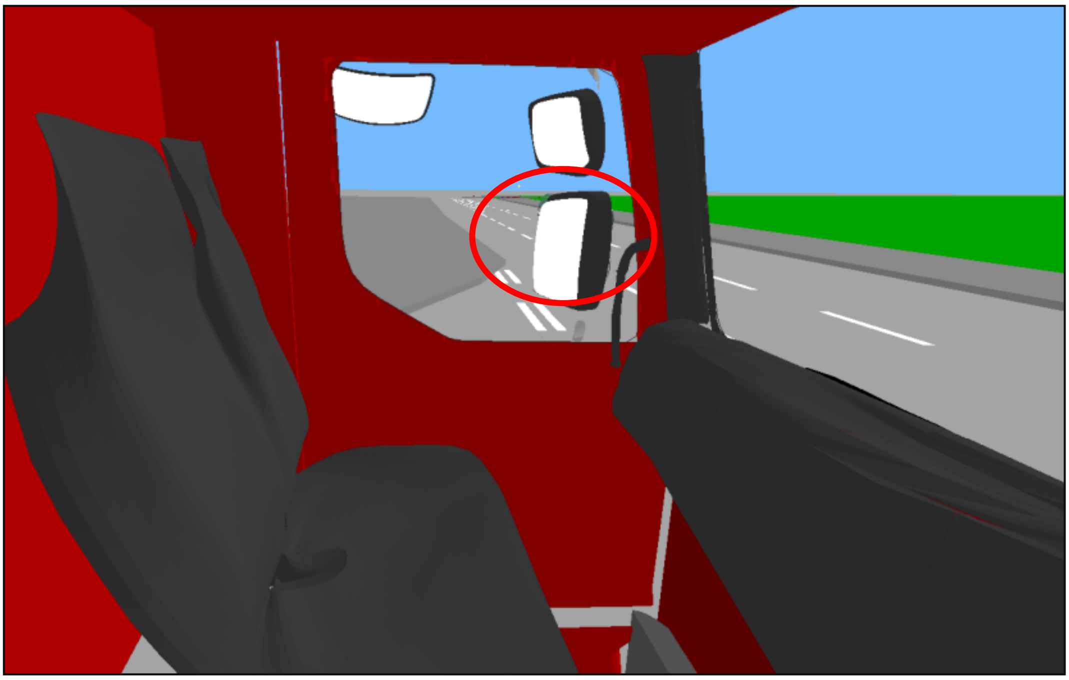

Figure 119. The driver's eye view: The approaching vehicle being obscured from the category N_2 Driver's vision due to the Class II mirror surround

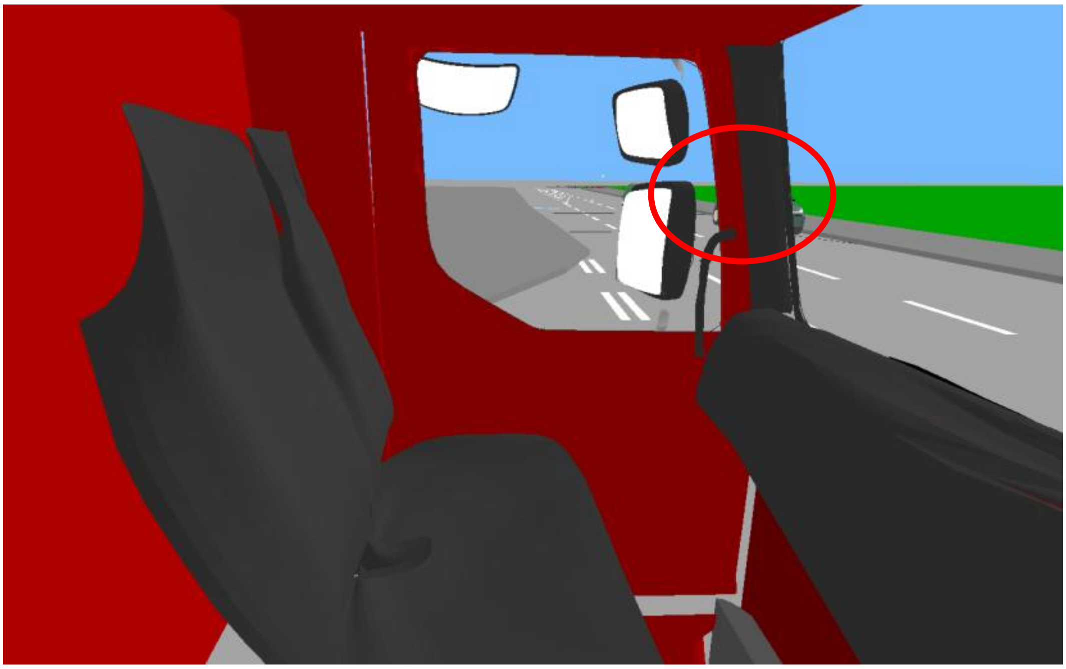

Figure 120. The driver's eye view: The approaching vehicle being obscured from the category N_2 Driver's vision due to the A-pillar

2.5.6.5.4 Visibility of the oncoming vehicle from the Renault Midlum 190 cab for a 99th%ile UK Male Driver

Figure 121, Figure 122 and Figure 123 show that for a driver with 99th%ile stature the oncoming car is only partially obscured by the mirror housings and the A-pillar.

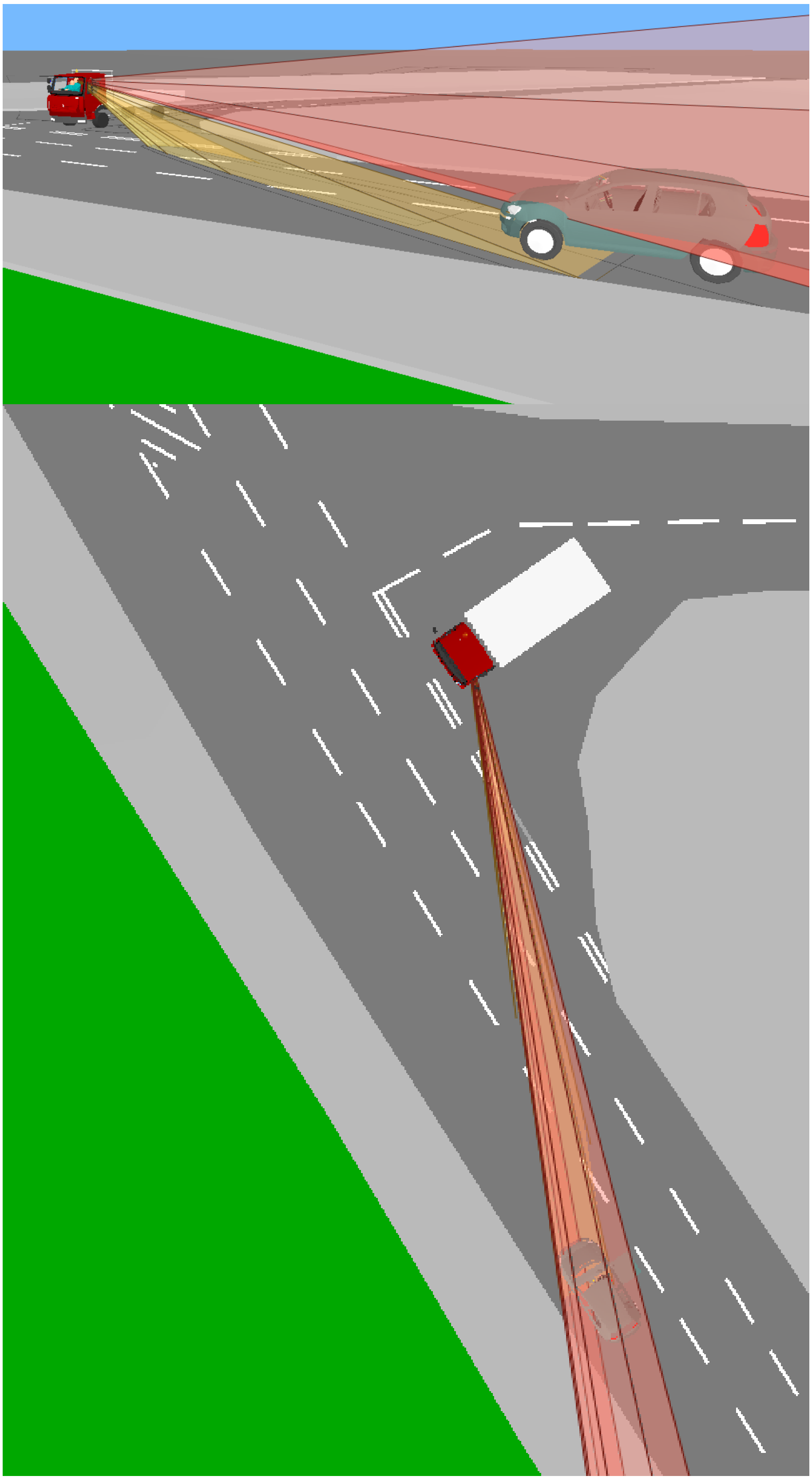

Figure 121. At a distance of 25.5m from the driver's ocular point the car can be partially obscured by the passenger side Class II and Class IV mirror surrounds

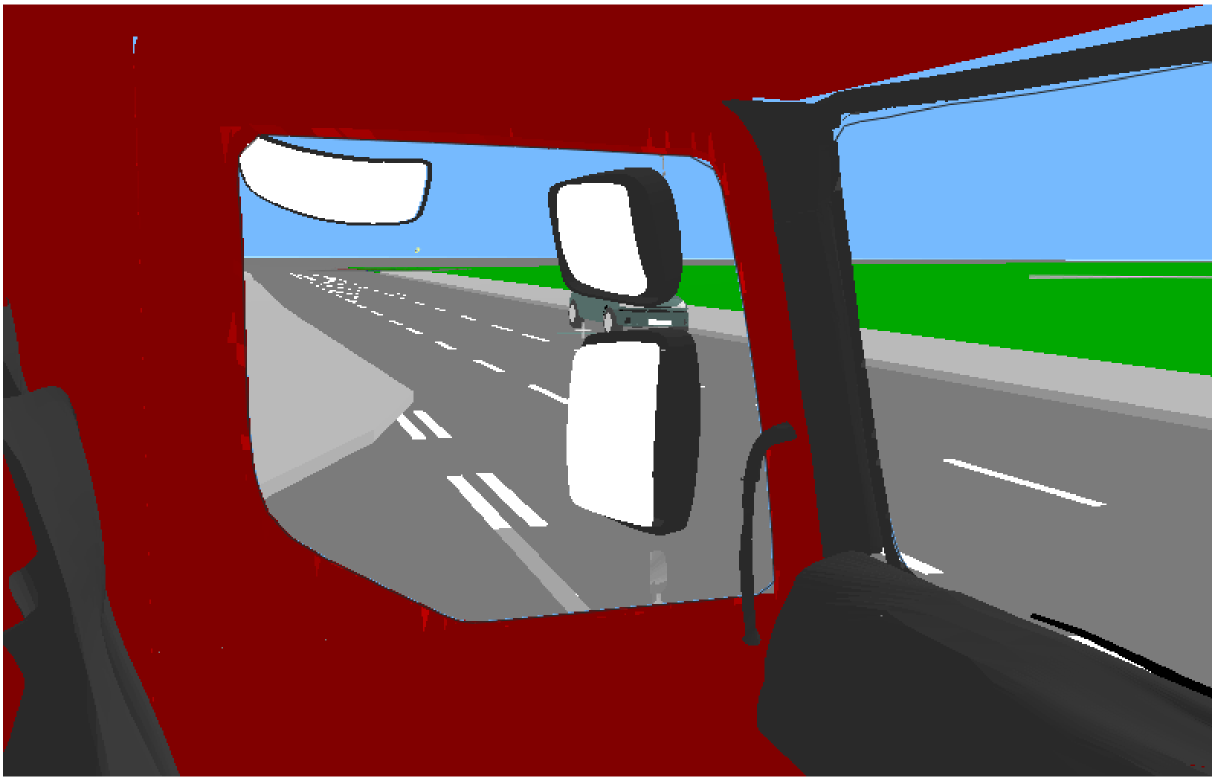

Figure 122. The driver's eye view: The approaching vehicle being partially obscured from the category N_2 Driver's vision due to the Class II and Class IV mirror surrounds

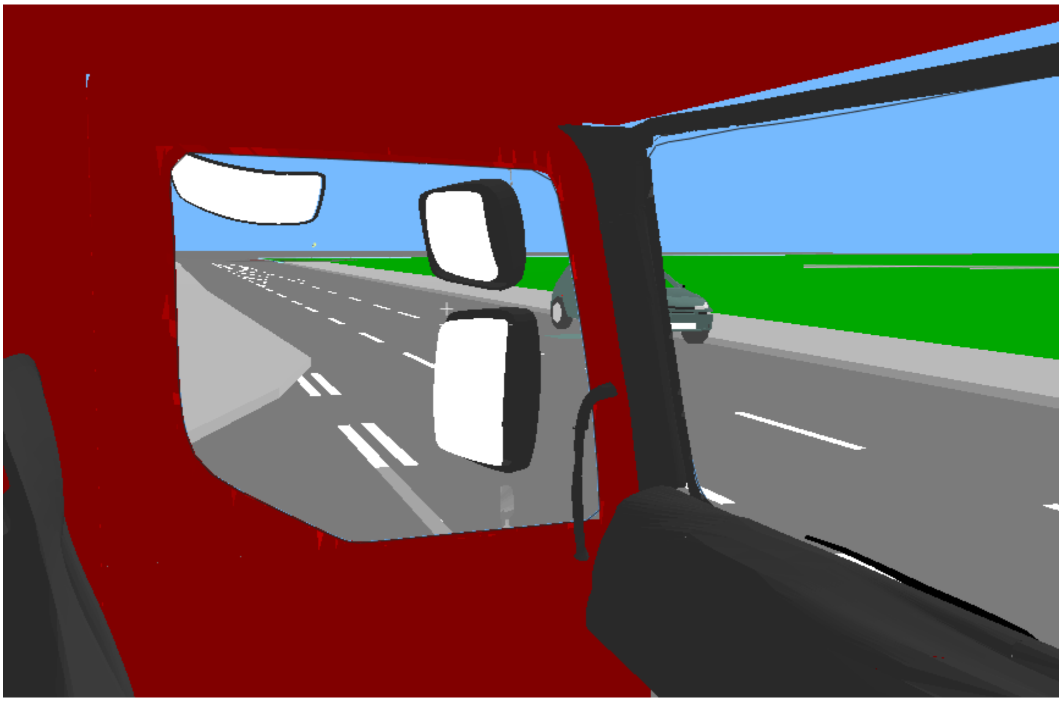

Figure 123. The driver's eye view: The approaching vehicle being partially obscured from the category N_2 Driver's vision due to the A-pillar

2.5.6.5.5 Summary for the Renault Midlum 190

It is possible that the driver of the category N_2 vehicle looked, but did not see the approaching vehicle due to obscuration by the mirror mounting structure and surround, the A-pillar, or a combination of both of these structures even if the vehicle had been positioned perpendicularly to the main carriageway. It is also possible that the approaching vehicle could have obscured by the interior walls of the category N_2 cab, if the vehicle had not been well positioned by the driver.

2.5.6.5.6 Visibility of the oncoming vehicle from the DAFLF 45 cab for a 4^{th}%ile UK Male Driver

Figure 124, Figure 125 and Figure 126 show that for a driver with 4^{th}%ile stature the oncoming car is partially obscured by the mirror housings and the A-pillar.

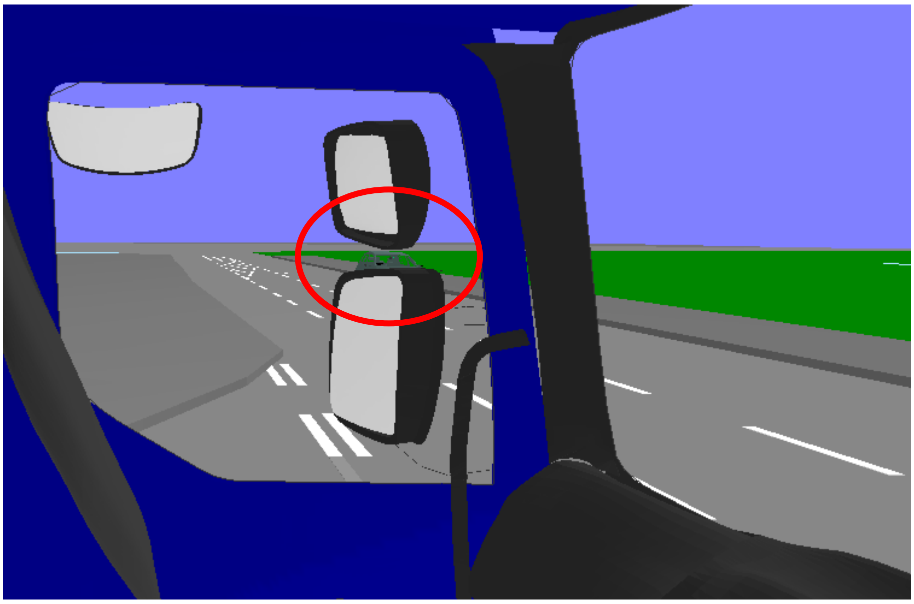

Figure 124. The driver's eye view: The approaching vehicle being partially obscured from the category N_2 Driver's vision due to the Class II and Class IV mirror surrounds

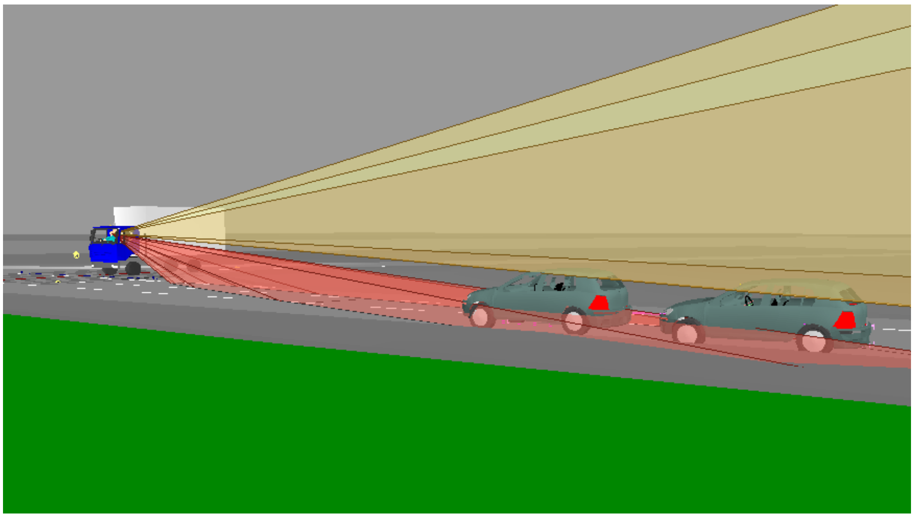

Figure 125. At a distance of 29.3m from the driver's ocular point the two cars, with a distance of 9.3m between the front bumper of one, and the rear bumper of the other, can be partially obscured by the passenger side Class II mirror surround

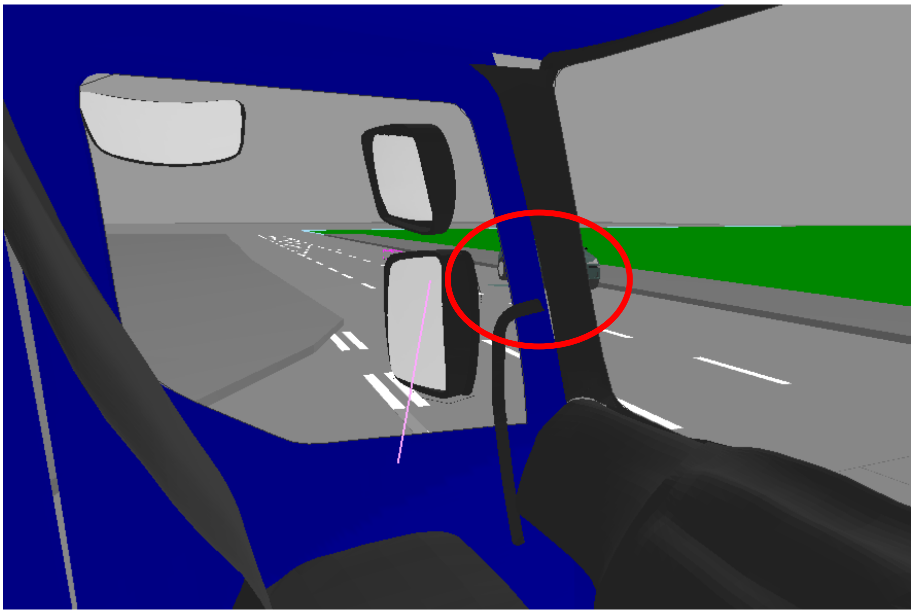

Figure 126. The driver's eye view: The approaching vehicle being partially obscured from the category N_2 Driver's vision due to the A-pillar

2.5.6.5.7 Visibility of the oncoming vehicle from the DAFLF 45 cab for a 99th%ile UK Male Driver

Figure 127, Figure 128 and Figure 129 show that for a driver with 99th%ile stature the oncoming car is partially obscured by the mirror housings and the A-pillar.

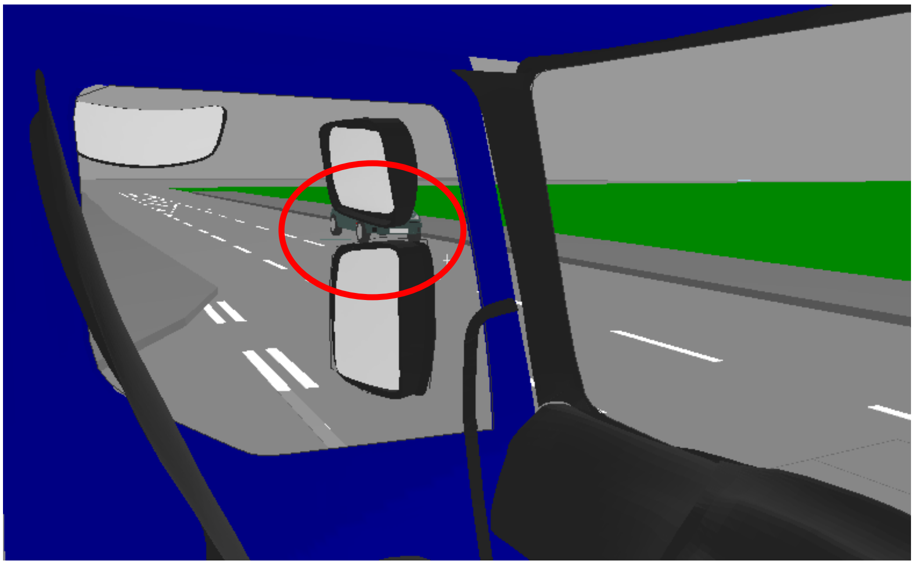

Figure 127. The driver's eye view: The approaching vehicle being partially obscured from the category N_2 Driver's vision due to the Class II and Class IV mirror surrounds

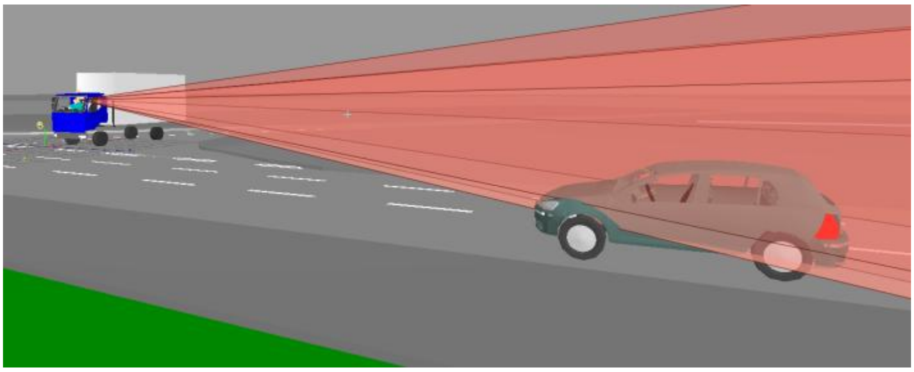

Figure 128. At a distance of 29.3m from the driver's ocular point the two cars, with a distance of 9.3m between the front bumper of one, and the rear bumper of the other, can be partially obscured by the passenger side Class II mirror surround

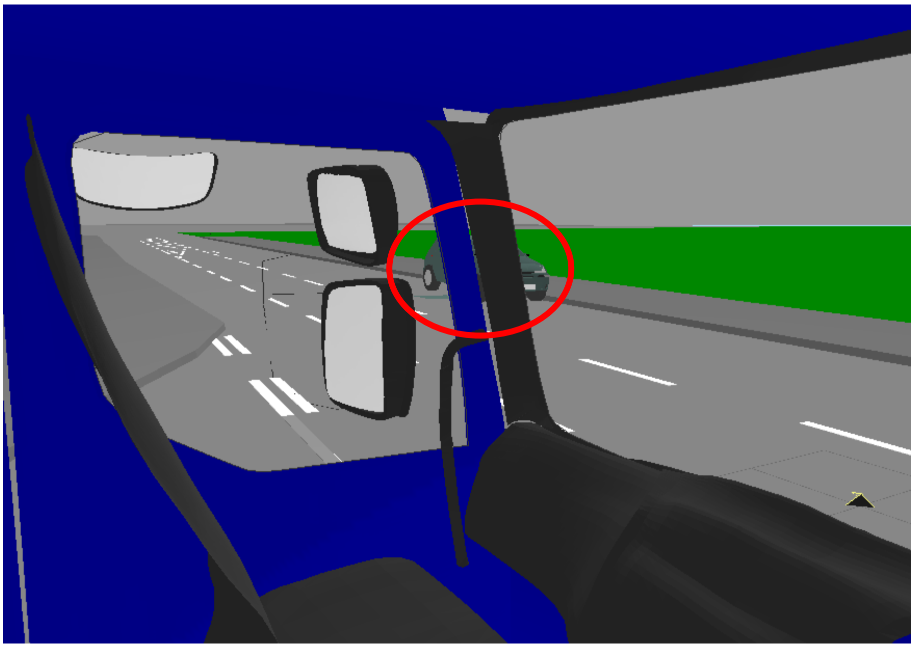

Figure 129. The driver's eye view: The approaching vehicle being partially obscured from the category N_2 Driver's vision due to the A-pillar

2.5.6.5.8 Summary for the DAF LF 45

It is possible that the driver of the category N_2 vehicle looked, but did not see the approaching vehicle due to obscuration by the mirror mounting structure and surround, the A-pillar, or a combination of both of these structures even if the vehicle had been positioned perpendicularly to the main carriageway. However the approaching vehicle is never completely obscured for the DAF LF.

2.5.6.5.9 Visibility of the oncoming vehicle from the Iveco Eurocargo cab for a 4^{th}%ile UK Male Driver

Figure 130 and Figure 131 show that for a driver with 4^{th}%ile stature the oncoming car is partially obscured by the mirror housings and the A-pillar.

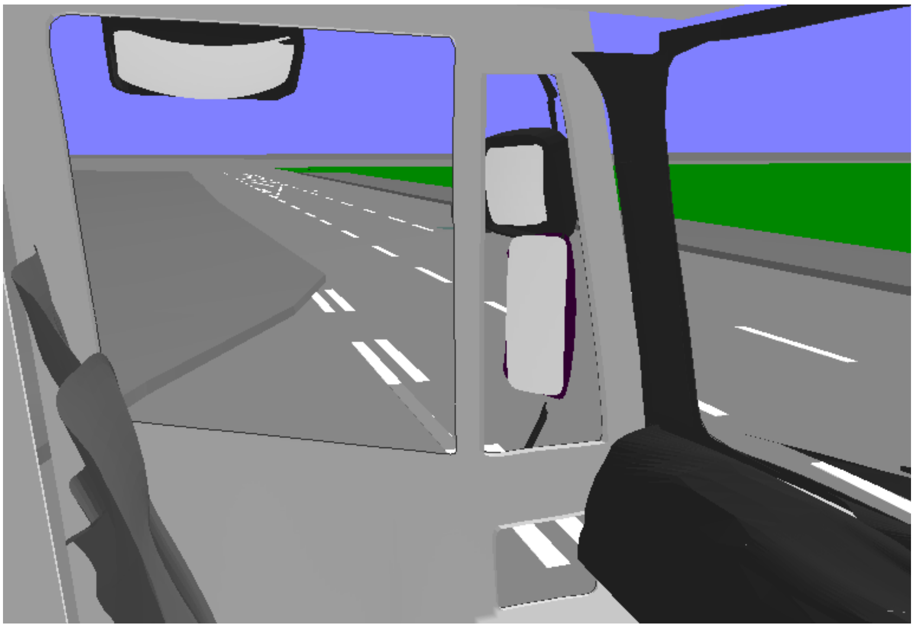

Figure 130. The driver's eye view: The approaching vehicle being partially obscured from the category N_2 Driver's vision due to the Class II and Class IV mirror surrounds

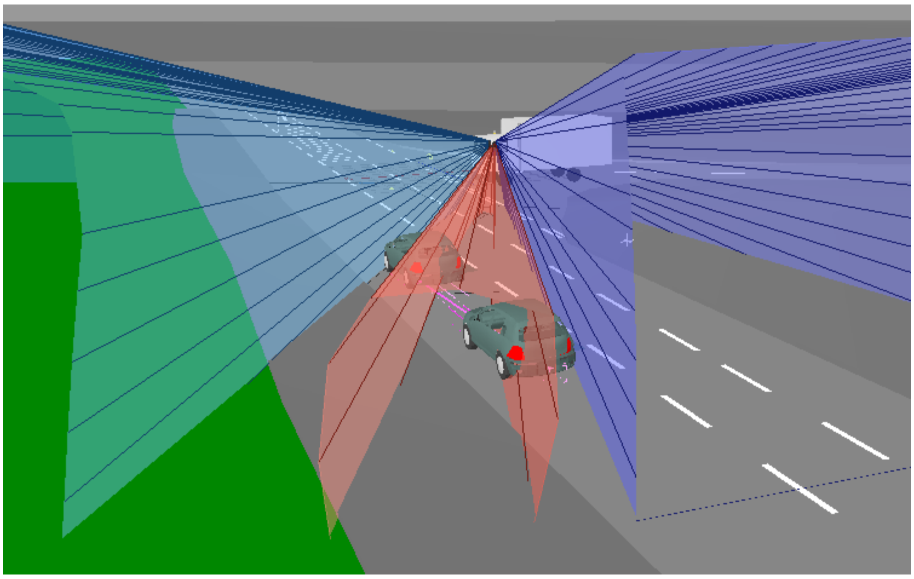

Figure 131. At a distance of 25m from the driver's ocular point two cars, with a distance of 9.4m between the front bumper of one, and the rear bumper of the other, can be obscured by the combination of the passenger side Class II mirror housing, the window frame and the A-pillar

2.5.6.5.10 Visibility of the oncoming vehicle from the Iveco Eurocargo cab for a 99th%ile UK Male Driver

Figure 132, Figure 133 and Figure 134 show that for a driver with 99th%ile stature the oncoming car is partially obscured by the mirror housings and the A-pillar.

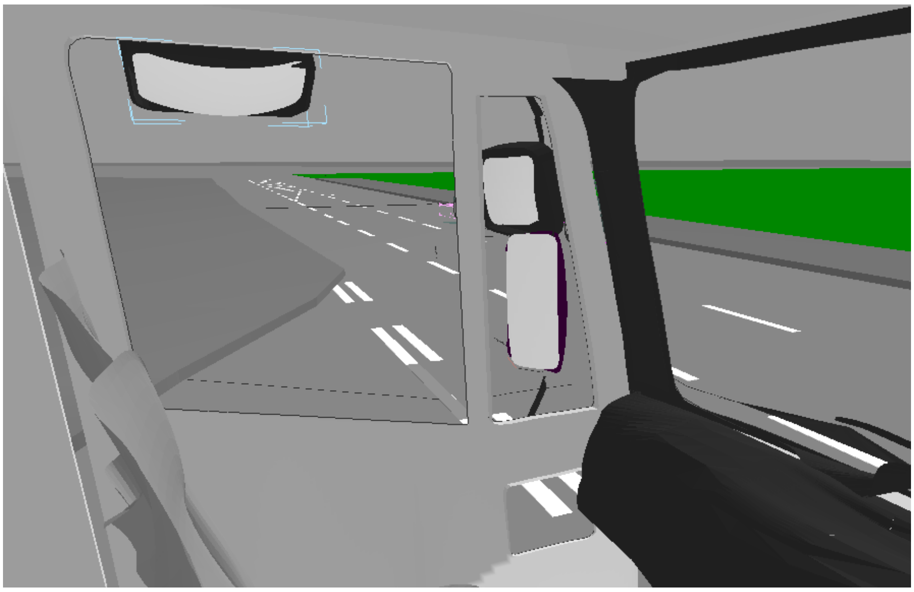

Figure 132. The driver's eye view: The approaching vehicle being partially obscured from the category N_2 Driver's vision due to the Class II and Class IV mirror surrounds

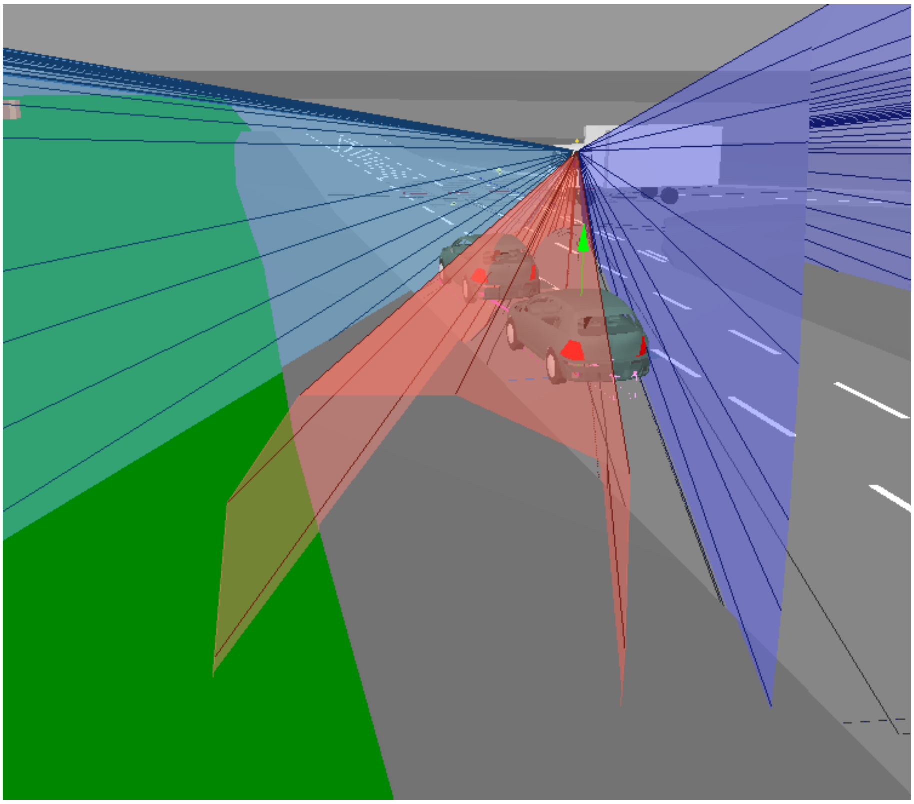

Figure 133. At a distance of 10.4m from the driver's ocular point two cars, with a distance of 9.4m between the front bumper of one, and the rear bumper of the other, can be obscured by the combination of the passenger side Class II mirror housing, the window frame and the A-pillar

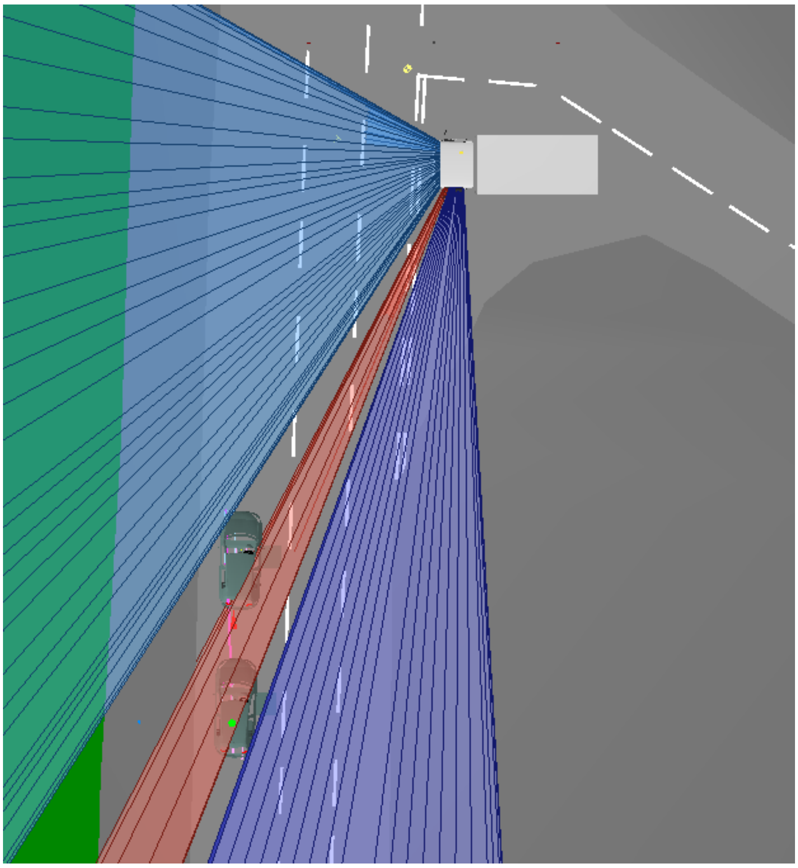

Figure 134. The obscured area bounded by the two blue window projections

2.5.6.5.11 Summary for the Iveco Eurocargo

It is possible that the driver of the category N_2 vehicle looked, but did not see the approaching vehicle due to obscuration by the mirror mounting structure and surround, the window frame and the A-pillar even if the vehicle had been positioned perpendicularly to the main carriageway.

2.5.6.5.12 OTS scenario setup: Scenario 2. A category N_2 vehicle merging left or right

The aim of this evaluation is to evaluate the visibility of the driver in order to determine if it is clear to perform a merging / changing lane manoeuvre to the left or right. In most circumstances the Class IV mirror will provide a clear view of any vehicle that may be in the target lane. However, it is possible that a vehicle may be positioned to the front of the field of view of the Class IV and the Class V mirrors if fitted. In this case the driver must be able to see the vehicle through direct vision or else not be able to detect the vehicle and potentially perform the manoeuvre and cause an accident.

2.5.6.5.13 Renault Midlum, merging left: visibility of the vehicle from the cab for a 4th%ile UK Male Driver

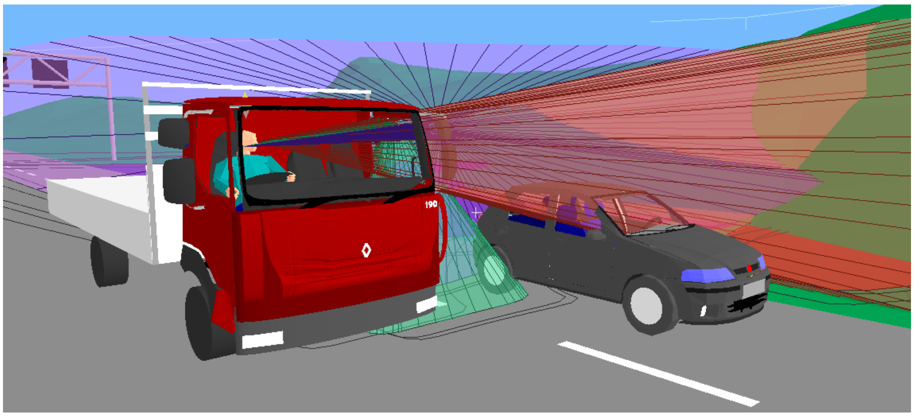

Figure 135. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is within the direct vision volume of a 4th%ile stature LGV driver

Figure 136. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 4th%ile stature LGV driver

Figure 135 and Figure 136 show that when a car is positioned to the left of the Renault Midlum in a position that is forwards of the volume of space that is visible through the Class IV mirror the car should be clearly visible with direct vision through the passenger's side window.

2.5.6.5.15 Renault Midlum, merging left: visibility of the vehicle from the cab for a 99th%ile UK Male Driver

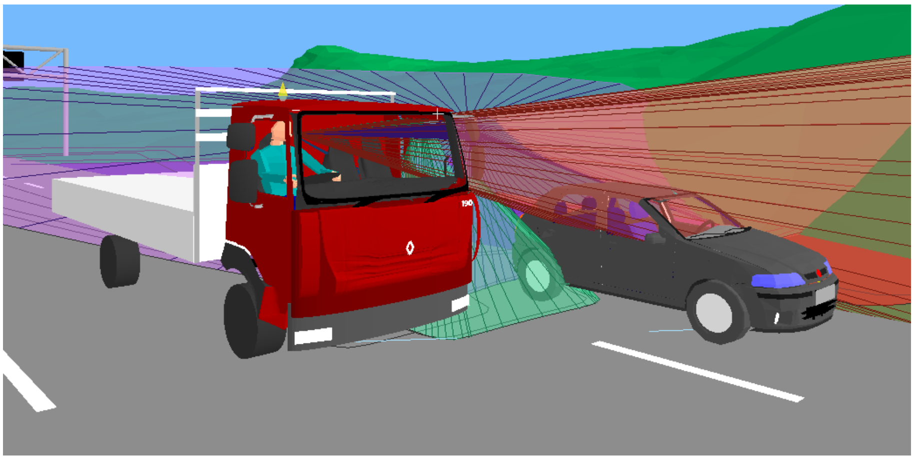

Figure 137. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is within the direct vision volume of a 4th%ile stature LGV driver

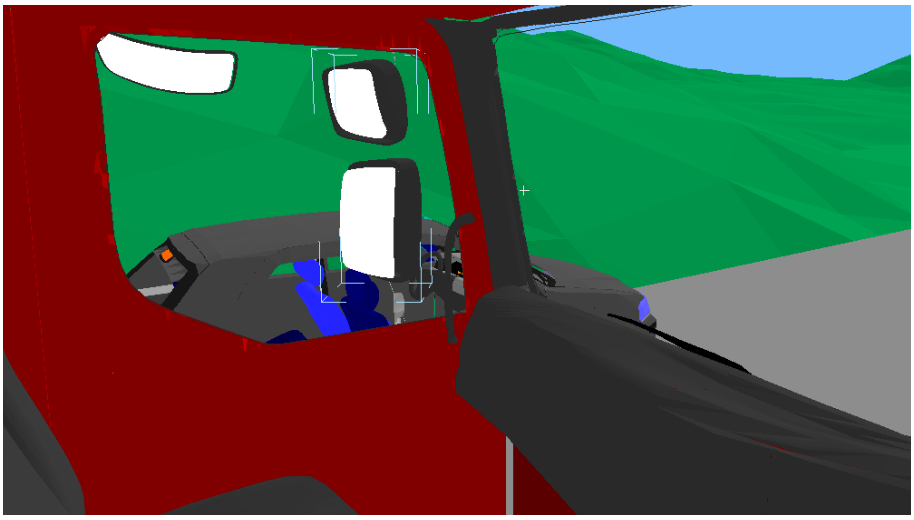

Figure 138. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 99th%ile stature LGV driver

As with the shorter driver, the Figure 137 and Figure 138 show that when a car is positioned to the left of the Renault Midlum in a position that is forwards of the volume of space that is visible through the Class IV mirror the car should be clearly visible with direct vision through the passenger's side window.

2.5.6.5.17 Renault Midlum, merging right: visibility of the vehicle from the cab for a 4th%ile UK Male Driver

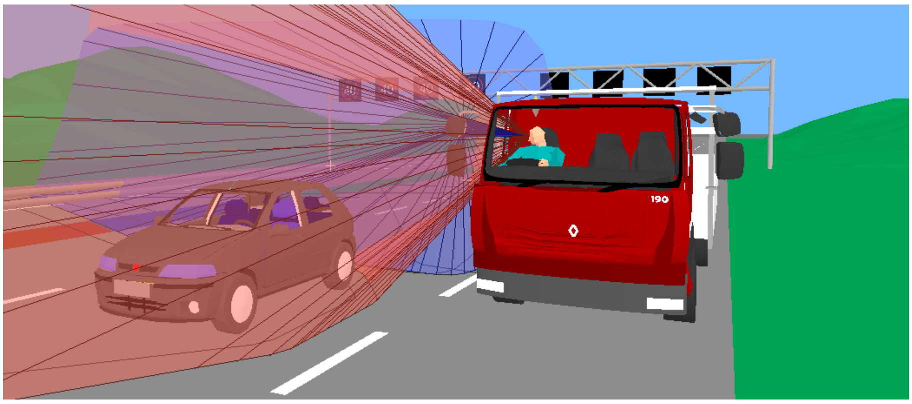

Figure 139. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is within the direct vision volume of a 4th%ile stature LGV driver

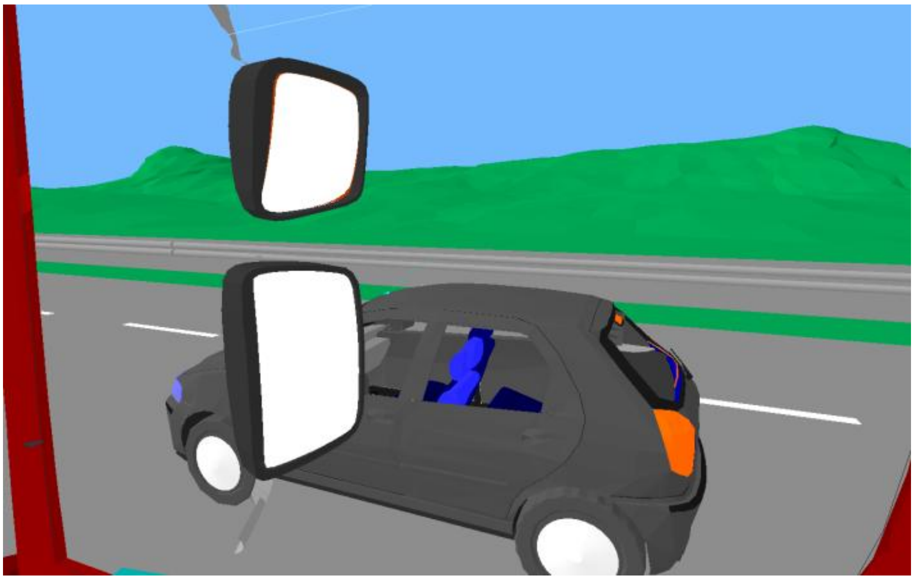

Figure 140. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 4th%ile stature LGV driver

Figure 139 and Figure 140 show that when a car is positioned to the right of the Renault Midlum in a position that is forwards of the volume of space that is visible through the Class IV mirror the car should be clearly visible with direct vision through the driver's side window. Due to the driver's proximity to the offside front window the complete vehicle is visible to the driver. It is interesting to note the obscuration from the Class II and IV.

2.5.6.5.18 Renault Midlum, merging right: visibility of the vehicle from the cab for a 99th%ile UK Male Driver

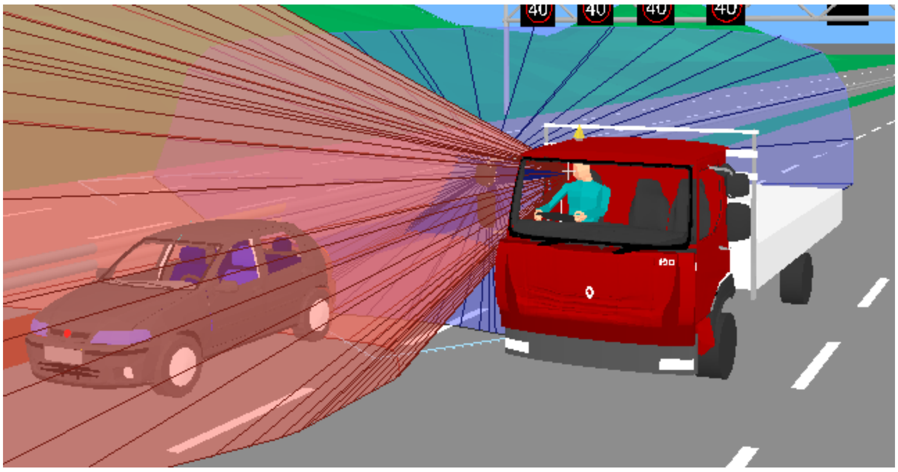

Figure 141. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror is within the direct vision volume of a 99th%ile stature LGV driver

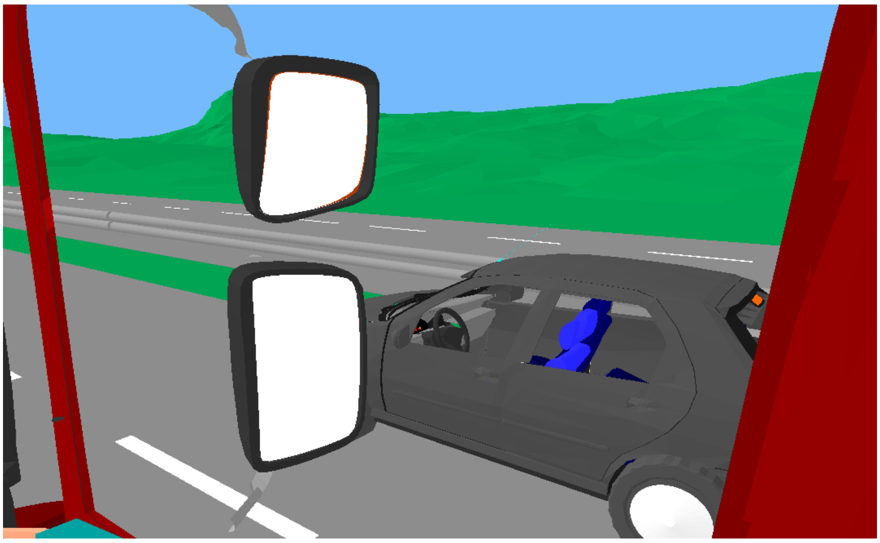

Figure 142. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 99th%ile stature LGV driver

As with the shorter driver, Figure 141 and Figure 142 show that when a car is positioned to the right of the Renault Midlum in a position that is forwards of the volume of space that is visible through the Class IV mirror the car should be clearly visible with direct vision through the driver's side window.

2.5.6.5.20 DAF LF 45, merging left: visibility of the vehicle from the cab for a 4th%ile UK Male Driver

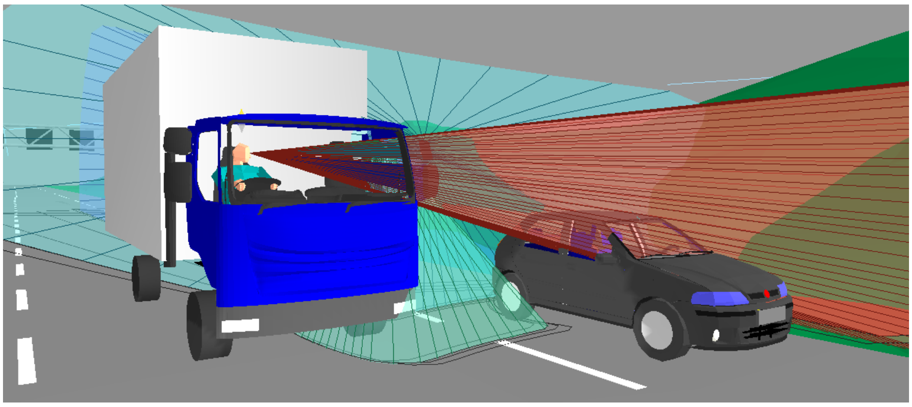

Figure 143. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is within the direct vision volume of a 4th%ile stature LGV driver

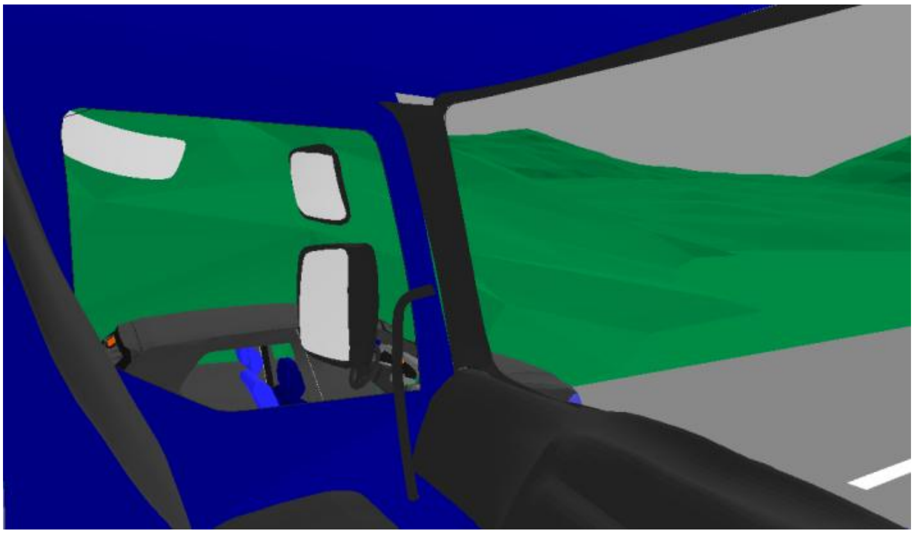

Figure 144. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 4th%ile stature LGV driver

As observed with the Renault, Figure 143 and Figure 144 show that when a car is positioned to the left of the DAF LF 45 in a position that is forwards of the volume of space that is visible through the Class IV mirror the car should be clearly visible with direct vision through the passenger's side window.

2.5.6.5.22 DAF LF 45, merging left: visibility of the vehicle from the cab for a 99th%ile UK Male Driver

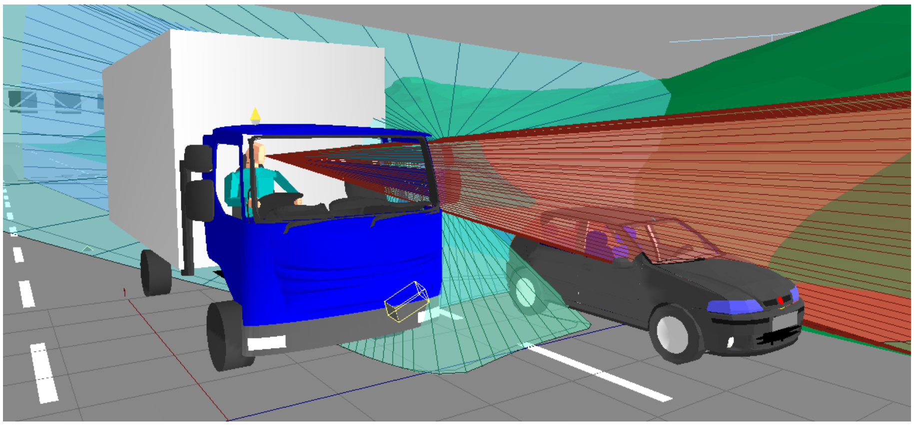

Figure 145. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is within the direct vision volume of a 99th%ile stature LGV driver

Figure 146. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 99th%ile stature LGV driver

As with the shorter driver, Figure 145 and Figure 146 show that when a car is positioned to the left of the DAF LF 45 in a position that is forwards of the volume of space that is visible through the Class IV mirror the car should be clearly visible with direct vision through the passenger's side window.

2.5.6.5.24 DAF LF 45, merging right: visibility of the vehicle from the cab for a 4th%ile UK Male Driver

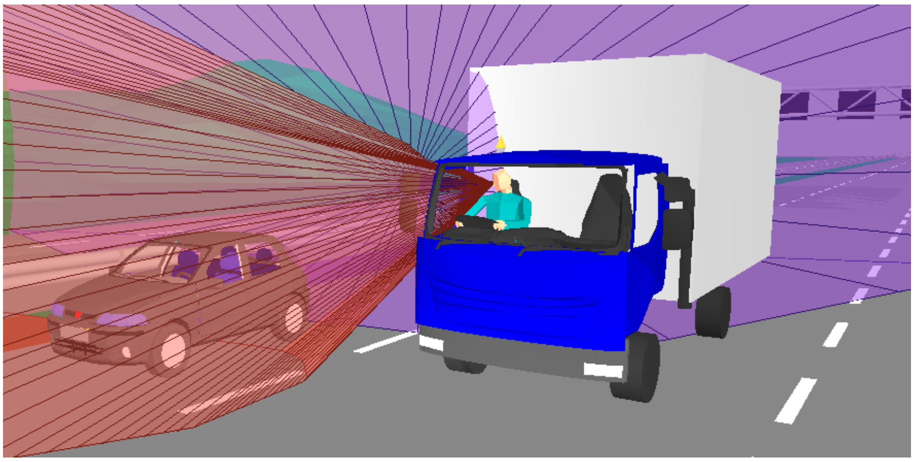

Figure 147. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror is within the direct vision volume of a 4th%ile stature LGV driver

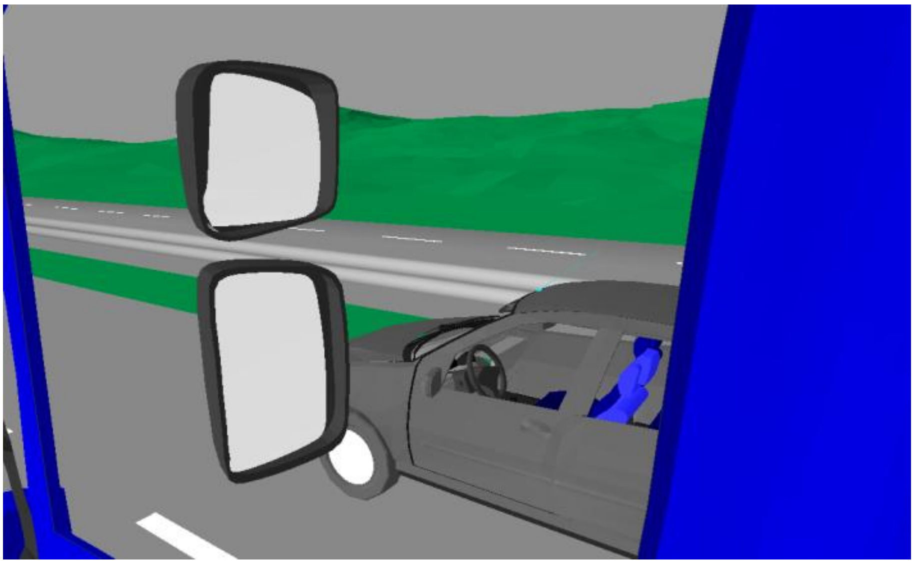

Figure 148. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 4th%ile stature LGV driver

Again, as observed with the Renault Figure 147 and Figure 148 show that when a car is positioned to the right of the DAF LF 45 in a position that is forwards of the volume of space that is visible through the Class IV mirror the car should be clearly visible with direct vision through the driver's side window.

2.5.6.5.26 DAF LF 45, merging right: visibility of the vehicle from the cab for a 99th%ile UK Male Driver

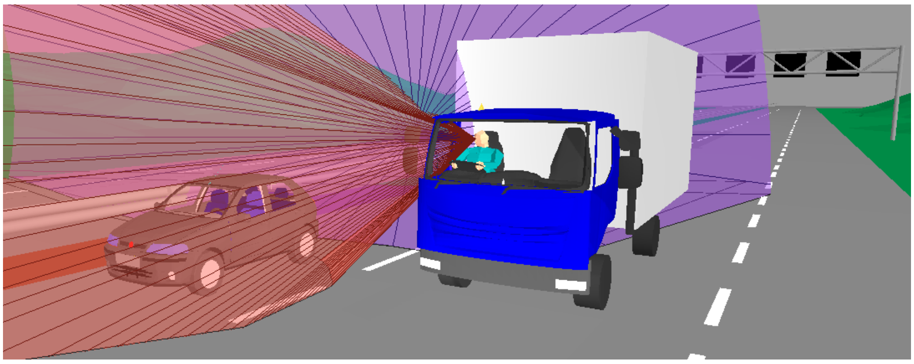

Figure 149. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror is within the direct vision volume of a 99th%ile stature LGV driver

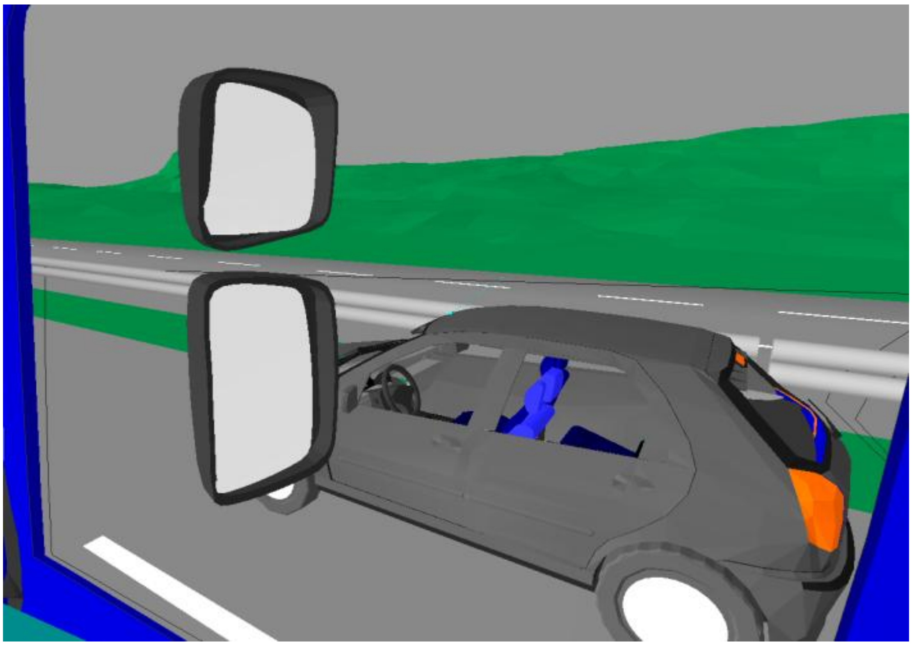

Figure 150. A car to the right of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 99th%ile stature LGV driver

As with the smaller driver Figure 149 and Figure 150 show that when a car is positioned to the right of the DAF LF 45 in a position that is forwards of the volume of space that is visible through the Class IV mirror the car should be clearly visible with direct vision through the driver's side window.

2.5.6.5.28 Iveco Eurocargo, merging left: visibility of the vehicle from the cab for a 4th%ile UK Male Driver

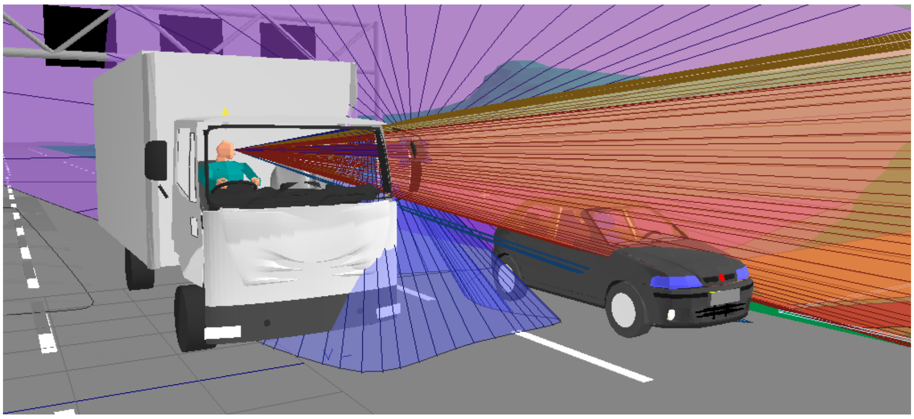

Figure 151. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is within the direct vision volume of a 4th%ile stature LGV driver

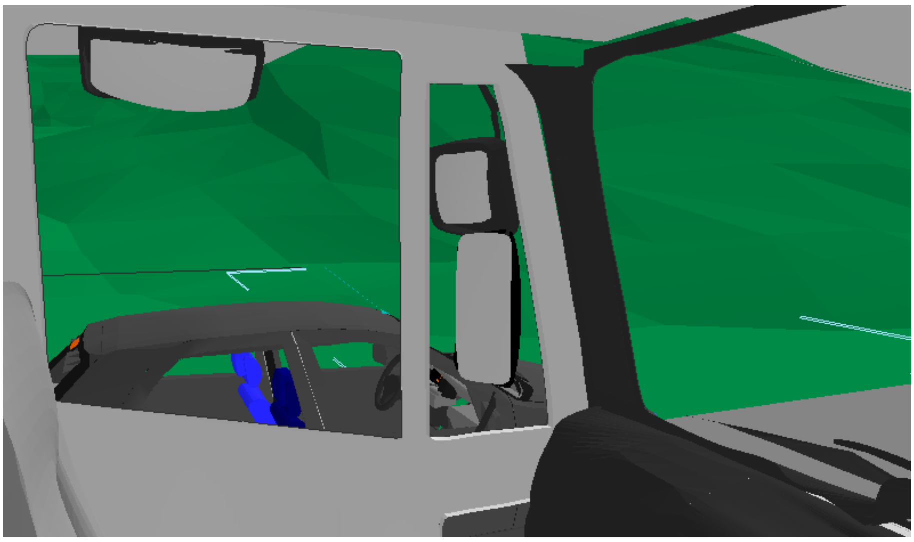

Figure 152. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 4th%ile stature LGV driver

As with the other N_2 vehicles, Figure 151 and Figure 152 show that when a car is positioned to the left of the Iveco Eurocargo in a position that is forwards of the volume of space that is visible through the Class IV mirror the car should be clearly visible with direct vision through the passenger's side window.

2.5.6.5.30 Iveco Eurocargo, merging left: visibility of the vehicle from the cab for a 99th%ile UK Male Driver

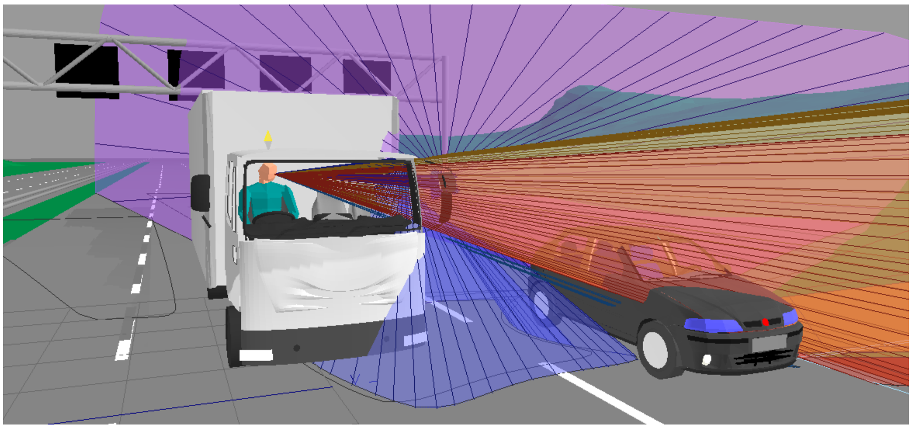

Figure 153. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is within the direct vision volume of a 99th%ile stature LGV driver

Figure 154. A car to the left of the driver's cab, and forward of the volume of space covered by the Class IV mirror is directly visible to a 99th%ile stature LGV driver

As with the smaller driver, Figure 153 and Figure 154 show that when a car is positioned to the left of the Iveco Eurocargo in a position that is forwards of the volume of space that is visible through the Class IV mirror the car should be clearly visible with direct vision through the passenger's side window.

2.5.6.5.31 Iveco Eurocargo, merging right

As the Iveco does not have a Class IV mirror on the offside the merging right scenario is very different. The lack of wide angle Class IV mirror on the offside means that the potential blind spots as highlighted in Section 2.5.6.3 are much greater to the right of this vehicle and so evaluating the visibility of a vehicle in the right hand lane when deliberately placed just to the front of the Class IV field of view cannot be evaluated.

2.5.7 Issues identified in the volumetric analysis and OTS scenario examination

2.5.7.1 Issue 1: Class V mirror blind spot

The volumetric analysis of vision from category N_2 and N_3 vehicles has highlighted a number of issues. The predominant issue was the blind spot that exists between the volume of space that is visible using the Class V mirror and the volume of space that is directly visible on the passenger side of category N_3 vehicles. This issue was also found to affect the DAF LF 45 in the N_2 category.

2.5.7.2 Issue 2: Obscuration by the Class II and Class IV mirror housing

The second issue that was identified was the obscuration caused by the Class II and IV mirror housings and A-pillars of both category N_2 and N_3 vehicles.

2.5.7.3 Issue 3: The time required to visually scan four mirrors

Comments from the driver's interviews highlighted the number of mirrors that must be interacted with to get a full view of the situation surrounding the vehicle. The motorway changing lane scenario highlighted the need to look at the Class II, Class IV, Class V and Class VI mirrors. Studies have shown that the mean 'eyes off road time' required to look at a Class III mirror in M_1 vehicles is 0.96 seconds with a mean eye movement time of 0.32 seconds (Sodhi, M. & Reimer, B., 2002). Applying these figures to the visual scanning of four mirrors gives a task time of 0.32+0.96+0.32+0.96+0.32+0.96+0.32+0.96+0.32 = 5.44 seconds. If it takes over five seconds to scan four mirrors there is the potential for the situation to have changed in the first mirror that was scanned by the time the last mirror has been scanned.

2.5.7.4 Issue 4: The blind spot next to the driver's door

The volumetric analysis of the category N_2 and N_3 vehicles highlighted a blind spot next to the driver's door that could hide a pedestrian.

2.5.7.5 Issue 5: Quality of image at the edge of Class IV, V and VI mirrors

In addition to the issues above the work that has been performed has raised some concerns regarding the distortion of the image seen at the edge of a curved mirror. There were a number of situations highlighted during the volumetric analysis where a visual target was only partially visible at the edge of the volumes of space that define the visibility from Class IV, V and VI mirrors. In order to explore the distortion that occurs at the edges of the Class IV, V and VI mirrors the CAD data for the Volvo 480 category N_3 vehicle was imported into a CAD system that is able to render mirrored surfaces. The following series of figures (Figures 155-160) show a category M_1 vehicle overtaking the left hand drive Volvo 480. It should be noted that the Class V mirror has been optimally adjusted to include vision of the side of the vehicle and an area that goes beyond the standardised coverage shown in Directive 2003/97/EC in this example.

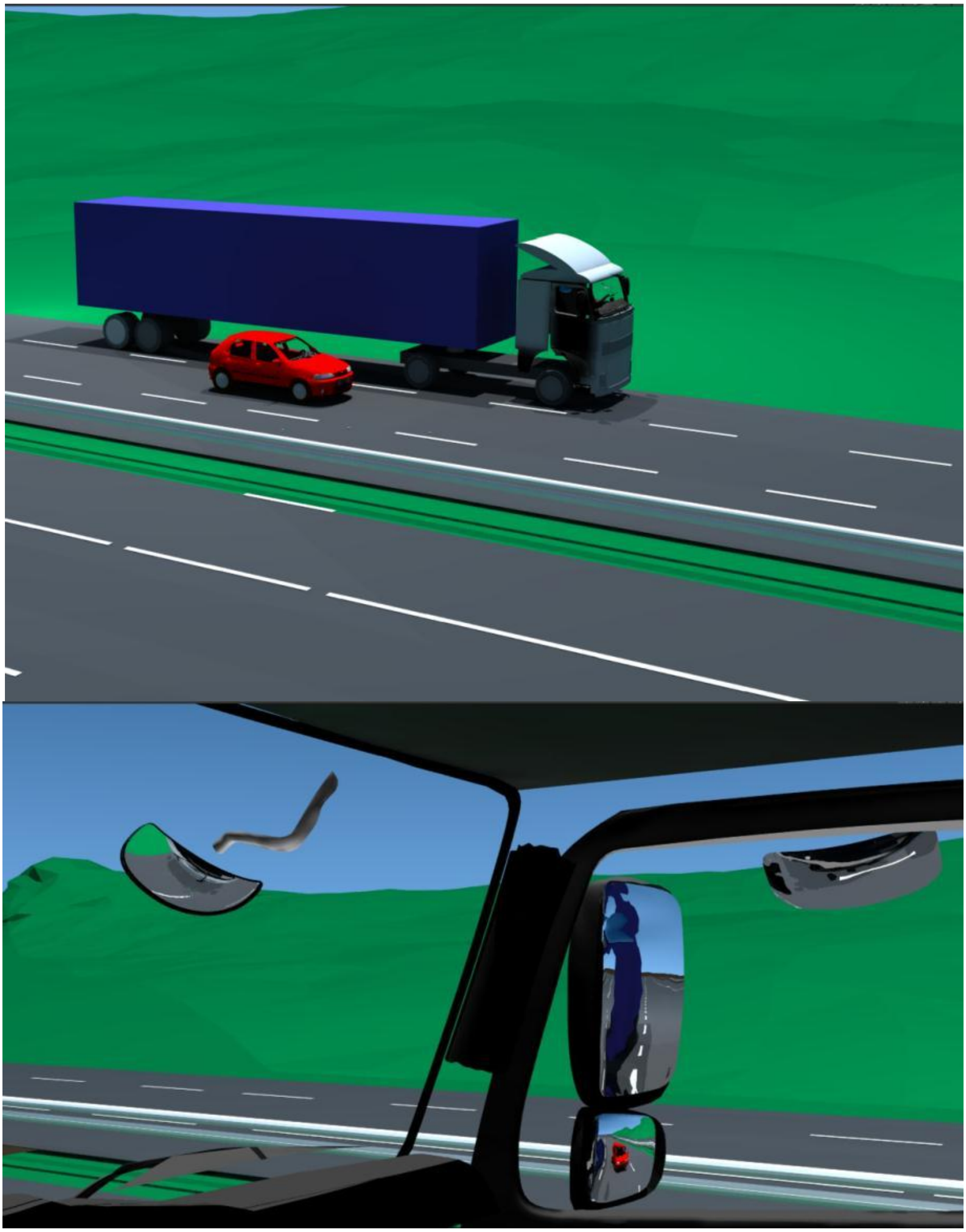

Figure 155. Stage 1: The vehicle is visible in the Class IV mirror only

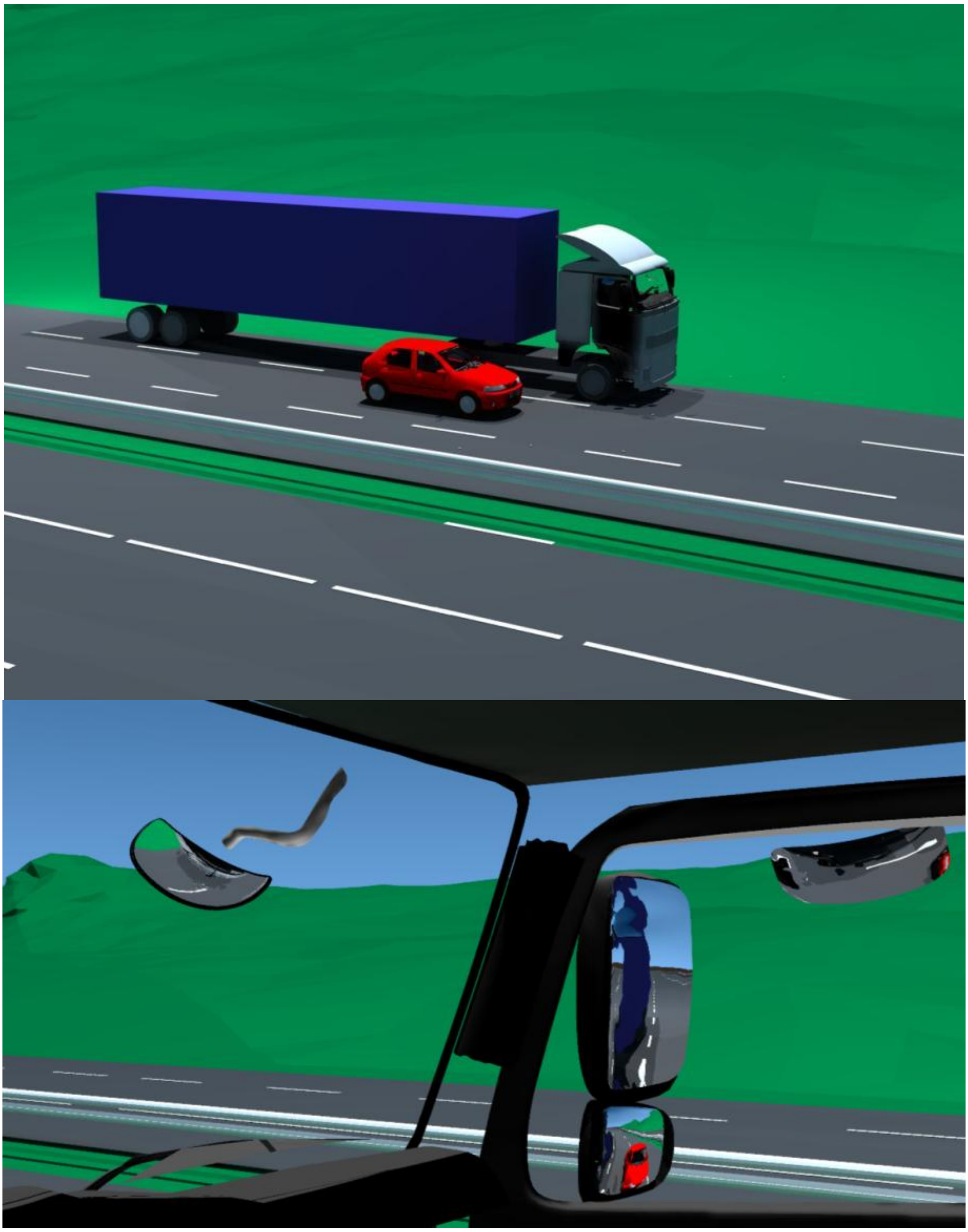

Figure 156. Stage 2: The vehicle is visible in the Class IV mirror and partially visible in the Class V mirror

Figure 157. Stage 3: The vehicle is partially visible in the Class IV mirror and partially visible in the Class V mirror and Class VI mirror

Figure 158. Stage 4: The vehicle is partially visible in the Class V mirror and Class VI mirror

Figure 159. Stage 5: The vehicle is partially visible in the Class V mirror and Class VI mirror

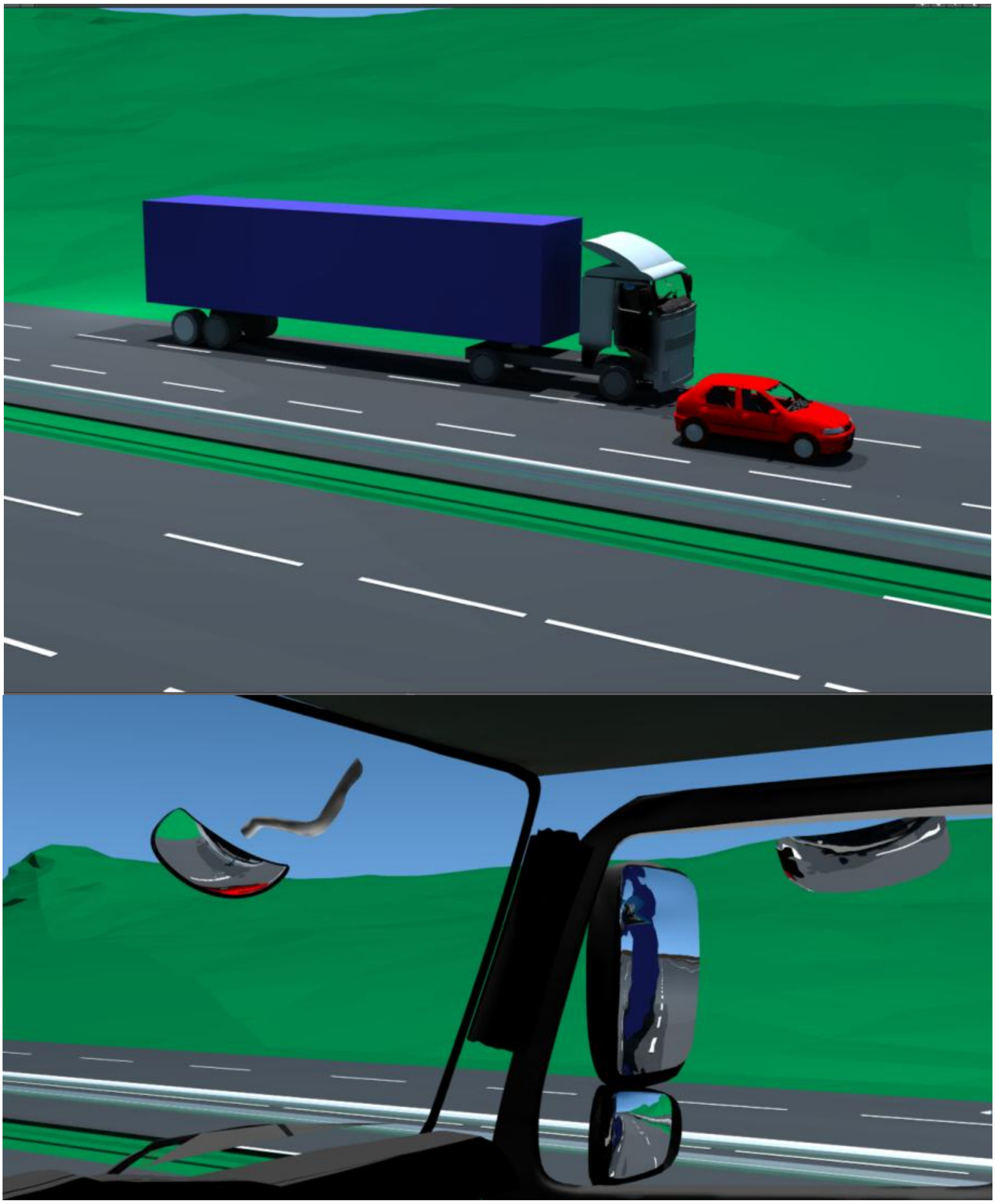

Figure 160. Stage 6: The vehicle is partially visible in the Class VI mirror

This analysis shows that for Stages four and five, where the M_1 vehicle is adjacent to the cab of the category N_3 vehicle, the M_1 vehicle can only be partially seen in the Class V and Class VI mirrors. Further research would need to be performed to determine if drivers can identify visual targets that are shown at the edge of Class IV, V and VI mirrors. However, the phase 1 report included the discussion of research that demonstrated that drivers only use the Class V and Class VI mirrors for close manoeuvring situations or when stationary at junctions.

2.5.8 Potential solutions to these issues

The technology review has highlighted the potential solutions that can be used to address the identified issues. Camera systems that process wide angle lens images to remove distortion, and combine multiple images to one screen location have the potential the solve all of the highlighted issues. The camera system could be used to fill the blind spot identified in issue 1, would allow the removal of the mirror housing that can cause obscuration as identified in issue 2, can provide one viewing location to solve issue 3, could include cameras to cover the driver's door blind spot identified in issue 4, and remove the distortion of images identified in issue 5. A more piecemeal approach could be taken if camera systems are deemed to be inappropriate.

2.5.8.1 Alternative solutions for Issue 1: Class V mirror blind spot

As part of this research project an extended view Class V style mirror that has been produced by a leading manufacturer has been tested. Whilst this mirror uses a 300mm radius of curvature which is common across Class V mirrors, it has a greater height and so covers a larger area to the side of the vehicle if adjusted properly. The relevant dimensions for the mirrors used in this Work Package are shown in Table 23 below.

Mirror	Width (mm)	Height (mm)	ROC (mm)
Category N2 Renault Midlum Class V	245	145	300
Category N2 DAF LF 45 Class V	245	145	300
Category N2 Iveco Eurocargo Class V	255	155	300
Category N2 DAF 45 Class V	245	145	300
Category N3 Daf XF 105 Class V	305	180	450
Category N3 Volvo 480 Class V	275	160	330
Category N3 SCANIA R420 Class V	305	175	300
Extended view Class V	282	185	300

Table 23. Mirror dimensions assessed in the work package

Figure 161 shows the blind spot that was identified in this research between the standard Class V mirror and the volume of space observable through the passenger window. Figure 162 shows that this blind spot can be filled.

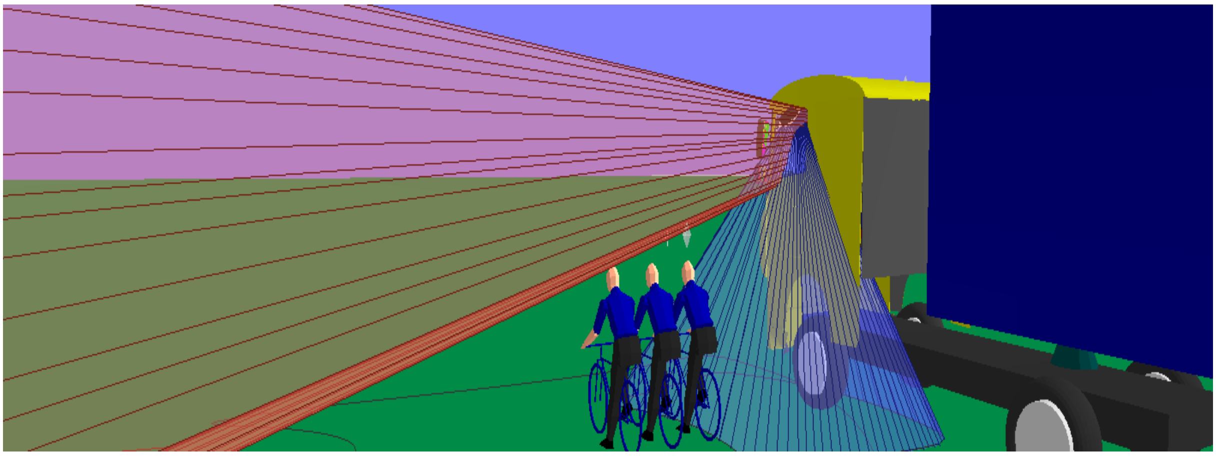

Figure 161. The blind spot that was identified between the standard Class V mirror and the volume of space observable through the passenger window

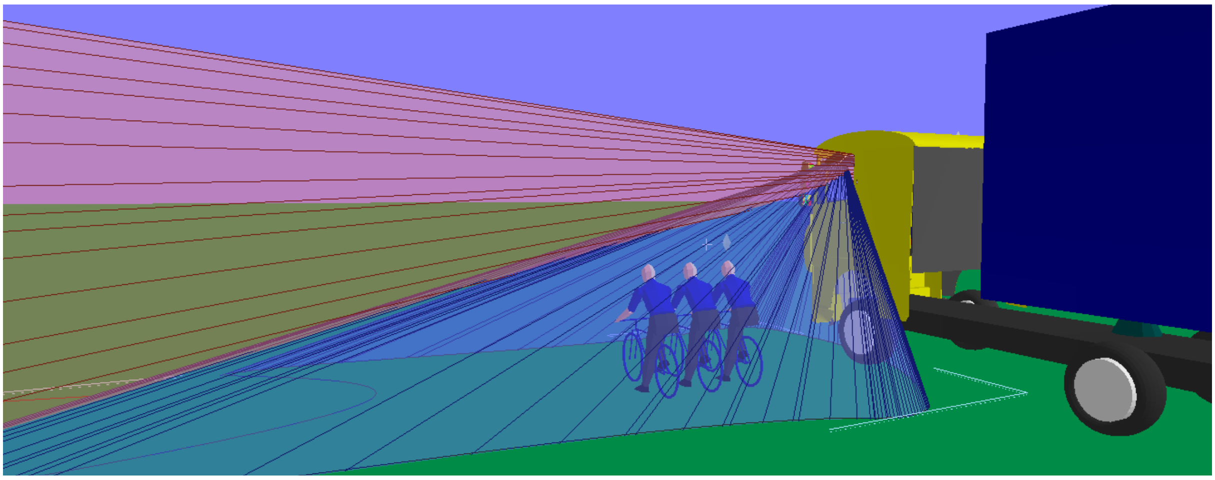

Figure 162. The extended view mirror fills in the blind spot

Taking this mirror as an example for the discussion of standardisation, a prescribed viewable area that extends the current 2m lateral distance from the side of vehicle to 4.5m would ensure that the targets shown in Figure 162 would be visible to the driver.

Other alternative solutions would be the lowering of window sill heights to allow improved direct vision, or the lowering of the driving position in a way that is similar to the driving position of buses and coaches.

2.5.8.2 Alternative solutions for Issue 2: Obscuration by the Class II and Class IV mirror housing

The differences found between the obscuration caused by Class II and IV mirror surrounds in the category N_2 T-Junction scenario highlighted the benefits of having a gap between the mirror housings. In addition, any possible reductions in housing size would be beneficial.

2.5.8.3 Alternative solutions for Issue 3: The time required to visually scan four mirrors

There are no current envisaged alternative solutions other than camera systems that can solve the time it takes to visually scan multiple mirrors in different locations.

2.5.8.4 Alternative solutions for Issue 4: The blind spot next to the driver's door

There are a variety of detection systems that could be used to alert the driver of the presence of a pedestrian next to the driver's door.

2.5.8.5 Alternative solutions for Issue 5: Quality of image at the edge of Class IV, V and VI mirrors

There are no current envisaged solutions other than camera systems for the distortion of mirror images at the edge of mirror surfaces.

2.6 Task 4: Technology review

2.6.1 Aim

The aim of the technology review was to:

- Identify the various methods available for improving indirect driver vision for category N_2 and N_3 vehicles (aftermarket 'add on' technologies.)
- Investigate the extent of variation within the market for these product types
- Gather their stated performance data.

The collated data was then analysed to determine the range of attributes available and consider their usability and support provided to the driver. In addition, manufacturers of concept and safety demonstrator vehicles were contacted to discuss in greater detail the improvements to vision accommodated within their concept vehicle, the rationale for these and any driver feedback regarding such improvements where trials have been undertaken.

2.6.2 Method

2.6.2.1 Product review

The product review consisted of conducting a search of the World Wide Web focusing on UK suppliers and manufacturers of technologies designed for improving indirect driver vision in N_2 and N_3 class vehicles. Keywords used in the search included: blind spot, blind spot detection, LGV safety, side detection, active safety, camera reversing systems, blind spot mirrors, commercial vehicle safety, field of view.

From the search a list of manufacturers and suppliers within the UK were identified that provided aftermarket 'add on' technologies. Information regarding the range of products and their technical specifications were collected from information provided on websites and product brochures. Where more detailed information was required manufacturers / suppliers were contacted directly.

2.6.2.2 Concept vehicles

The following companies with known concept vehicles were contacted and visited to observe the systems / vehicle design;

- Brigade Electronics
- DHL.

Descriptions of the technologies employed, and the vehicle design in terms of direct and indirect vision were collated.

2.6.3 Results

2.6.3.1 Product review

2.6.3.1.1 Manufacturers/suppliers

The search of the World Wide Web resulted in identifying the following manufacturers and UK suppliers of technologies designed for improving indirect driver vision:.

- Alpine Electronics
- A.R.K Automotive
- Brigade Electronics plc
- Delphi
- Groenveld UK

- Iteris
- Magnum Vehicles Solutions ltd
- Orlaco
- Reversing made easy Ltd
- Sentinel Systems LTd
- Spillard Safety Systems
- Transport Support
- Valeo
- Vision Techniques PLC
- Vision UK.

2.6.4 Technologies and products designed for improving driver awareness

2.6.4.1 Systems

Systems for informing the driver of nearby hazards fall broadly into three categories

- Auxiliary and improved mirrors
- Enhanced vision systems
- Driver alert systems.

Devices other than mirrors need to incorporate an additional Human-Machine Interface (HMI), such as a warning light, buzzer or display. Different forms of HMI can be matched to a given type of hazard warning, so these are reviewed separately.

2.6.4.2 Auxiliary mirrors and improved mirrors

These are after-market mirrors that are intended to supplement or replace the standard mirrors fitted to a vehicle. Whilst replacement mirrors must comply with the legal requirements for curvature, field of view etc., they may be larger than the standard mirror to give a wider field of view. One example of these is the Spafax VM5, which incorporates a glass of 300mm radius of curvature (which is common across Class V mirrors), but has a greater height and so covers a larger area to the side of the vehicle if adjusted properly. This mirror was studied closely in this project, because it can give a view of the surface extending 4.5m from the cab side (see Section 2.5.8.1. Auxiliary mirrors are sometimes installed to fill in the boundary between the Class II and Class IV mirrors, or between Class V and Class VI mirrors for example.

Whilst some vehicle manufacturers specify original-equipment mirrors with glass that has a radius of curvature which is greater than the minimum specified for type-approval, nearly all replacement mirrors are produced with glass that is very close to the minimum radius of curvature allowed. This is for commercial reasons (to standardise on glass blanks) and to ensure that the replacement continues to achieve the minimum required field of view.

The introduction of the mirror retrofitting requirements for LGVs already in service in Directive 2007/38/EC saw a short-lived market for replacement mirrors in Europe. At other times, however, the number of replacement mirrors sold is limited.

2.6.4.3 Motorised mirrors

The importance of mirrors that can be adjusted easily from the driver's seat, including the Class V and Class VI, is highlighted in Work Package 4. The technology for adjusting exterior mirrors electrically is already mature, and this feature is now available on the majority of category M_1 vehicles. Some category N_2 and N_3 vehicles are already offered with electrical adjustment on the Class II mirrors, and sometimes the Class IV as well. This shows devices that will function with 24v electrical systems and the larger, heavier mirrors found on these category of vehicle are already on the market.

In a market survey, no examples of electrically adjustable Class V or Class VI mirrors were found. Discussion with a large UK mirror manufacturer revealed that there are no technical problems to incorporating this feature, and that it could be achieved at relatively small cost.

2.6.4.4 Enhanced vision systems

These include camera / monitor systems operating in the visible spectrum, offering the driver a view that would not be possible using mirrors alone, for example the area immediately behind the vehicle. They also include systems that display images using parts of the spectrum other than the visible, such as infra-red or radar.

2.6.4.5 Driver alert systems

These are systems that automatically detect the presence of an object, vehicle or person in a critical area close to the vehicle, and activate a warning to the driver. These are often based on the same technologies as systems in the previous category, and may be combined with enhanced vision systems. As well as warning the driver, some advanced systems may also automatically activate other systems to avoid a collision, such as automatic braking.

Generally, all vision or alert systems can be considered as a combination of a detection system and a human-machine interface (HMI) system, with an information processing system that links the two. The following section describes some of the technologies that are utilised in the detection systems, and then the subsequent section discusses the HMI units.

2.6.5 Imaging and detection technologies

The following technologies are used in automotive applications to detect objects in a vehicle's blind spot, or to provide an enhanced image.

- Video
- Ultrasound
- Radar
- Active Infra-Red
- Passive Infra-Red (Thermal Imaging).

2.6.5.1 Video

This is the familiar technology that supports almost all modern digital camera and video products. A portion of the electromagnetic spectrum approximating to that which is detected by the human eye as "visible light" is focused through a lens onto a semiconductor array called a Charge Coupled Device (CCD). This generates a stream of discrete voltage steps corresponding to the light intensity falling on each element in the array, in turn. It is these steps which generate the image on the display. The CCD can be used to produce a monochrome image, or with the addition of a 3-colour filter array a colour image is possible. The video signal is generally processed electronically to compensate for changes in ambient light level, or large differences in contrast between one part of the image and another.

Since it uses the visible spectrum, video is subject to the same limitations as human vision namely high or low light intensity, fog, spray etc. These can be overcome to some extent by generating an enhanced image by using other parts of the spectrum such as ultrasound, radar or infra red.

2.6.5.2 Ultrasound

Ultrasound comprises acoustic waves that are above the upper threshold for human hearing, approximately 20kHz. Like audible sound, they propagate through air and are reflected from any surface they encounter. However, the shorter wavelengths of ultrasound give the waves more directional properties, and means that the signal is less easily contaminated by background sounds in a noisy environment.

Ultrasound is produced by converting electrical voltage into mechanical displacement in a piezo-electric emitter and hence into air pressure waves. The face of the emitter can be flat or curved to give the waves more or less directional properties. A similar device is used to detect objects, by converting the reflected waves into electrical voltage. The strength of the reflected pressure wave is dependent on the hardness and roughness of the reflecting surface; for example the flat, hard surface of a car body panel will reflect much more strongly than the fabric of a pedestrian's clothing. The range of an ultrasonic device in air is limited, but it is quite suitable for detecting objects within 3-4 metres of the vehicle.

Since acoustic waves propagate at a fixed speed through air, the time taken for a reflected pulse of ultrasound to return to the sensor is a measure of its distance from the device. This allows for a cut-off to eliminate reflections originating outside the zone being scanned, and can be used to drive a range-display when an object is detected. However, since it is an acoustic wave, it can be affected by airflow and particularly turbulence. Also, the longer wavelength in comparison with electromagnetic systems means it is not suitable for generating detailed two-dimensional images that could be displayed on a screen.

2.6.5.3 Radar

This is the familiar technology that is used in detecting and locating ships or aircraft, and consists of transmitting a directional beam of electromagnetic radiation and detecting the reflected signal. Two forms of reflection are used. In primary radar, the return signal is simply a reflection from the surface of the target, and the strength of this is dependent on the shape and dielectric properties of the surface. In secondary radar, a separate transponder is incorporated into the target. When this detects the incoming radar pulse, it transmits a return signal whose strength is independent of the surface properties of the target. The transponder can be designed so that the return signal also transmits additional encoded information about the target. The EU-funded research project WATCH-OVER developed systems for alerting drivers to vulnerable road users (VRU's), using transponders carried by the VRU (and which might eventually be suitable to be incorporated into clothing).

Previously, automotive radar systems have used frequencies around 24GHz. However, this frequency was not formally licensed for automotive applications, so future systems will use higher frequencies in the region of 79GHz.

2.6.5.4 Active infra-red

The infra-red portion of the electromagnetic spectrum comprises waves of longer wavelength than visible light, and occupies the portion between the red end of the visible spectrum and short wavelength radio waves that are used for applications such as radar and microwave transmissions. Like visible light, waves can be projected, and those which are reflected by surfaces can be collected and used to produce a visual image of the scene. Using infra-red in this way to enhance the driver's vision offers two major advantages:

- It is less affected by suspended water droplets in the atmosphere than visible light, allowing a clearer image of objects in road spray, mist or haze
- It will not dazzle other drivers.

Systems using reflected radiation in this way tend to use the far infra-red portion of the spectrum and are called "active" infra-red, because they include a source mounted on the vehicle. The reflected waves are capable of generating a detailed image of the scene that can be displayed to the driver.

2.6.5.5 Passive infra-red

Infra-red waves that lie closest to the visible spectrum (near infra-red) comprise the radiated heat that is emitted by all surfaces above 0 degrees Kelvin (-273degC).

Since radiation from hotter surfaces is more intense and of shorter wavelength than that from colder surfaces, and the infra-red can be focused onto a detector array in a similar way to visible light, it can generate a digital image of objects by the difference in emissions from their background.

Detectors for near infra-red require special materials for the lenses, and a detector that is maintained at a cold temperature. These requirements used to make passive infra-red devices too expensive for use in vehicles, but developments in these technologies have led to imaging systems using passive infra-red being available in higher-segment cars and other vehicles.

In a typical passive infra-red system image, "cold" objects are visible by the reflection of ambient near infra-red radiation, but hot objects appear brighter due to their higher temperature. They are therefore capable of highlighting humans and animals against their background.

Figure 163. Brigade PathFindIR Thermal Imaging Camera

2.6.6 Human-machine interfaces

Human-Machine Interface refers to the manner in which the system presents the information from the detection device to the driver. Currently, these can be classified under three different headings:

- Driver alerts
- Displays
- Intervention systems.

These systems are frequently used in combination. For example, some display systems use image processing software to detect the characteristic shape of a human in the image. These then draw the driver's attention to this part of the image, for example by drawing a rectangular outline around the object. As well as alerting the driver, some systems also broadcast an alert to the person on the outside of the vehicle who is at risk.

2.6.6.1 Driver alerts

Ultrasound and some infra-red and radar systems only provide a warning to the driver. These may activate an audible alarm, or light, or some form of haptic device. Each of these has advantages and disadvantages insofar as:

- Its ability to compete with background sensory inputs
- Its ability to identify this particular warning against others
- Its ability to direct the driver's attention in the appropriate direction.

In addition, the intensity of the alert must be set so that it commands the driver's attention, but does not frighten, annoy or distract the driver from more important tasks. A well designed alert system will also prompt the driver to identify the cause of the alert, using direct or indirect vision. For example, where a light is used this is often positioned close to the appropriate mirror. To be effective, such systems need to be designed to avoid overloading the driver's attention with false alerts, and this can be done by activating the alert only when the appropriate control is activated. For example, a side-mounted warning system may only be activated when the driver operates the indicators to signal their intention to turn in that direction. Alternatively, a rear-mounted warning may only be activated when the driver selects reverse gear.

Where a warning system also provides information on the distance that the target is away from the sensor, this information is transmitted to the driver to indicate the urgency of response required. In audible alerts, the range may be indicated by changes in tone or by the repetition frequency of an intermittent sound. Some visible alerts indicate this by displaying the range in metres in a numeric display, while others present an analogue display, such as light bars. Where multiple sensors are used, the analogue displays may be combined into some form of array to indicate the approximate location of the detected object.

2.6.6.2 Displays

With the exception of ultrasound, each of these technologies is capable of generating a detailed image of nearby objects. Radar or infra-red returns can be used to generate a monochrome or false colour image, which can be displayed separately. Some systems project this onto a reflector mounted inside the windscreen to produce a head-up display, whereas others display it on a separate screen on the instrument panel or navigation screen.

Where a screen is employed, the brightness of the image must be automatically regulated to the ambient lighting conditions so as not to dazzle the driver. In a head-up display this is particularly important, but in addition the system must monitor the position of the driver's eyes to ensure that the projected image is precisely aligned with the exterior view.

Image-processing is quite demanding in terms of computing power and this may limit the application of some imaging systems. For example, a system for processing passive infra-red may cope with the forward view at low speed, but would not have the capacity to provide a view to the side at a higher speed. As greater processing power becomes available, further applications will no doubt arise. One promising area which is still at an early stage in the automotive field is the use of "sensor fusion", which automatically over-lays video, radar and infra-red data to form a single composite image.

2.6.6.3 Intervention systems

These comprise systems that automatically intervene with the driver's control of the vehicle, for example if the vehicle is reversing and it senses an object close behind, the system would automatically bring the vehicle to a halt. Current technology and also certain legal conventions (Vienna Convention, amongst others) will not permit such systems to take priority over the driver's wishes, so the driver must always be able to over-ride the intervention system whenever he or she so chooses. Security is also an important consideration, so that the system cannot be used by a hijacker to immobilise the vehicle, for example. Another example is the Volvo "Safe Start" system. When the vehicle is stationary, this system prevents the driver from moving off whenever an object is detected close to the front of the vehicle.

2.6.7 Applications

Technologies dedicated to the improvement of indirect driver vision are relatively new. As with many other innovations in an early stage of development, these were initially limited to some higher-specification cars, but are quickly spreading to other categories of vehicle as their price falls. These systems were discussed previously in the Phase 1 report and included the following;

- Blind spot monitoring system / Lane change assistant
- Lane departure warning systems
- Co-operative communication systems
- Vision Enhancement Systems.

In turn, commercial vehicle manufacturers are also now starting to provide similar systems as standard or optional extras, albeit not providing the same extensive range of products currently available for category M_1 vehicles. For example, Scania, Volvo and DAF, provide the option of Orlaco camera systems to the front, side and rear. However, currently the most popular approach to making improvements to the indirect field of view is through the addition by fleet operators of aftermarket 'add on' technologies. This section provides a summary of the type of aftermarket products available and the range within those products in terms of specification and capabilities. Products reviewed include front, side and rear blind spot detection systems currently available for fitment onto category N_2 and N_3 vehicles. These include the following technologies; sensor systems, camera systems and mirrors.

2.6.8 Examples of systems currently available for category N_2 and N_3 vehicle applications

2.6.8.1 Sensor systems

Sensor systems provide a means of detecting objects which are within the monitoring range of the device. The sensors can be radar, infrared or ultrasonic. They present a warning to the driver that an object is present either through a visual or auditory warning. Sensors are intended to supplement standard mirrors, they are not designed to be used in isolation or offer a replacement to regulation mirrors.

2.6.8.1.1 Front

Front sensors provide coverage to the front of the vehicle. Figure 164 presents an outline of a region in which a front sensor system may provide coverage. One potential problem with front systems used to activate a driver alert is that they may generate unnecessary alerts whenever the vehicle is close to another vehicle in a traffic queue. It is not possible to limit the system's operation automatically, in the same way that a reversing sensor only operates when reverse gear is selected.

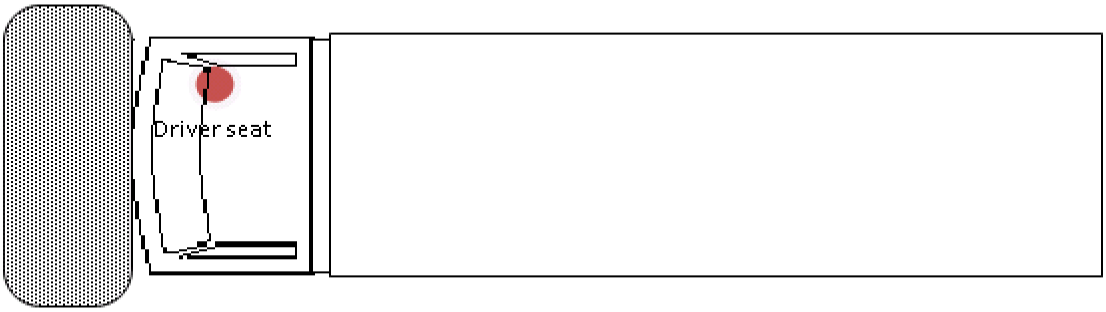

Figure 164. Shaded area indication of the area covered by front sensor systems.

Many category M_1 vehicles are now available with front-mounted radar sensors as part of intelligent cruise control systems. These systems are intended primarily to help the driver maintain headway in traffic; however, some manufacturers have used the radar as the base of additional safety systems, such as front collision mitigation. In these, the system continuously monitors the gap and closing speed in relation to the vehicle in front. When it detects a combination of high closing speed and small gap indicating that the performance of the braking system will not prevent a collision, these systems automatically activate emergency braking. This is not sufficient to prevent a collision, but will mitigate the relative velocity of the collision and hence the impact severity. Although such systems could be designed to avoid a collision completely, manufacturers choose not to do this because the emergency braking could interfere with the driver's attempts to avoid the collision by steering the vehicle.

2.6.8.1.2 Front corner

Front corner sensors provide coverage to the front corners of a vehicle. This can either be one corner (most commonly the corner opposite the driving position) or both corners. Figure 165 presents an outline of regions in which a front corner sensor system may provide coverage.

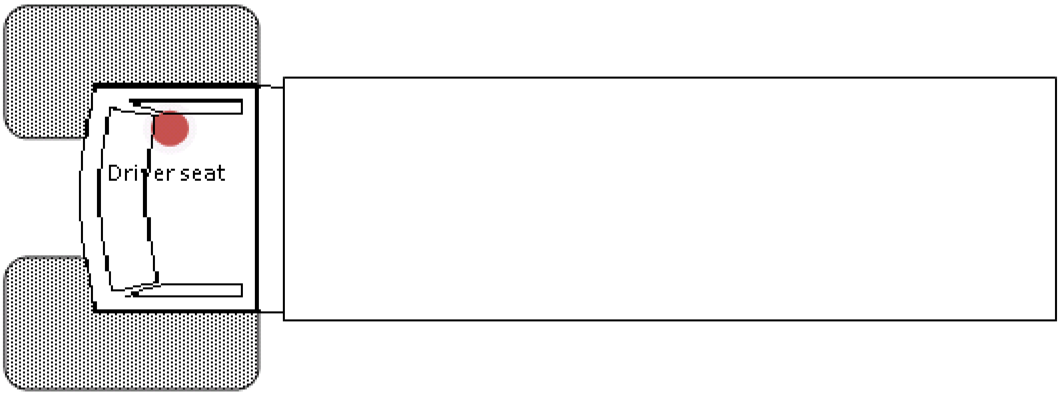

Figure 165. Shaded area indication of the area covered by front/side sensor systems.

Front corner sensors are useful for protecting the near-side and / or off-side front corners of the vehicle, particularly if reversing into tight spots when the driver's attention is towards the rear of the vehicle. Near-side sensor systems are also claimed to be particularly useful at traffic lights, junctions and roundabouts in towns and cities where cyclists tend to 'creep up' the nearside of a waiting LGV. There is a danger that a system which generates too many unnecessary alerts (from roadside furniture etc.) could annoy or distract the driver, and may lead to the driver ignoring alerts or turning the system off. For this reason, most systems will only be activated when the warning will be useful to the driver. This is generally done in two ways. Some systems only function at low speeds that are typical of a vehicle about to manoeuvre. Some of these have a preset activation speed whereas others have an optional programmable speed trigger where the driver can set the speed below which the system will become activated. Other systems will only provide a warning when the driver has signalled their intention to make a turn, by activating the appropriate direction indicator. These sensors are typically close proximity offering detection areas close to the vehicle typically within 1.5metres.

When an object is detected an audible and/or visual warning is presented to the driver, this is aimed at prompting the driver to check their mirrors to assess the situation fully and/or to proceed with caution. Visual alerts also indicate in which area relative to the vehicle the potential object is located and consequently which mirrors should be checked. Where the sensors provide information on the distance between them and the object detected, this may be displayed as a number, or by some analogue display such as light bars to indicate the urgency of the warning. Where multiple sensors are used, a more complex analogue display may be used to indicate the longitudinal position of the target in relation to the vehicle.

In addition to providing an audio or visual alert to the driver, some of these types of system provide an external verbal warning to the cyclist or pedestrian in close proximity to the vehicle. A speaking alarm can be fitted to the underside of the vehicle that will alert the cyclist or pedestrian with a warning message that the vehicle is turning.

A review of the products on the market shows that:

- Detection ranges vary from 0.3m to 1.5m. However, sensor detection areas can also be described in terms of sensor angles. Products reviewed using this method of description reported ranges of 120 degrees.
- The presentation warning can either be an audible warning or a visual warning.

Figure 166. Example of Visual Warning System Mounted on the Nearside A-Pillar

2.6.8.1.3 Side

Side sensors provide coverage to the one or both sides of the vehicle. Figure 167 presents an outline of the typical area covered by a side sensor system.

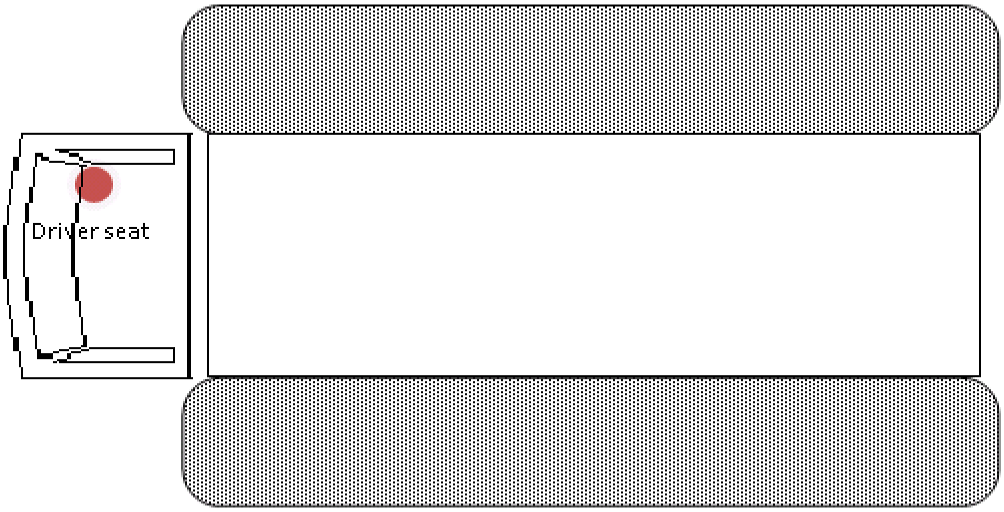

Figure 167. Shaded area indication of the area covered by side sensor systems

Side sensors are installed along the side of the vehicle to detect and inform drivers when a vehicle, pedestrian or cyclist is alongside, and so reduce risk of side swipe incidents. They are aimed at providing drivers with more time to react to obstacles that may be difficult to see in the side mirror when changing lanes or making a turn. They provide visual freedom in that they do not require drivers to monitor visual displays unlike camera-based systems, instead they provide an audible or visual alert to another vehicle's presence in the system's detection zone. These systems claim to operate under a wide range of environmental conditions (rain, snow, ice, fog, day, night, and noisy). They can be used to monitor the sides of the trailer in articulated or drawbar combinations, using either cable or wireless communication between the trailer and tractor. However, the tractor and trailer systems must be compatible with each other.

A review of the products on the market shows that:

- Most systems reviewed had a detection range extending approximately 2.5m from the side of the vehicle.
- The alert is presented to the driver either as an audible warning or a visual warning. Example- Forewarn® Side Alert provides a visual alert in the side mirror. When the turn signal is activated, an audible alert on the outside of the vehicle is also provided.

2.6.8.1.4 Rear

Rear sensor systems provide coverage to the rear of the vehicle. Figure 168 presents an outline of the typical area covered by a rear sensor system.

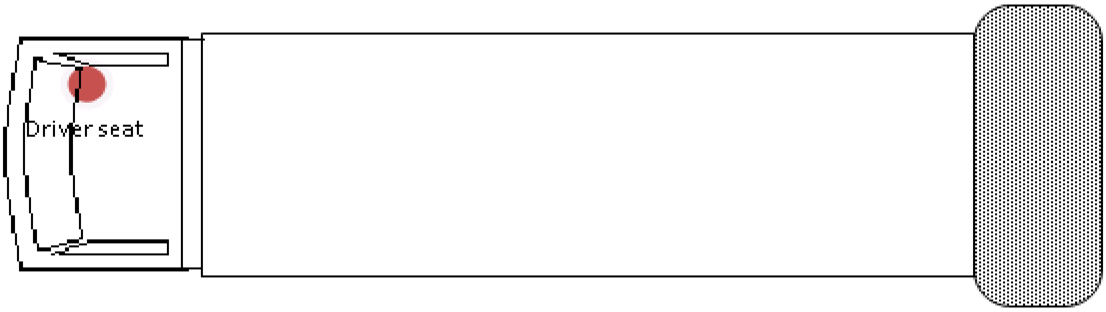

Figure 168. Shaded area indication of the area covered by rear sensor systems.

Reversing sensors are designed to aid reversing and parking in confined spaces. They are the most common type of driver alert and are available as a standard or optional feature on most types of car, as well as offering a wide choice of after-market kits. For category N_2 and N_3 vehicles, single sensor ultrasound or radar installations are most commonly used to help the driver to stop the vehicle the correct distance from a loading deck, whereas for category M_1 and N_1 vehicles, multiple sensors (4 or 6) are employed to help when reversing into a parking bay. Whenever reverse gear is engaged the sensors start scanning to the rear of the vehicle. The technologies inform the driver of the presence of object (a person or obstacle) at the rear and they can also provide information regarding the distance between the vehicle and the object either though three stage lighting indicators or actual distance measures. The distance may also be indicated by the tone of an audible device, or by the repetition frequency of an intermittent sound. For vehicles which operate with and without a trailer, the towing vehicle sensor must be disabled automatically or manually whenever the trailer is connected.

Figure 169: Brigade Backsense Radar Detection Sensor

Figure 170. Typical Ultrasonic Reversing Sensor Installation on M_1 Vehicle

A review of the products on the market shows that:

- Detection ranges vary from 0.3m to 3.5m
- Warnings can be presented either as an audible warning or a visual warning.

2.6.8.2 Camera monitor systems

Camera Monitor Systems (CMS) provide a means of viewing objects around a vehicle which are located within the viewing range of the mounted camera lenses. They are capable of providing the driver with a viewpoint which is not practical using mirrors, for example the area immediately to the rear. The image is presented to the driver by an internal monitor, that can display a single image or multiple images in a split screen arrangement. The display is often immobilised to avoid distracting the driver when the view is not necessary. For example a view to the rear is only displayed when reverse gear is selected, or a side view may only be displayed when the vehicle speed is below a certain threshold.

A number of human factors considerations need to be taken into account when using camera systems to enhance driver awareness:

- When used in conjunction with the mirrors, it may be necessary to "reverse" the camera image to avoid confusion
- In order to maintain spatial awareness, the driver should either be aware of the camera's field of view, or able to relate the position of objects viewed in relation to fixed datum points on the vehicle. This is particularly important where multiple views are displayed

- The display screen should be positioned where the driver can easily switch their attention between the screen and the corresponding mirror or direct view of the object.

Directive 2003/97 and 2007/38 permit the use of a Camera / Monitor System (CMS) in place of the Class V and VI mirrors. However cameras to the side of the vehicle must be used in addition to directive compliant mirrors and not used as replacements or in isolation.

Figure 171. Brigade Electronics Compact Flush-Mounted Camera Unit

2.6.9 Enhanced vision systems

2.6.9.1 Volvo night vision

Figure 172. Display from Volvo Night Vision System

The Volvo Night Vision System is the first enhanced vision system to be offered on a production vehicle. It was developed by Raytheon, launched on the Volvo SCC Safety Concept car in 2001 and went on sale on the XC90 car in 2002. It uses a thermal imaging sensor (passive infra-red) mounted just below the headlamp and projects an image onto a head-up display reflector screen just inside the windscreen, so as to overlay the image on top of the driver's normal view. The image shown above shows how the background detail can be seen in the reflected ambient infra-red, but the hotter person on the left is highlighted by their own internally-generated IR emissions. Similar systems are used by other car manufacturers, such as Audi, BMW, GM and Honda.

2.6.9.2 Mercedes night view assist

Figure 173. Mercedes Night View Assist Instrument Panel Display

This system is one example of an enhanced vision system using active infra-red, using IR emitters on the front of the vehicle to illuminate the roadway and sensors detecting the reflected IR to form an image. It was first offered on sale on the Mercedes S-class car in 2005. In 2009, Mercedes Benz introduced Night Vision Assist Plus, with image processing alerting the driver to pedestrians. Similar systems are now offered by Toyota.

The cost of night vision systems is reducing as systems are developed. The current cost as an option on higher end cars is approximately £1500, but this seems likely to reduce, and the systems will no doubt become available on lower-segment vehicles. Some recent developments could herald a dramatic reduction in the cost of night vision sensors. Fraunhofer IMS have recently announced the development of the IFRPA (Infra-Red Focal Plane Array). This is a 256 x 256 pixel array that does not require the cooling technology in current IR detectors, and is claimed to generate a digital output signal directly, without an intermediate converter.

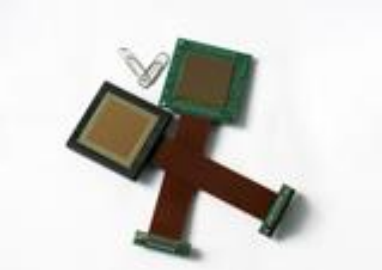

Figure 174. Fraunhofer IRFPA Sensors

2.6.9.3 Lane departure warning (LDW)

Figure 175. Tracking of Lane Markers by the Iteris Auto Vue LDWS

These systems assist drivers in keeping to their lanes by warning them when their vehicles are in danger of leaving their lane unintentionally (mainly due to lack of driver attention). These work by automatically detecting the white lines at the side of the lane as shown in Figure 175. Current systems use either an audible beep or a "rumble strips" noise, which mimics the sound made when a tyre runs over a lane divider. The first production LDW system was developed by Iteris and offered on the Mercedes Benz Actros in 2000. It is now available on most cars and LGVs on sale in Europe, and the European Commission plans to make its installation compulsory on all new category N_2 and N_3 vehicles as well as category M_2 and M_3 vehicles by 2015.

Although an LDW system is not suitable for detecting objects in the driver's blind spot, some systems might incorporate components such as cameras that might be used to support blind spot detection. For example, it might be feasible for an integrated system to provide the driver with LDW information at high speed and blind spot warning at low speed, or when manoeuvring.

An example of a simple system is the one fitted by Peugeot on some of its cars. This uses 6 infra-red sensors mounted under the front bumper. These detect when the car is about to cross a white line, either solid or dashed, and trigger a warning to the driver. The system is deactivated when an indicator is being used, and when the car is travelling at less than 80km/h. The warning is in the form of a vibrator mounted on the side of the seat cushion. A driver drifting out of lane to the right will feel the vibration on their right side. This is claimed to mimic the effect of a rumble strip interacting with the right side wheels, and to trigger an instinctive driver response.

A more sophisticated system is the Lane Keeping Assist System (LKAS) offered on Honda cars. This uses a forward-looking camera mounted in front of the interior mirror, and image processing software to plot the positions of lane dividers in the forward view. When these detect that the vehicle is drifting out of lane, the electric power steering system applies a proportion of the restoring torque necessary to return the vehicle to its lane.

It has been suggested that with the deployment of more accurate navigation systems, future LDWS may utilise a database of road-width data to supplement the information gathered by their camera systems. No regulations currently exist that set out mandatory requirements for LDW systems. However, ISO17361:2007 offers a classification for different types of system and gives guidelines for their performance. Two different classes of device are defined, according to the minimum vehicle speed (V) and the minimum radius of curvature of the road:

- Class I systems operate when V>/=72km/h and R>500m
- Class II systems operate when V>/=61km/h and R>250m.

The performance of the device is defined in terms of the earliest and latest point at which the system triggers, in terms of the distance between the side of the vehicle and the lane marker

- The latest warning threshold is 0.3m inside the lane marker for all classes of system
- The earliest warning threshold depends on the rate of departure (lateral velocity component) of the vehicle, and varies between 0.75m and 1.5m according to system class.

2.6.9.4 Lane change assistants (LCA) and blind spot warnings (BSW)

Figure 176. Lane Change Assistant Warning Next to Mirror

These assist drivers intending to change lanes. The LCA monitors the adjacent lanes and warns the driver if another vehicle is likely to come within colliding distance during the lane change. This occurs, for example, if the other vehicle is located in the LCA-equipped vehicle's blind spot (See Figure 176).

There are several types of system depending on the extent of the warnings they are able to give. Blind Spot Warning systems monitor only the zones alongside the vehicle, whilst Lane Change Assistant systems monitor zones to the rear. Systems may use radar, cameras, infra-red or ultrasound for sensing the other vehicles. Ultrasonic sensors have proved popular for systems fitted to longer vehicles, where multiple sensors can indicate to the driver the position of the overtaking vehicle in the blind spot. The most common form of HMI is a warning symbol or light displayed in or close to the rear view mirror on the relevant side. The warning operates at two levels of urgency; if the driver is not signalling a steady light is used to draw the driver's attention. However, if the driver signals their intention to turn in that direction, the warning light flashes, and may be accompanied by an audible warning.

No regulations currently exist that govern the performance LDA or BSW systems, but ISO17387:2008 offers a classification for different types of system and gives guidelines for their performance. This standard does not cover systems fitted to articulated vehicle combinations.

- Type I systems monitor zones to the side (blind spot warning only)
- Type II systems monitor zones to the rear (closing warning only)
- Type III systems monitor zones to the side and rear.

In addition, systems are classified on their performance, according to the maximum closing speed at which they trigger (Vc) , and the minimum radius of curvature of the road:

- For Type A systems, Vc </= 36km/h and R>125m
- For Type B systems, Vc </= 54km/h and R>250m
- For Type C systems, Vc </= 72km/h and R>500m.

2.6.10 Concept vehicles

2.6.10.1 Royal Mail safety concept vehicle

Royal Mail have produced a demonstrator LGV that incorporates numerous devices to improve driver vision and traffic awareness.

Figure 177. Royal Mail Safety Concept Vehicle

The vehicle is based on a DAF CF85 410, coupled to a Cartwright trailer. As well as a number of features dedicated to the health and safety of the driver in handling the trailer, the combination incorporates a number of key features to help driver awareness and avoid cyclist and pedestrian collisions. These are:

- Sensors mounted on the nearside of the cab to detect pedestrians and cyclists in the driver's blind spot
- A high mounted video camera to the nearside of the driver's cab that allows the driver to detect cyclists and pedestrians in this area. By being mounted high on the cab, the view extends inwards right up to the edge of the cab and avoids contamination of the lens by dirt and spray. To avoid unnecessary distraction, the driver's display only activates when the vehicle is moving slowly and the driver has activated their indicator.

- Reversing sensors on the trailer detect objects to the rear while reversing. These are linked to the braking system and automatically stop the vehicle when there is an object less than 1m behind the trailer.
- While reversing, two loudspeakers generate a “white noise” warning to anyone close to the rear of the trailer. White noise is used in preference to more traditional types of warning, because it is easier for a pedestrian in the danger zone to locate the source of the sound. In addition, it generates less annoyance to people who are not in the immediate vicinity.

2.6.10.2 Keltbray safety concept

Figure 178. Keltbray Safety Concept Vehicle

Keltbray is a large demolition business which operates a fleet of 38 tipper lorries in the London area. As a safety initiative, they have installed these with a number of safety systems produced by Brigade Electronics, designed to avoid collisions with pedestrians and cyclists. The systems include the following:

- Installation of 4 Brigade “Sidescan” ultrasonic sensors on the nearside of the cab. These detect the presence of pedestrians or cyclists in the nearside blind spot, and alert the driver by an audible warning in the cab. The alert also triggers a visual signal in a small unit mounted at the top of the nearside windscreen pillar. This is positioned close to the blind spot mirror, drawing the driver's attention to this so that they will identify the cause of the signal in the mirrors. The visual display also displays the distance of the object from the vehicles's nearside.
- If the system is triggered while the vehicle's left turn indicator is activated, a loudspeaker on the outside of the cab transmits an audible message, warning the cyclist or pedestrian that the vehicle is about to turn.

- A Brigade reversing camera is installed on the back of the vehicle, and transmits an image to a screen on the header rail, whenever reverse gear is selected.
- While reversing, two loudspeakers on the back of the vehicle transmit a "white noise" to warn any pedestrians in the vicinity. This uses Brigade's BBS-TEK technology. White noise is used because it allows pedestrians to locate the source of the sound more easily, while the noise is more directional so its distribution is confined to a smaller area, reducing its environmental impact.

2.6.10.3 Volvo integrated safety vehicle

Figure 179. Volvo Integrated Safety Vehicle

The Volvo Integrated Safety Vehicle was presented in 2006 and incorporates many features to increase driver awareness and avoid collisions, developed under the EU-funded Integrated Safety Program. The features include the following:

- Blind-spot awareness using a 3-D integrated camera system. This alerts the driver to passing vehicles with a display on the instrument panel. If the driver signals their intention to change lanes in that direction, the system provides a haptic warning through the steering wheel. If they then steer in that direction, the system applies a steering torque that inhibits (but does not prevent) the manoeuvre.
- Start Inhibit, using sensors to detect objects in the front blind spot when the vehicle is stopped. If the driver attempts to pull away when objects are detected, vehicle movement is prevented.
- A Night-Vision Camera with Image Processing gives the driver a better view of the road.

- The Adaptive Driver-Vehicle Interface helps the driver to focus on safety critical driving tasks. The system uses a GPS map based system and automatic detection of roadside hazards to identify whether maximum attention is required. When this situation is detected, the system delays incoming mobile media messages and calls until the driver is better able to attend to them.
- There are other systems incorporated into the vehicle which, while not directly contributing to driver awareness, help minimise possible distractions.

2.6.10.4 Mercedes-Benz Actros integrated safety vehicle

Figure 180. Mercedes Benz Integrated Safety Vehicle

This is equipped with the following features dedicated to improving driver awareness:

- Active Brake Assist. Three radar units detect when the vehicle is closing on traffic in front. The system initially warns the driver and if they do not respond, applies the brakes to prevent a collision
- Large, electrically-heated mirrors
- Lane Departure Warning System

The Mercedes Benz website has the following to say about the visibility from the Integrated Safety Vehicle:

> "Good visibility is a major factor in accident prevention. With their large field of view, the exterior mirrors of the Actros already meet the future ECE regulation 46/02. Clear-lens headlamps with free-form reflectors provide optimal illumination of the road surface. On request, Actros models with air suspension are available with xenon headlamps for a further significant improvement in road illumination. The accompanying headlamp cleaning system improves safety even further.
> Visibility is improved for other road users by the spray guards in the wheel arches, which effectively prevent clouds of spray on wet roads. The optional daytime driving

> lights are already mandatory in many European countries, at least during the darker months of the year. These help other road users to see the truck under unfavourable lighting conditions, e.g. when the sun is low or when driving along tree-lined avenues."

It also has the following to say about the lane departure warning system:

> "In recent years the Actros has caused a sensation with its optionally available, electronic driver support and safety systems. The Telligent Lane Assistant warns the driver when the vehicle is in danger of leaving its lane unintentionally. For this purpose it uses a camera to constantly monitor the distance between the vehicle and the lane markings. If the truck appears likely to cross the lane marking, the driver is alerted by a noise similar to that produced by a corrugated surface on the relevant side."

Intentionally Blank

3 WORK PACKAGE 2: M_1 FORWARD FIELD OF VIEW – A/B PILLAR OBSCURATION

3.1 Aim

Phase 1 identified that the obscuration to the driver's field of view by A / B – pillars for category M_1 vehicles was a potential concern particularly with the conflicting requirement between thin sections for visibility and thick sections for structural crashworthiness. The aim of this Work Package is to investigate and understand the field of view obscuration issues for category M_1 vehicles and their relationship with reported accident data. Investigations will focus on the impact of A / B – pillar design, size and configuration.

3.2 Rationale

Earlier work for the Department for Transport under the Quality and Field of Vision project confirmed that A-pillar sizes were increasing in length, inclination angle from the vertical and thickness resulting in decrements to driver vision. Later work by Millington et al (2006) found that VRU may be obscured from view by A-pillars and that A-pillar obscuration was particularly problematic for smaller and taller drivers. This Work Package extends the understanding of vision-related issues in this area by considering the impact of more recent developments in A-pillar design as shown below in Figure 181, which illustrates a split A-pillar configuration.

http://www.google.co.uk/imgres?imgurl=http://www.ridelust.com/wp-content/uploads/opel_corsa_gsi_2.jpg&imgrefurl=http://www.ridelust.com/saturn-poised-to-adopt-opel-corsa/&usg=___wF8MlEQbVMl9JfTGJYdhgmQHtk=&h=332&w=500&sz=39&hl=en&start=58&um=1&itbs=1&tbnid=pYH95R1EKaRthM:&tbnh=86&tbnw=130&prev=/images%3Fq%3Dvauxhall%2Bcorsa%2Binterior%26start%3D54%26um%3D1%26hl%3Den%26sa%3DN%26ndsp%3D18%26tbs%3Disch:1

Figure 181. Recent trends in A-pillar design

In addition, this Work Package will also investigate the emerging area of interest concerning B-pillar design and its relationship to driver vision.

3.3 Task 1: Accident data

3.3.1 Introduction

As in the previous Work Package, the aim of this accident data Task is to ensure that the wider project activities are based on issues that are identified in the GB accident data. It is important that the overall project is strongly based on the real-world accident situation from which the issues of importance are identified from the perspective of the type and frequency of events and the resulting casualty severity outcomes. However, it is also useful to be able to identify in the data those issues which are considered to be of importance by 'users' and experts but which may not necessarily appear as significant problems in the accident data.

While existing studies were carefully examined during Phase 1, this Task has analysed recent accident national police-gathered data (STATS19) and in-depth data from the UK Government's On The Spot project. In order to focus the analysis, STATS19 data for 2008 was analysed using a new Cluster Analysis methodology to obtain representative scenarios for cars (A1 vehicles) where 'Vision affected by vehicle blind spot' was recorded on the database as a contributory factor (no. 710). In discussion with the other project members the results of this analysis were then used to undertake a case review of the OTS database in order to identify relevant case examples for closer examination.

3.3.2 Methodology

The Cluster Analysis methodology described in section 2.3.2 above was used.

3.3.3 Results

The national accident database STATS 19 (2008) contains 1,906 cases for which 'Vision affected by vehicle blind spot' was registered as a contributory factor. This includes 733 goods vehicles and 1009 cars – M_1 vehicles (Table 2). The analysis conducted in section 2.3.2 for goods vehicles, i.e. to identify representative accident circumstances where 'blind spot' was listed as a contributory factor, is replicated in this section for passenger cars (including taxis and hire cars). Vehicles that were parked, that did not make contact with another vehicle or object, or for which there was unknown or missing information in any of the fields were excluded from further consideration. The direction of movement of the collision partner (vehicle or pedestrian) was the main field with unknown information (80 cases). This left 862 passenger cars for full analysis.

A simplified dataset formed from a selection of the fields available in STATS19 was prepared for the 862 passenger cars for which 'blind spot' was identified as a contributory factor (Table 24). Where the categories for each field differ from those in STATS19, they were formed by aggregating categories in the source database with the exception of 'angle between paths' which is derived from the compass point origin ("from" direction) of both vehicles and the movement direction of the pedestrian where applicable. This parameter is intended to approximate where a driver might have been looking prior to impact to see the collision partner. Where, for example, the case vehicle was coming from the south and the other vehicle from the west, the angle is set to 'left 90 degrees'. For pedestrians crossing the road, the angle was set to a nominal 45 degrees (left or right) on the basis that they would not be moving fast enough to require the driver to turn the head towards 90 degrees.

Field	Type	Value	Description
Accident severity	Ordinal	0.0	Slight
		0.5	Serious
		1.0	Fatal
Light conditions	Nominal	1	Daylight
		2	Darkness
		9	Unknown
Road class	Ordinal	0.00	Motorway or A(M)
		0.33	A
		0.67	B
		1.00	C or unclassified
Junction type	Nominal	1	Not at junction
		2	Roundabout
		3	Junction (other)
Junction location	Nominal	1	Not at junction
		2	Entering
		3	Mid-junction
		4	Leaving
Angle between paths	Ordinal	0.00	Straight ahead
		0.25	Left 45 degs
		0.50	Left 90 degs
		0.75	Left 135 degs
		1.00	Behind
		1.25	Right 135 degs
		1.50	Right 90 degs
		1.75	Right 45 degs
Vehicle manoeuvre	Nominal	1	Going ahead
		2	Forwards - bend, turn L
		3	Forwards - bend, turn R
		4	Backwards
		8	Other
First point of impact	Nominal	0	No impact
		1	Front
		2	Back
		3	Right
		4	Left
Collision partner size	Ordinal	0.00	Pedestrian
		0.33	Pedal cyclist
		0.67	Motorcycle
		1.00	Car or larger

Table 24. Simplified dataset from STATS19 for cluster analysis of passenger cars

	Cluster										
	1	2	3	4	5	6	7	8	9	10–21	Total
Cluster representativeness (%)											
Slight	14	15	12	10	10	8	5	5	5	15	100
Serious	21	15	15	5	5	10	5	3	3	18	100
Fatal	0	20	40	0	0	20	20	0	0	0	100
Total	15	15	12	10	10	8	5	5	5	15	100

Table 25. Representativeness of accident scenarios for passenger cars

The outcome of the cluster analysis is shown in Table 26. The accident population is partitioned into 21 groups and the characteristics of the nine largest clusters which comprise 85% of the population are shown in columns. Cells highlighted in green indicate (a) that the distribution of numbers in the given field is significantly different from the distribution in the total population of 862 cars (chi-squared test to 99.5% significance) and (b) that the particular numbers highlighted are over-represented. This is intended to assist in identifying salient features. The 'representativeness' figures in Table 25 are derived directly from the 'accident severity' category, expressing the latter as row percentages.

	Cluster										
	1	2	3	4	5	6	7	8	9	10–21	Total
Accident severity											
Slight	105	110	86	76	76	58	36	38	38	111	734
Serious	26	19	18	6	6	12	6	4	4	22	123
Fatal	0	1	2	0	0	1	1	0	0	0	5
Total	131	130	106	82	82	71	43	42	42	133	862
Light conditions											
Daylight	110	122	92	81	61	57	38	42	0	78	681
Darkness	21	8	14	1	21	14	5	0	42	55	181
Total	131	130	106	82	82	71	43	42	42	133	862
Road class											
Motorway	0	0	2	0	13	5	3	0	0	10	33
A	16	66	16	31	32	23	25	18	18	77	322
B	13	15	12	11	6	7	2	6	4	17	93
C, unclassified	102	49	76	40	31	36	13	18	20	29	414
Total	131	130	106	82	82	71	43	42	42	133	862
Junction type											
No junction	0	0	106	0	81	71	0	0	0	16	274
Roundabout	0	0	0	2	0	0	41	0	0	43	86
Junction	131	130	0	80	1	0	2	42	42	74	502
Total	131	130	106	82	82	71	43	42	42	133	862
Junction location											
No junction	0	0	106	0	81	71	0	0	0	16	274
Entering	81	78	0	70	0	0	32	0	17	53	331
Mid-junction	24	35	0	12	1	0	9	0	6	36	123
Leaving	26	17	0	0	0	0	2	42	19	28	134
Total	131	130	106	82	82	71	43	42	42	133	862
Angle between paths (degs)											
Straight ahead	0	21	0	13	10	44	19	20	19	9	155
Left 45°	0	4	0	9	0	9	1	8	6	6	43
Left 90°	3	12	2	26	0	10	5	4	5	48	115
Left 135°	34	0	24	1	0	2	0	0	0	3	64
Behind	57	0	56	7	0	0	0	0	0	7	127
Right 135°	30	3	20	3	1	1	1	1	1	5	66
Right 90°	7	78	4	19	71	1	16	3	3	50	252
Right 45°	0	12	0	4	0	4	1	6	8	5	40
Total	131	130	106	82	82	71	43	42	42	133	862
Vehicle manoeuvre											
Going ahead	0	13	3	68	44	50	29	17	22	37	283
Forwards- left	0	0	1	14	3	4	8	5	0	58	93
Forwards- right	0	117	3	0	35	17	6	20	20	34	252
Backwards	131	0	99	0	0	0	0	0	0	4	234
Total	131	130	106	82	82	71	43	42	42	133	862
First point of impact											
Front	1	51	0	53	0	59	43	25	37	11	280
Back	119	1	99	7	0	1	0	0	0	10	237
Right	7	71	1	4	82	3	0	3	2	50	223
Left	4	7	6	18	0	8	0	14	3	62	122
Total	131	130	106	82	82	71	43	42	42	133	862
Collision partner size											
Pedestrian	111	7	85	11	1	20	2	11	14	15	277
Pedal cyclist	8	19	1	23	8	9	22	14	6	34	144
Motorcycle	7	43	6	4	29	5	9	6	9	42	160
Car or larger	5	61	14	44	44	37	10	11	13	42	281
Total	131	130	106	82	82	71	43	42	42	133	862

Table 26. Accident scenarios for passenger cars

Table 26 is a precise and succinct presentation of the results of the cluster analysis and it would not necessarily be informative to re-express it in words; however a few broad observations may be of interest. Clusters 1 and 3, which together constitute 27% of the population and 36% of killed or seriously injured cases (46 of 128) are predominantly cars reversing into pedestrians, the main difference being whether this occurs at a junction or not. This is the single most important 'blind spot' scenario for passenger cars suggested by the accident data. Cluster 2, which constitutes 15% of the population, is mainly cars entering or in junctions which collide with a car, motorcycle or pedal cycle that might have been visible on the right-hand side or forward-right side of the driver. It can be hypothesized that the A-pillar on the driver's side may be a factor in these accidents. Cluster 4, which constitutes 10% of the population, is analogous to Cluster 2 except that it involves the left-hand side and features a much lower proportion of motorcycles. Cluster 5, which also constitutes 10% of the population, involves motorised vehicles away from junctions with impact on the right side. This is likely to include many lane-change or similar incidents where vision along the driver's side of the vehicle and roadway is relevant. The only scenario among the nine largest that involves roundabouts is Cluster 7 which constitutes 5% of the population. The collision partner in most of these cases were pedal cyclists or motorcyclists. Daylight and darkness were included in the analysis in case pedestrians or two-wheeled vehicles (with just one headlight) were more frequently involved, however the largest group to occur solely in darkness, Cluster 9, does not reveal a strong imbalance in road user type, i.e. collision partner size, compared to the whole population.

3.3.4 Conclusion

In summary, the most common accident scenarios for passenger cars where 'blind spot' was registered in STATS 19 as a contributory factor are:

- Reversing into pedestrians (Clusters 1 and 3)
- Right-hand side and frontal impacts at (non-roundabout) junctions with an over-representation of motorcycles and larger vehicles (Cluster 2)
- Left-hand side and frontal impacts at (non-roundabout) junctions with an over-representation of pedal cyclists, cars and larger vehicles (Cluster 4)
- Right-hand and frontal impacts away from junctions consistent with lane-change type of incidents (Cluster 5).

Clusters 2, 4 and 7 were considered to be of particular interest to Task 2. On this basis the OTS database was interrogated and some 50 in-depth case examples representing these clusters were provided to Task 2 for consideration.
In addition clusters 1 and 3 were relevant to Work Package 3.

3.4 Task 2: Digital human modelling

Following a similar approach to section 2.5.3, DHM was performed using the SAMMIE system to establish a full volumetric evaluation of both direct and indirect fields of view of the category M_1 vehicles. In addition, specific evaluations were performed of the occluded area generated from A-pillars, the split A / A1-pillars and B-pillars. Finally an incremental evaluation was made of the changes to field of view produced through a reduction in A-pillar width for one vehicle (the Volkswagen Golf). From these evaluations specific blind spots or other field of vision problems are to be identified.

The DHM evaluation includes the following:

1. Three appropriate category M_1 vehicles identified to provide a variety in the location and size of the pillars (Hyundai i10, Volkswagen Golf, Volkswagen Touran). Two of the vehicles share the same platform, one of which includes the split A-pillar configuration (Golf and Touran).
2. The capture of 3d data from these vehicles.
3. CAD Modelling of the vehicles and the building of mirror Classes I and III.
4. The CAD models are then analysed to determine the blind spots with reference to a 360° field of view. The field of view is represented by volumes of visible space through window apertures and mirrors visualised using a ray tracing method. This is performed using a suitable range of size of human model to represent the variability of the European driving population (smallest female capable of driving the vehicle to 99^{th}%ile Dutch male i.e. tallest European population).
5. Scenarios defined in Task 1 are modelled to understand the impact of the 360° field of view identified in point 4 above for right hand drive vehicles.

3.4.1 Data capture of the assessment vehicles

All of the vehicles assessed in this project were recreated from the real vehicles through a process of data capture using a Faro arm and touch probe system. At the MIRA vehicle testing facilities in Nuneaton, the touch probe was used to trace contours on the vehicle to capture all of the major exterior surfaces and key interior elements as well as glazed apertures and mirror surfaces. The following features were traced for each vehicle:

- The outer edges of exterior panels including roof, pillars, doors, bonnet and boot / tailgate
- The vertical profiles of exterior panels to capture the surface curvature
- The outer edges of the windows
- The limit of the visible area of windows
- The outer edges and profiles of all interior pillars
- The outer edges and profiles of front and rear trim in proximity to the windows
- The dash, and instrument binnacle
- The steering wheel and its adjustability
- The outer edges of the pedals
- The outer edges and profiles of the driver's seat in its lowest rearmost and upper forward most positions
- The outer edges and profiles of the passenger and rear seats
- The outer edges and profiles of the head restraints and the limits of their adjustability
- The outer edges of mirrors and a vertical and horizontal trace across the centre of the mirror to capture the curvature

This procedure resulted in a neutral format datafile consisting of the traced line segments. This datafile was then taken into the CAD tool PRO/Engineer and curves mapped onto the captured data. From these curves, surfaces were created to model the various features of the vehicle. Once the vehicle was created the surfaces were then exported into the SAMMIE Digital Human Modelling system. In SAMMIE the vehicle elements were named, grouped, and coloured appropriately to create a realistic looking model. Where necessary, generic additional elements such as wheels, bumpers, lights, etc. were added to increase realism. Adjustability for mirrors, seats, head restraints, and steering wheels were implemented as 'modifications' within SAMMIE to provide automated and constrained control over the positioning of those elements.

3.4.2 Digital human models, positioning and posturing

As part of the data capture process the SAE h-point manikin was used to establish a h-point to reference for positioning the human models within the SAMMIE system. The h-point manikin was positioned in the real vehicle with the seat in its lowest rearmost position, loaded to 75Kg and with its legs set to the 95%ile length with the right foot placed on the accelerator pedal. To aid posturing, the torso, hip and lower leg structure of the manikin was also scanned to allow a virtual equivalent of the h-point manikin to be oriented accurately within SAMMIE.

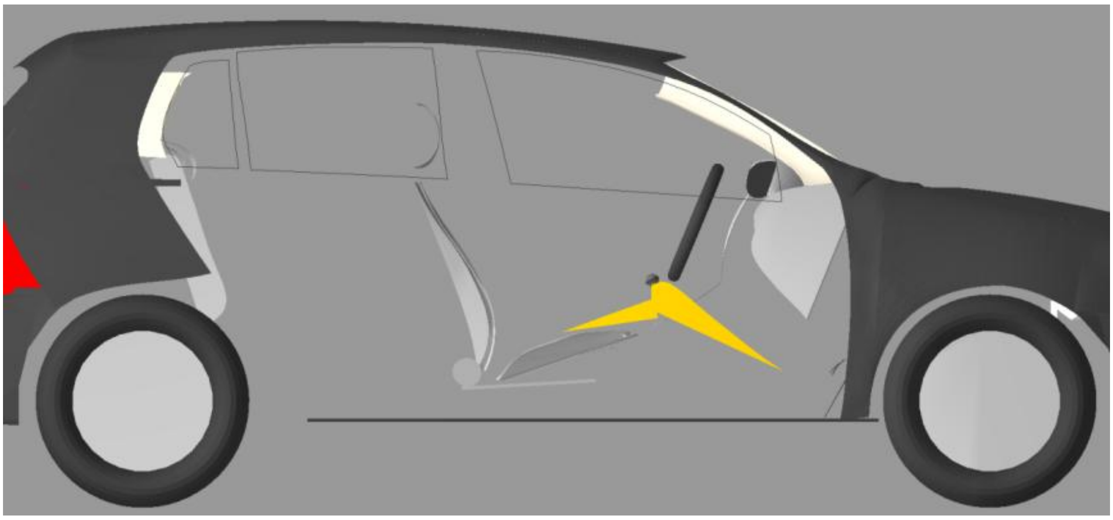

Figure 182. Volkswagen Golf showing the driver's seat and the scan of the thigh and leg of the h-point manikin (orange)

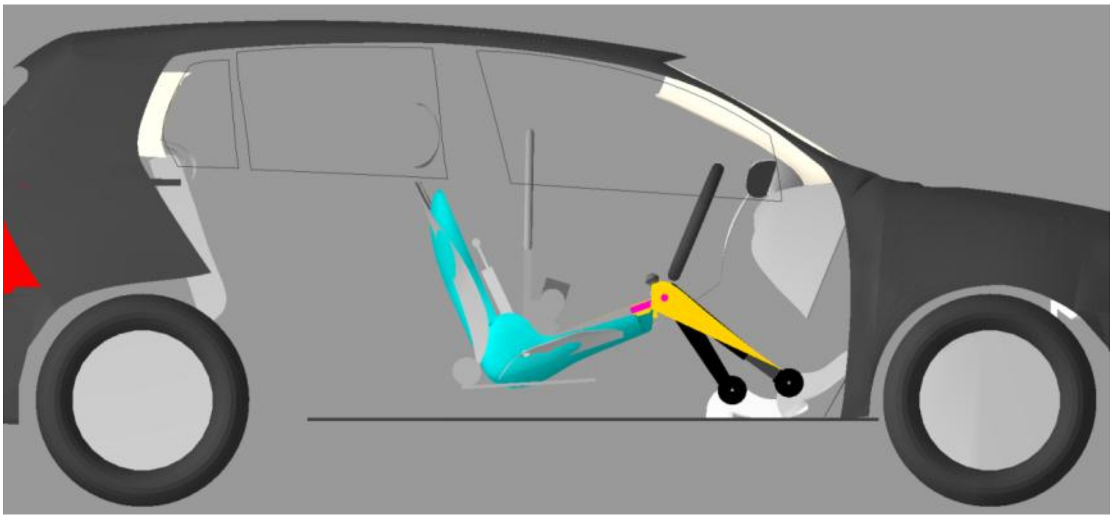

Figure 183. Volkswagen Golf showing the driver's seat and the virtual h-point manikin mapped to the scanned h-point manikin

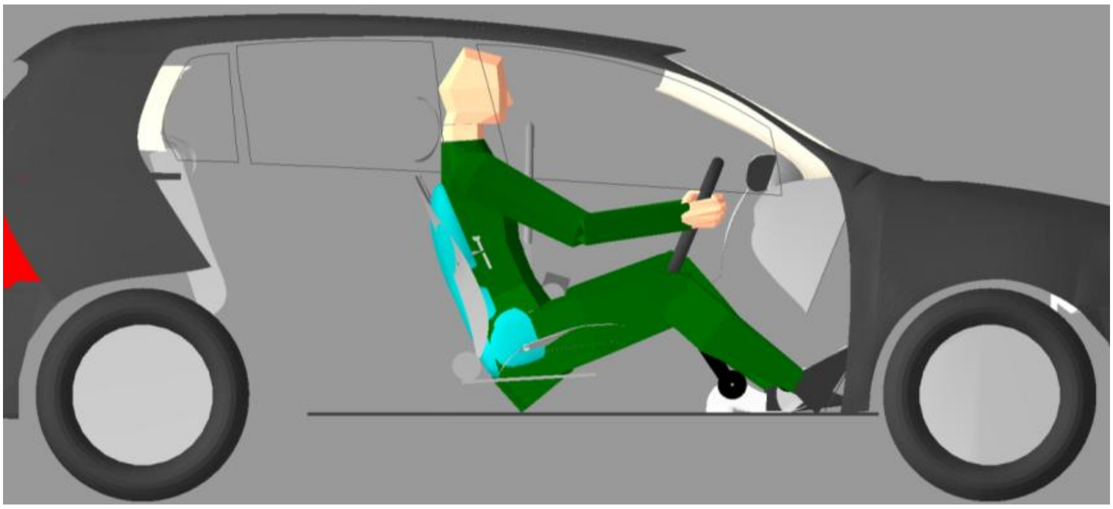

Figure 184. Volkswagen Golf showing the Dutch male driver positioned based in the data from the h-point manikin

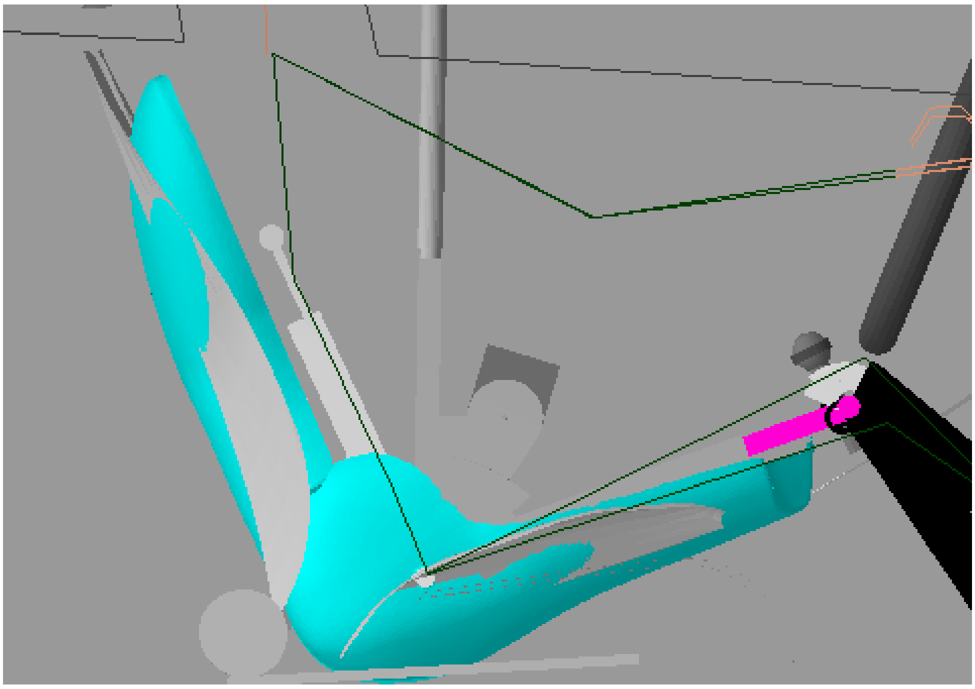

Figure 185. The human model 'stick man' with its h-point mapped to the h-point of the manikin

Figure 182, Figure 183, Figure 184, and Figure 185 show the process of matching the position and initial posture of the human model within SAMMIE based on the data captured from the scanning activity. To finalise the posture the driver is reclined to provide a realistic driving posture, relatively reclined for the larger driver, relatively upright for the smaller driver. In addition, the view of the driver and the position of the steering wheel (if it is adjustable), to ensure a clear view of the road and of the instrument binnacle are used to help posture the human (see Figure 186).

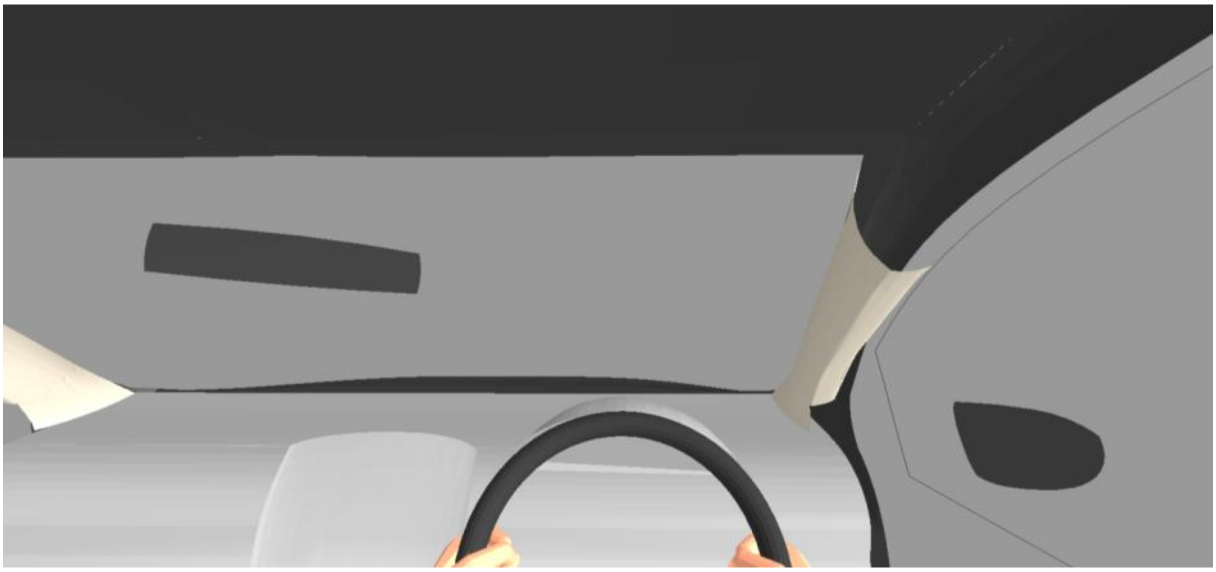

Figure 186. Volkswagen Golf showing the view of the Dutch male

Further posturing is done to provide an appropriate grip of the steering wheel in the recommended quarter to three, or ten to two positions, and to position the right leg on the accelerator pedal.

3.4.3 Evaluation vehicles

The category M_1 vehicles selected for the DHM evaluations included:

- A current (2010 on) model Volkswagen Golf (Golf VI platform) shown in Figure 187 A-C.
- A current (2010 on) model Volkswagen Touran – this MPV style vehicle is based upon the current Golf VI platform and has a split A-pillar configuration, shown in Figure 188 A-C.
- A current (2010 on) model Hyundai i10 shown in Figure 189 A-B.

Figure 187A. Volkswagen Golf

Figure 187B. Volkswagen Golf

Figure 187C. Volkswagen Golf

Figure 188A. Volkswagen Touran MPV

Figure 188B. Volkswagen Touran MPV

Figure 188C. Volkswagen Touran MPV

Figure 189A. Hyundai i10

Figure 189B. Hyundai i10

3.4.4 Methodology

All three vehicles were scanned, and imported in the SAMMIE system using the protocol defined in 3.4.1. The vehicles were fitted with Class I, and III mirrors and all had front, side and rear windows as shown.

The evaluation methodology consisted of three phases all evaluating direct vision through the glazed areas of the vehicle together with indirect vision through the mirrors available on each vehicle. The eye point used for the evaluations was determined using the initial posturing of the human models within the SAMMIE system (see 3.4.2) and specific postures based on the task being undertaken.
All three phases of evaluation were completed with two 'driver' human models (see Table 27). The human models used consisted of both the largest and smallest people capable of driving the vehicle. The human models able to 'fit' the vehicles with a realistic driving posture are shown in the table below. Note that the human models used are relatively consistent apart from the 35%ile UK female used for the Touran*. This is due to the Touran's relatively high seat and thus inability to accommodate smaller drivers.

	Category M_1 vehicles		
	Volkswagen Golf	Volkswagen Touran	Hyundai i10
Largest Driver	99%ile Dutch male	99%ile Dutch Male	99%ile Dutch Male
Smallest Driver	5%ile UK female	35%ile UK female*	5%ile UK female

Table 27. Human models used in the evaluations of WP 2

The three phases of evaluation included:

1. A 360° field of view assessment showing a volumetric analysis of direct and indirect vision. To complement the volumetric approach three 2D field of view assessment plans are shown including visual plots at the ground plane, the ground plane +1000mm and the ground plane +1560mm (95%ile UK Male shoulder height)
2. Three scenarios established via accident data taken from the On The Spot database. In each of these scenarios, the three vehicles, with two different driver extremes, (99^{th} %ile Dutch Male and the smallest UK female capable of driving the vehicle) are assessed to attempt to evaluate the possibility of the accident being caused by offside A-pillar obscuration, nearside A-pillar obscuration and offside B-pillar obscuration.
3. An assessment using only the Volkswagen Golf to quantify the impact of A-pillar size. Plots are taken of the field of view obscuration from the current Golf A-pillar and in 10mm incremental decrements of both width and length of

the A-pillar. The assessment is made in both visual angle and also real world obscuration.

3.5 Task 3: Analysis and write-up

3.5.1 360° volumetric field of view evaluations

3.5.1.1 M_1 – Volkswagen Golf

3.5.1.1.1 99th %ile Dutch Male

The postures adopted for direct forward (windscreen) and indirect rearward (Class I and Class III mirrors), direct rearward (rear window), and direct left and right (side windows) views are shown in Figure 190, Figure 191, Figure 192, and Figure 193 below.

Figure 190. Forwards view posture (99th%ile Dutch male)

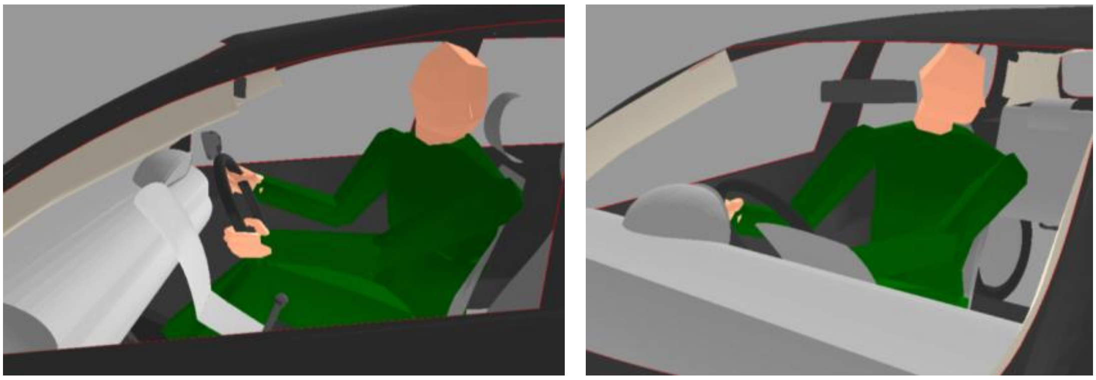

Figure 191. Rearwards view posture (99th%ile Dutch male)

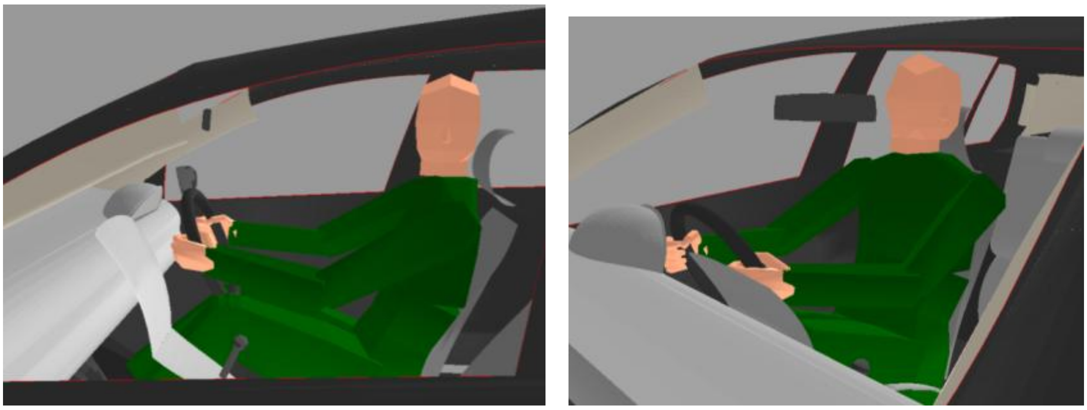

Figure 192. Left view posture (99th%ile Dutch male)

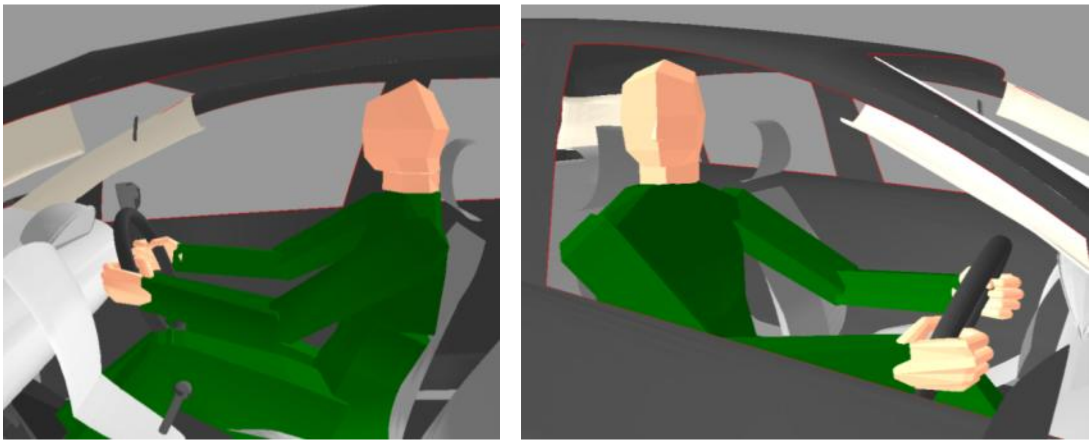

Figure 193. Right view posture (99th%ile Dutch male)

Figure 194, Figure 195, Figure 196, Figure 197 and Figure 198 show the full 360° volumetric projections from the windows as well as the two Classes of mirror fitted.

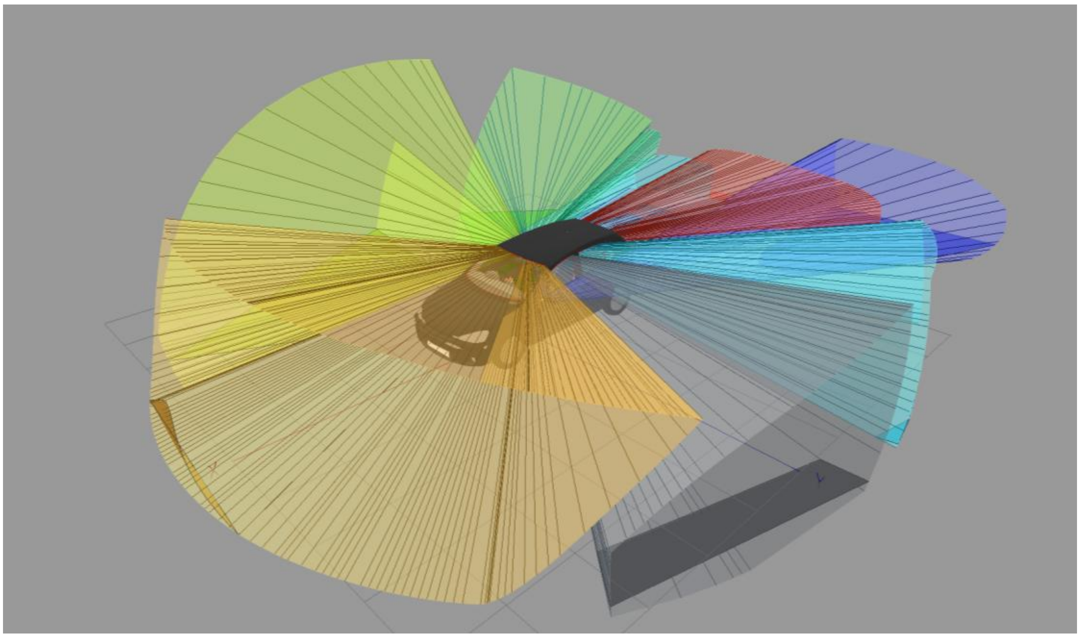

Figure 194. The projected volumes that demonstrate the 360° visibility (view from front left)

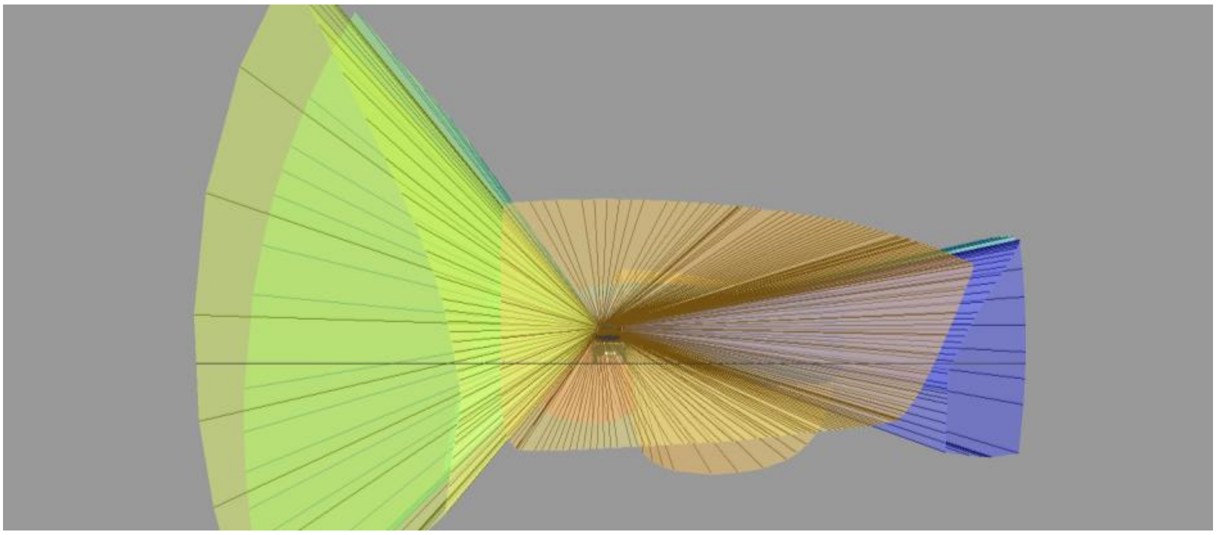

Figure 195. 360° visibility projections – front elevation

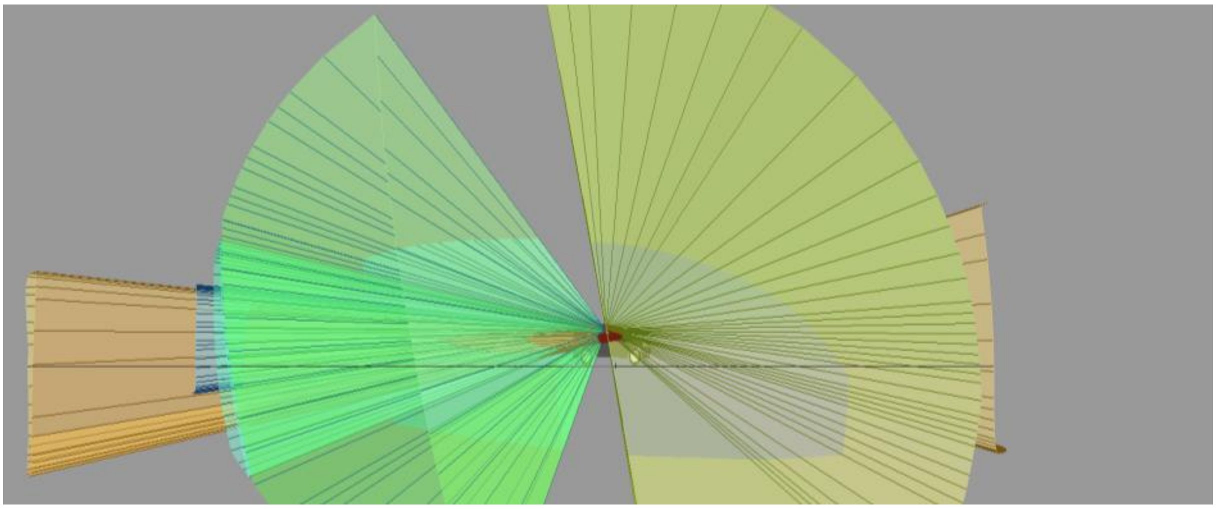

Figure 196. 360° visibility projections – right elevation

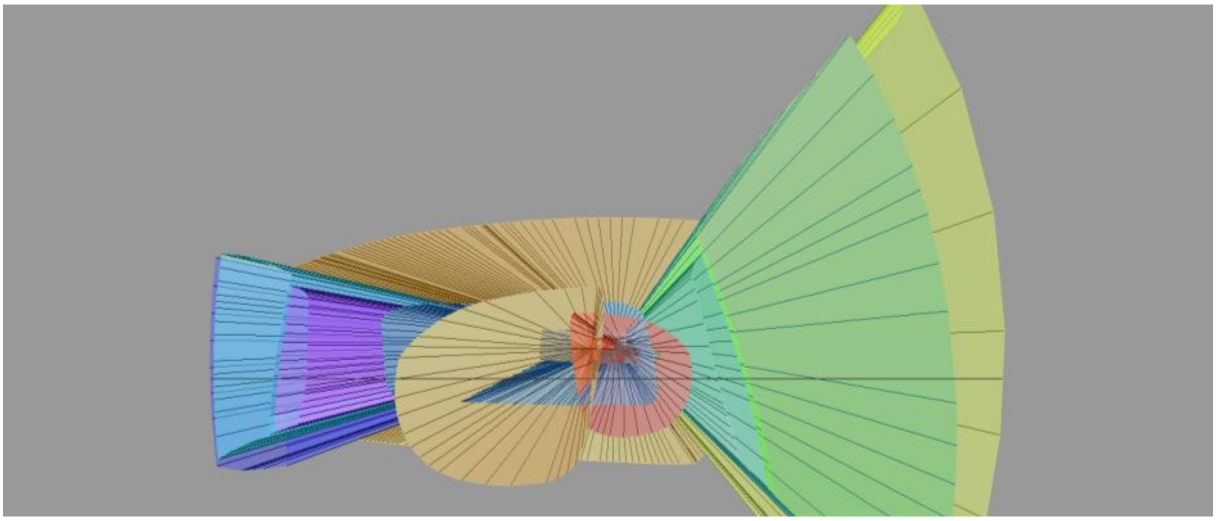

Figure 197. 360° visibility projections – rear elevation

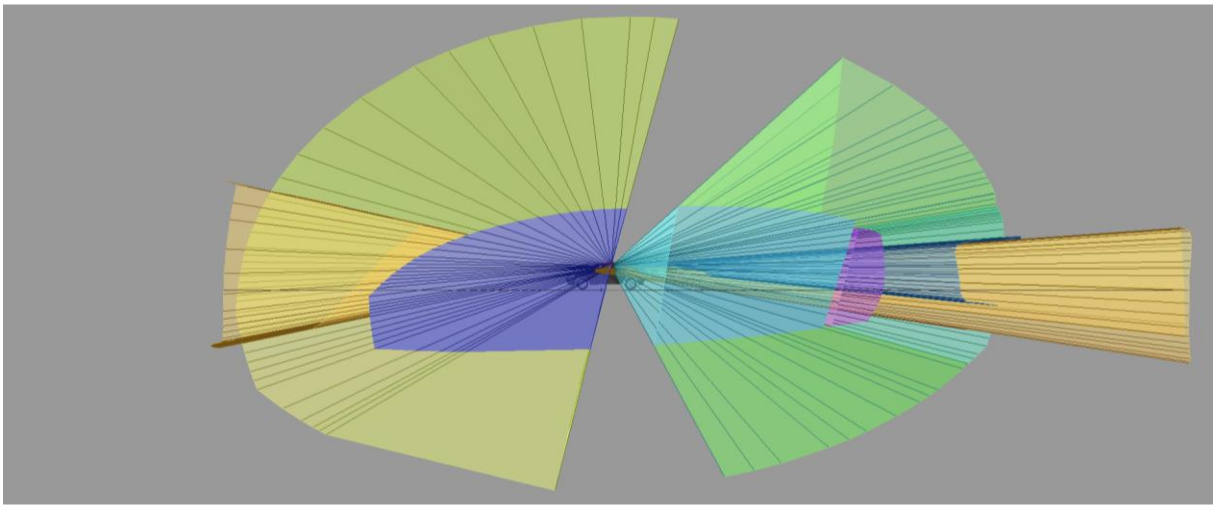

Figure 198. 360° visibility projections – left elevation

In addition to the volumetric plots, three 2D plots are shown in Figure 199, Figure 200 and Figure 201 at three planes: ground plane, ground +1m, and ground +1.56m. The +1.56m has been taken to represent the visibility at 95%ile UK male shoulder height. The plots show three visual areas: green is the area of visibility from direct vision through window apertures; blue is indirect vision through mirrors; and red is the area not visible to the driver.

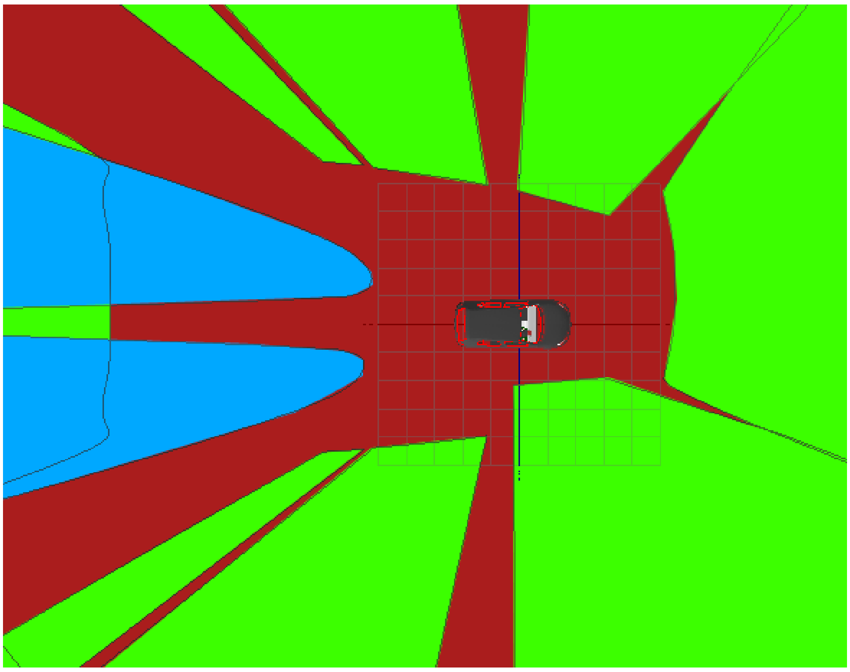

Figure 199. 360° visibility projections – ground plane

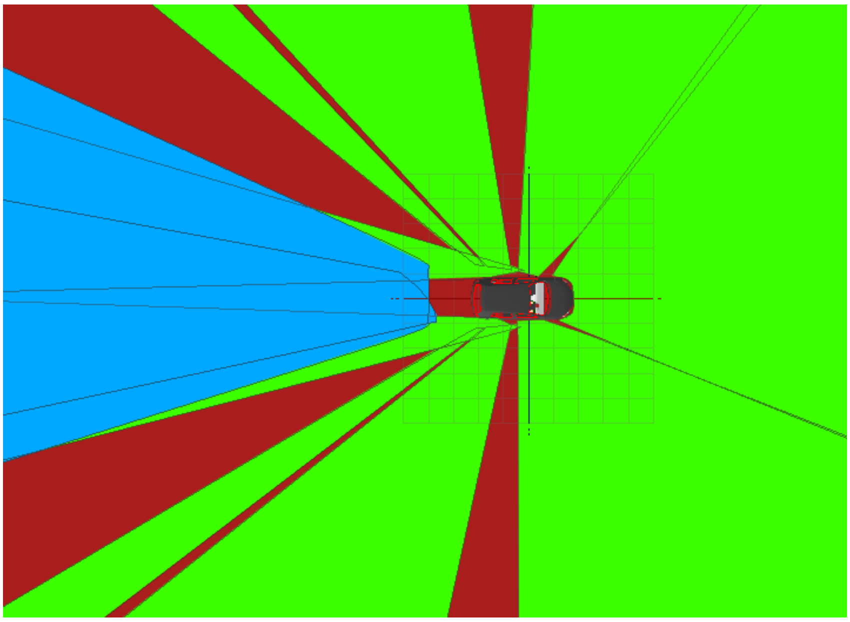

Figure 200. 360° visibility projections – ground +1m plane

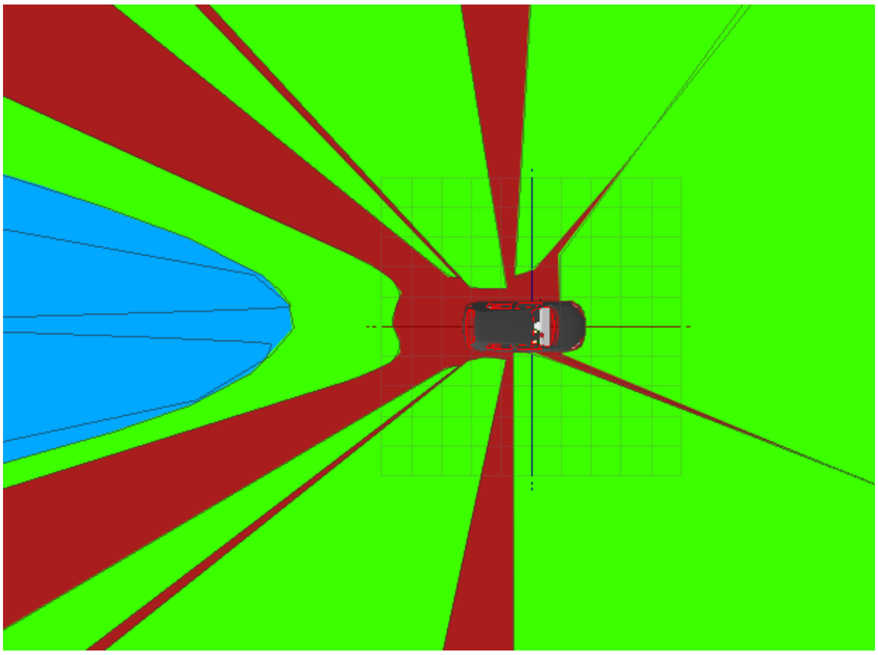

Figure 201. 360° visibility projections – ground +1.56m plane

The projections clearly identify the blind spots around the vehicle. The blind spots appear significant on the ground plane but shrink significantly at +1m. There is a clearly identifiable zone directly rearwards of the vehicle that is obscured irrespective of the height of projection. B and C pillar obscuration is also significant. Interestingly, different viewing postures for front, left and right windows effectively removes obscuration from the A-pillars at a distance from 2-12m from the eye point.

3.5.1.1.2 5th %ile UK female

The postures adopted for direct forward (windscreen) and indirect rearward (Class I and Class III mirrors), direct rearward (rear window), and direct left and right (side windows) views are shown in Figure 202, Figure 203, Figure 204 and Figure 205 below.

Figure 202. Forwards view posture (5th%ile UK female)

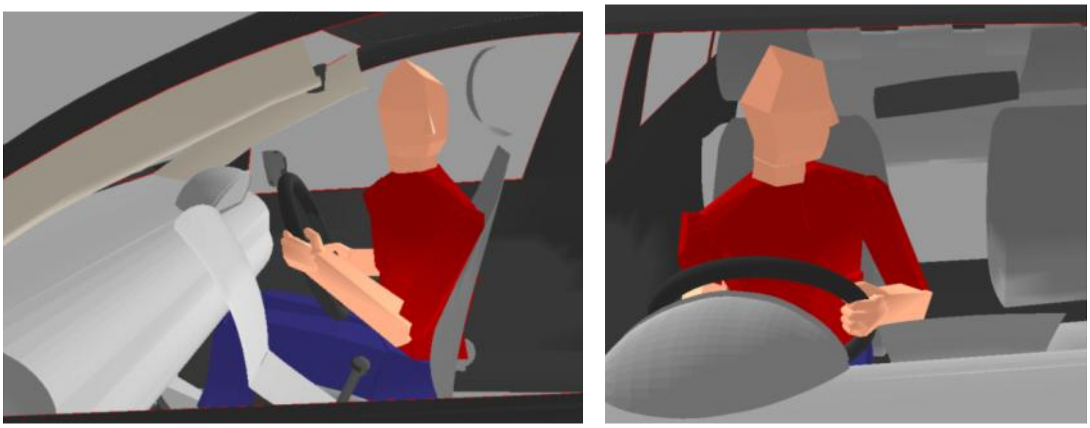

Figure 203. Rearwards view posture (5th%ile UK female)

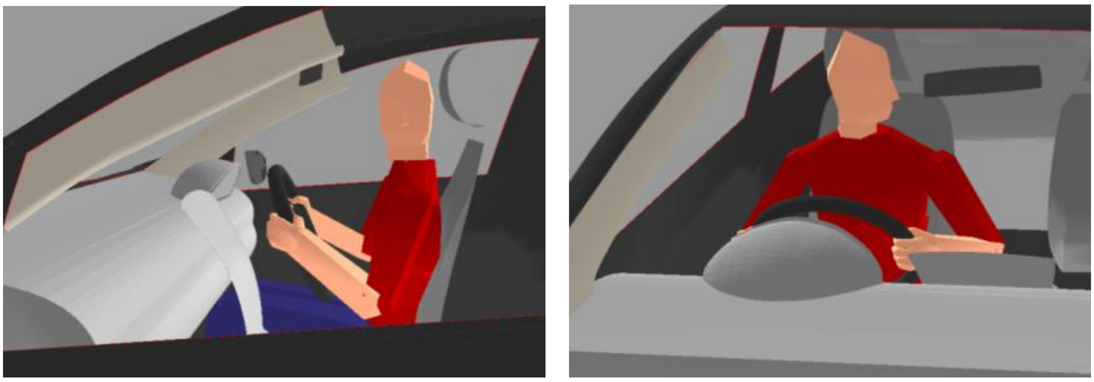

Figure 204. Left view posture (5th%ile UK female)

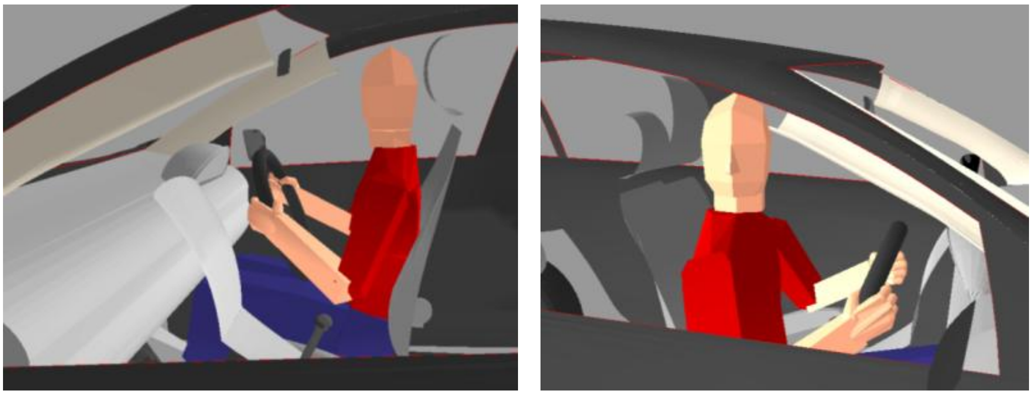

Figure 205. Right view posture (5th%ile UK female)

Figure 206, Figure 207, Figure 208, Figure 209 and Figure 210 show the full 360° volumetric projections from the windows as well as the two Classes of mirror fitted.

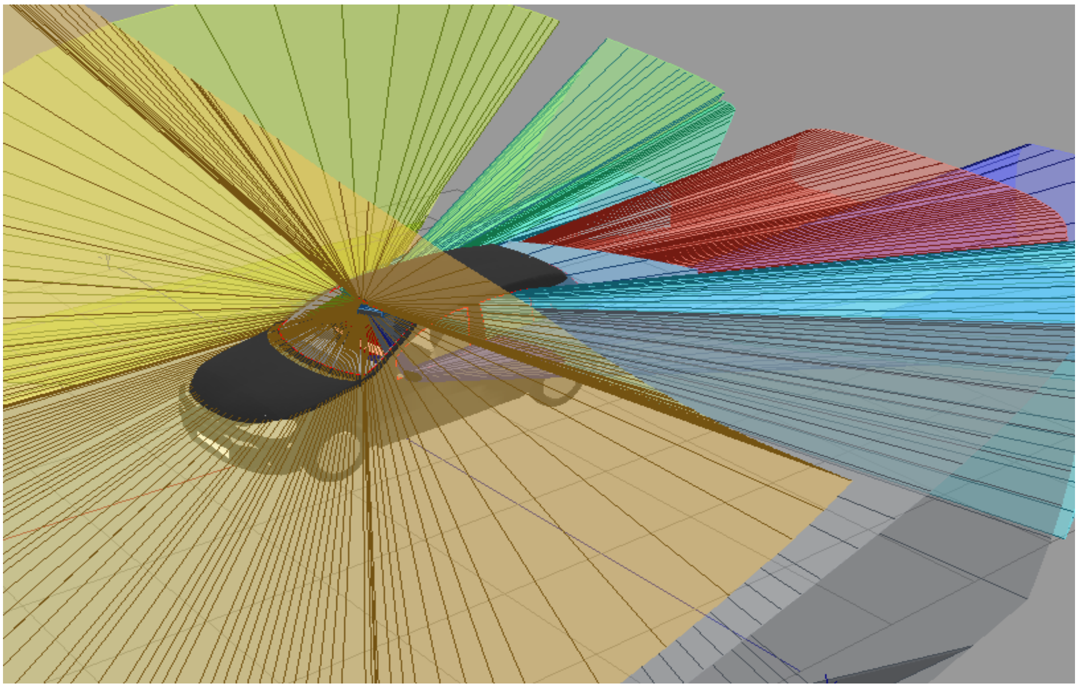

Figure 206. The projected volumes that demonstrate the 360° visibility (view from front left)

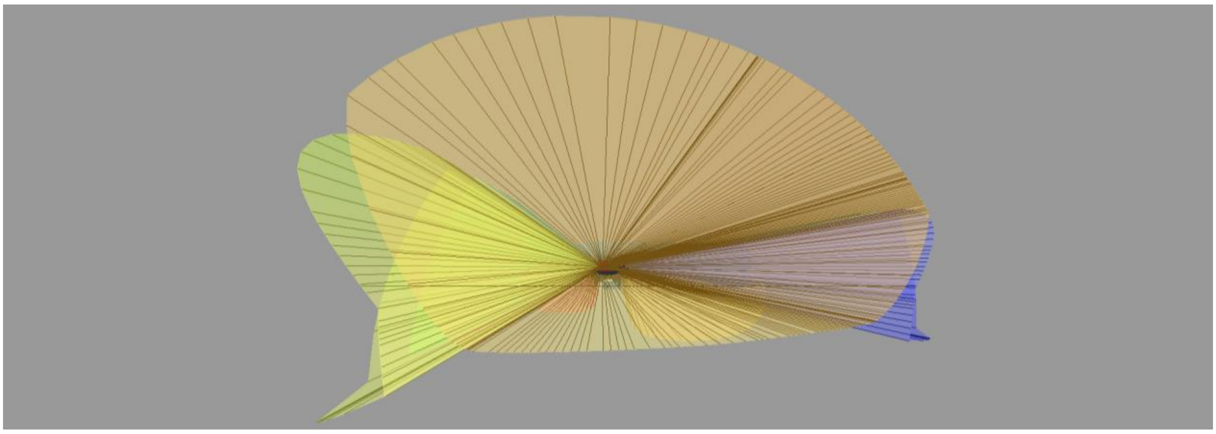

Figure 207. 360° visibility projections – front elevation

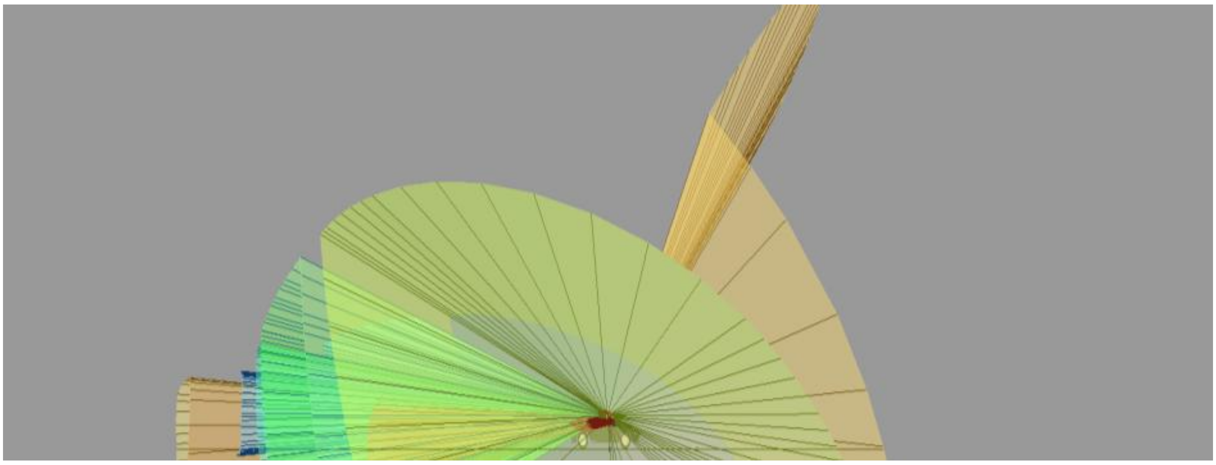

Figure 208. 360° visibility projections – right elevation

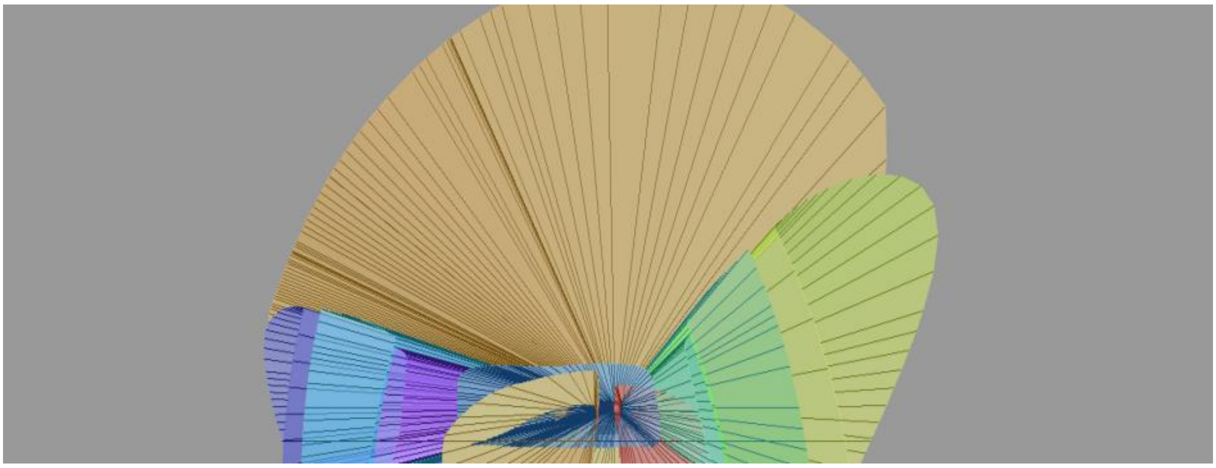

Figure 209. 360° visibility projections – rear elevation

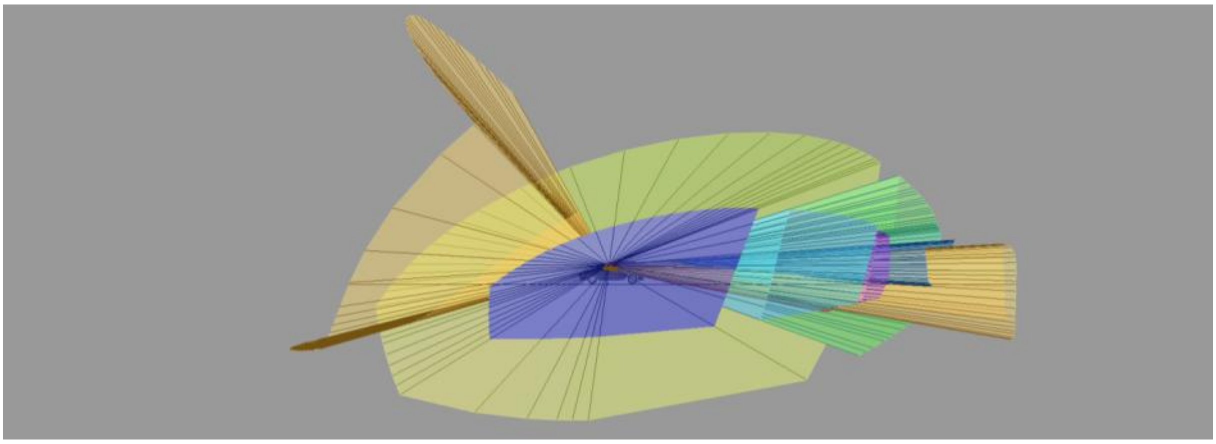

Figure 210. 360° visibility projections – left elevation

Again, three 2D plots are shown in Figure 211, Figure 212 and Figure 213 at three planes: ground plane, ground +1m, and ground +1.56m. The plots show three visual areas: green is the area of visibility from direct vision through window apertures; blue is indirect vision through mirrors; and red is the area not visible to the driver.

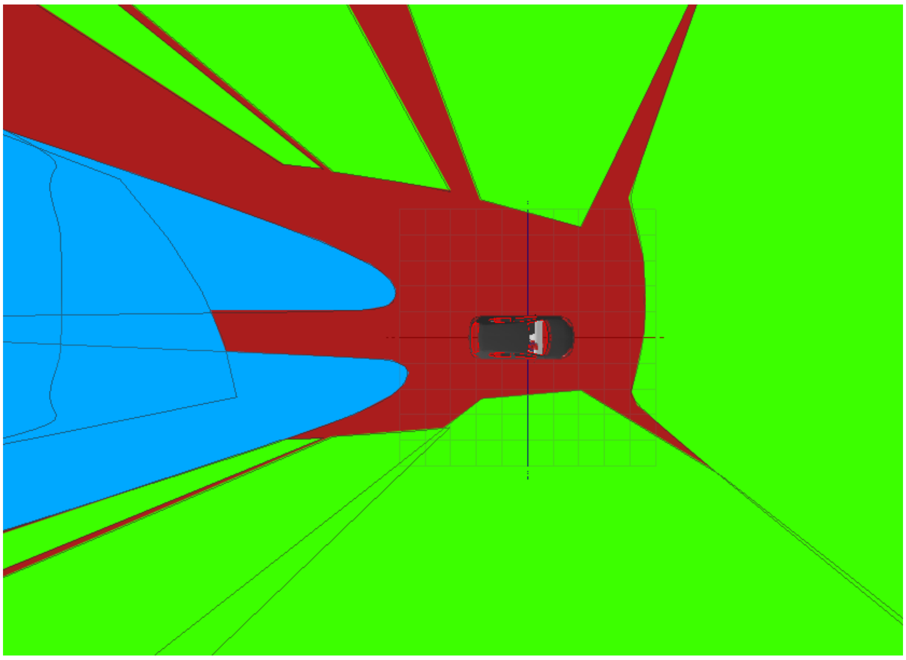

Figure 211. 360° visibility projections – ground plane

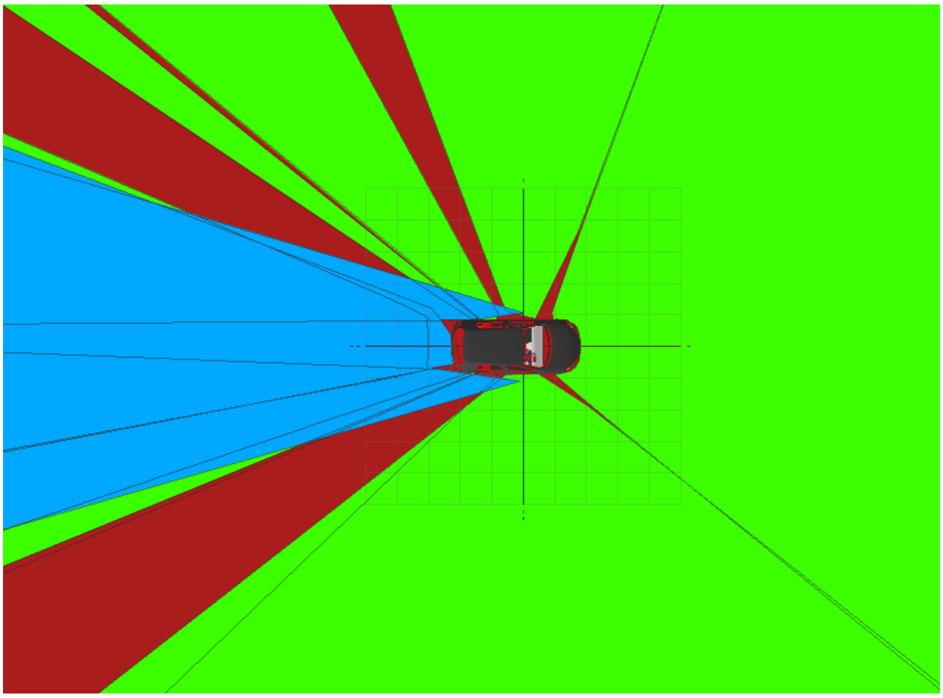

Figure 212. 360° visibility projections – ground +1m plane

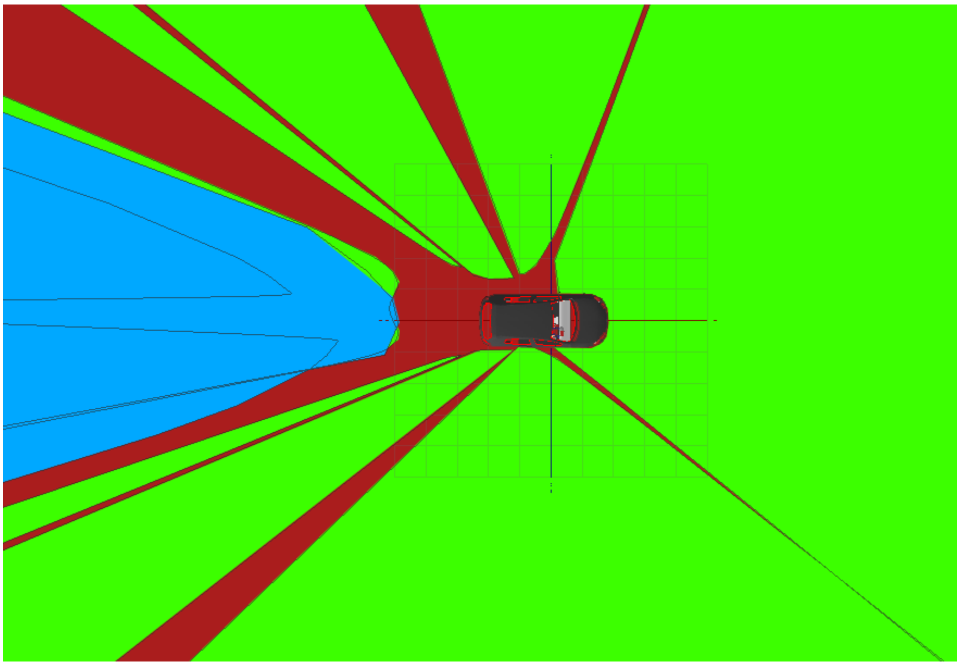

Figure 213. 360° visibility projections – ground +1.56m plane

As with the Dutch male the projections clearly identify the blind spots around the vehicle. The blind spots appear significant on the ground plane but shrink significantly at +1m. The area directly rearwards of the vehicle is again obscured but is visible at +1m. B and C pillar obscuration is reduced over that of the Dutch male. A-pillar obscuration appears relatively similar but is not always eliminated over distance in the same way as with the Dutch male, due to the proximity of the eye point to the pillars.

3.5.1.2 M_1 – Volkswagen Touran

3.5.1.2.1 99^{th} %ile Dutch male

The postures adopted for direct forward (windscreen) and indirect rearward (Class I and Class III mirrors), direct rearward (rear window), and direct left and right (side windows) views are shown in Figure 214, Figure 215, Figure 216 and Figure 217 below.

Figure 214. Forwards view posture (99th%ile Dutch male)

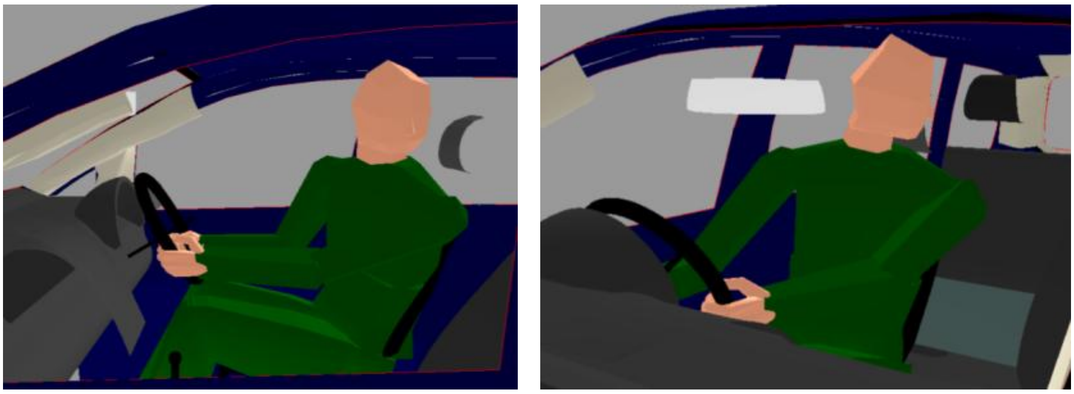

Figure 215. Rearwards view posture (99th%ile Dutch male)

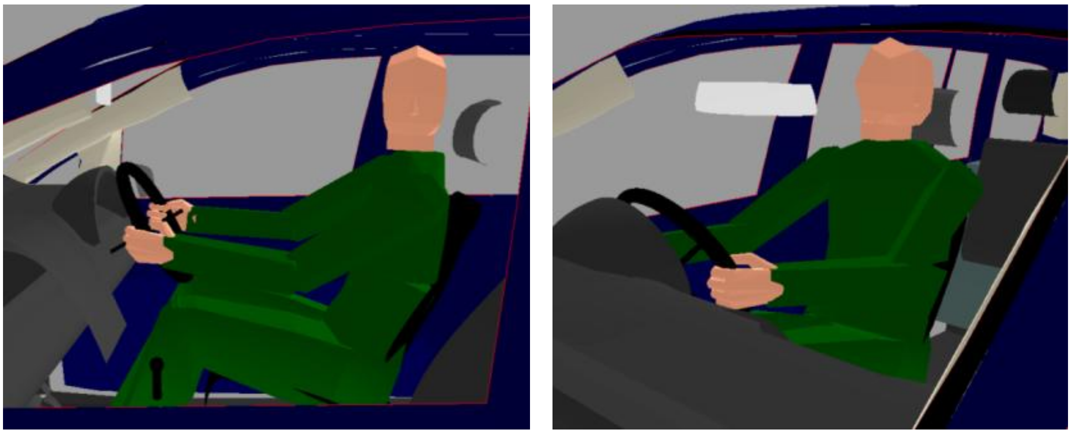

Figure 216. Left view posture (99th%ile Dutch male)

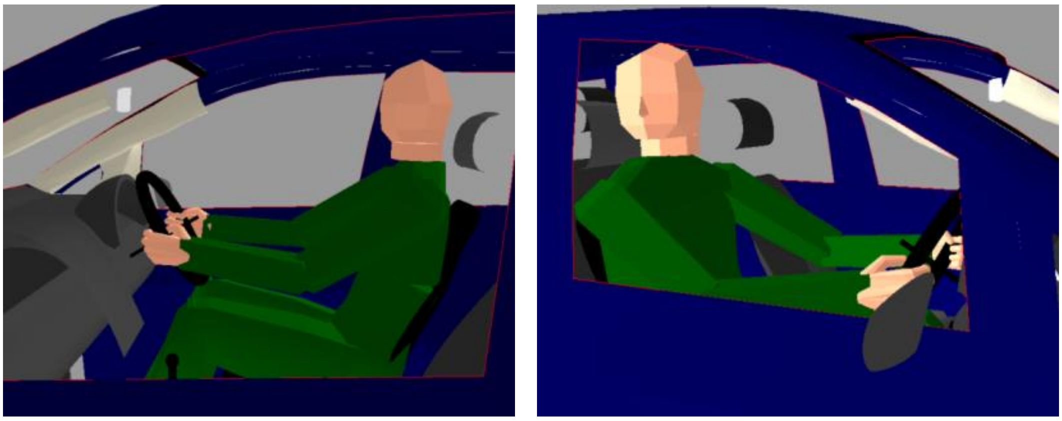

Figure 217. Right view posture (99th%ile Dutch male)

Figure 218, Figure 219, Figure 220, Figure 221 and Figure 222 show the full 360° volumetric projections from the windows as well as the two Classes of mirror fitted.

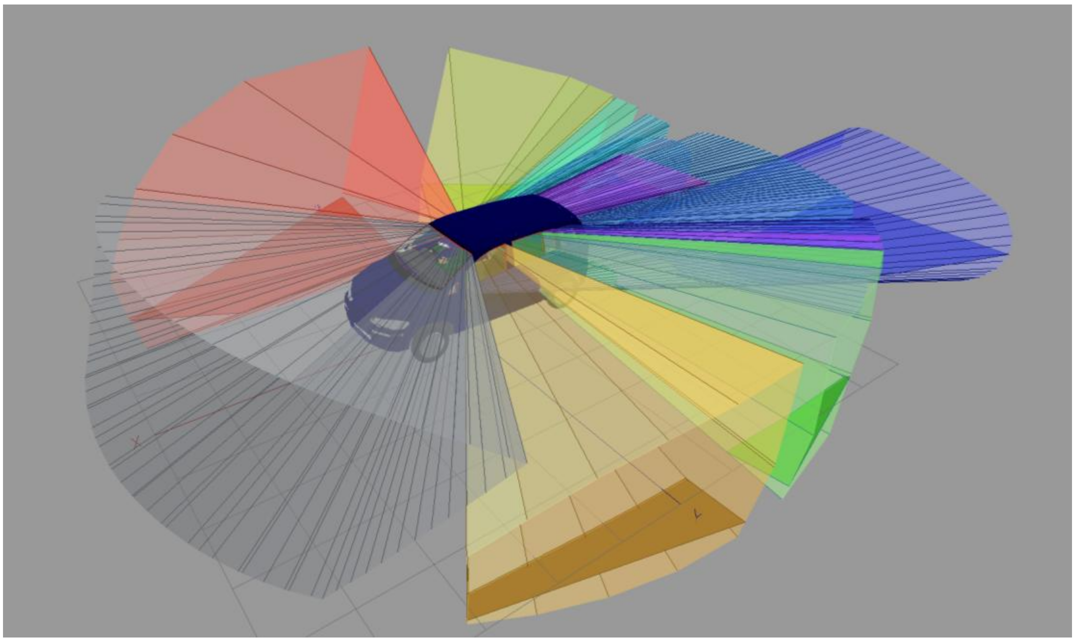

Figure 218. The projected volumes that demonstrate the 360° visibility (view from front left)

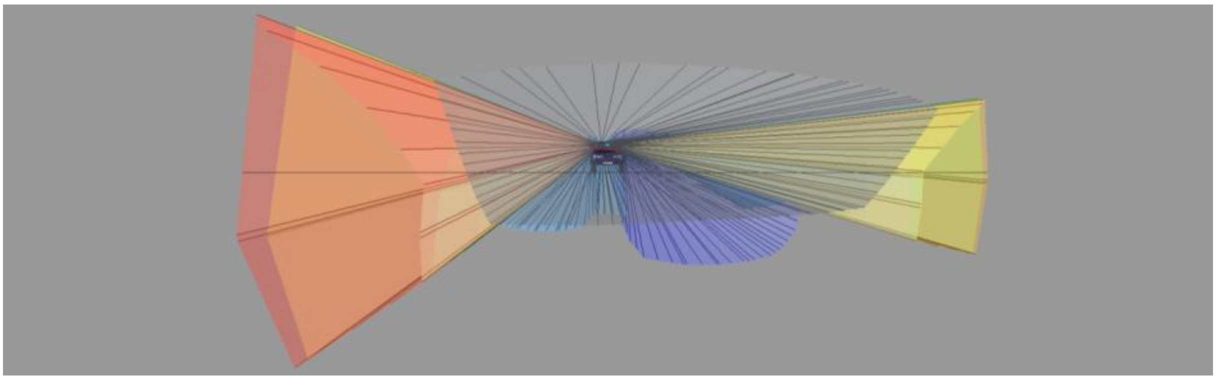

Figure 219. 360° visibility projections – front elevation

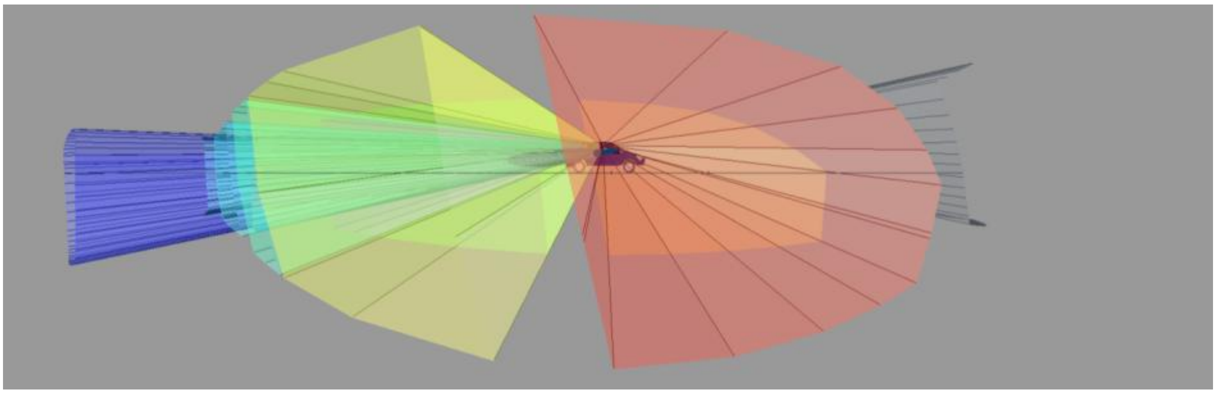

Figure 220. 360° visibility projections – right elevation

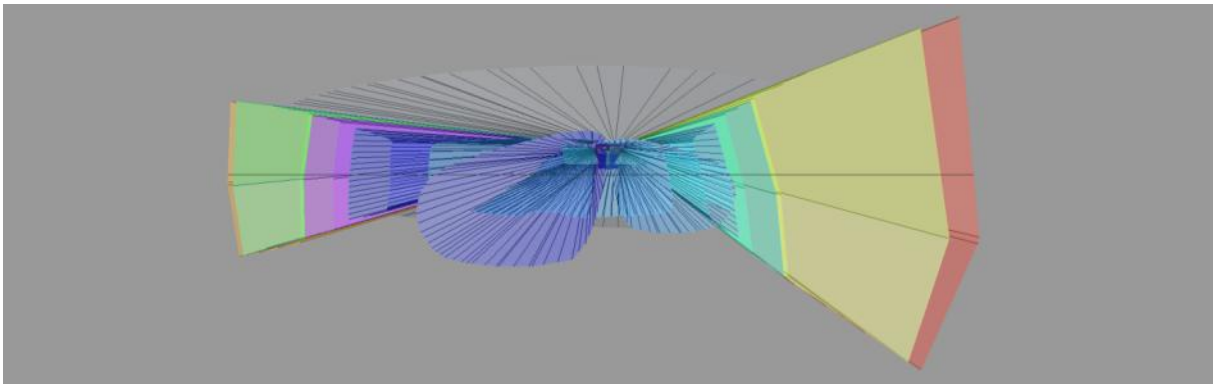

Figure 221. 360° visibility projections – rear elevation

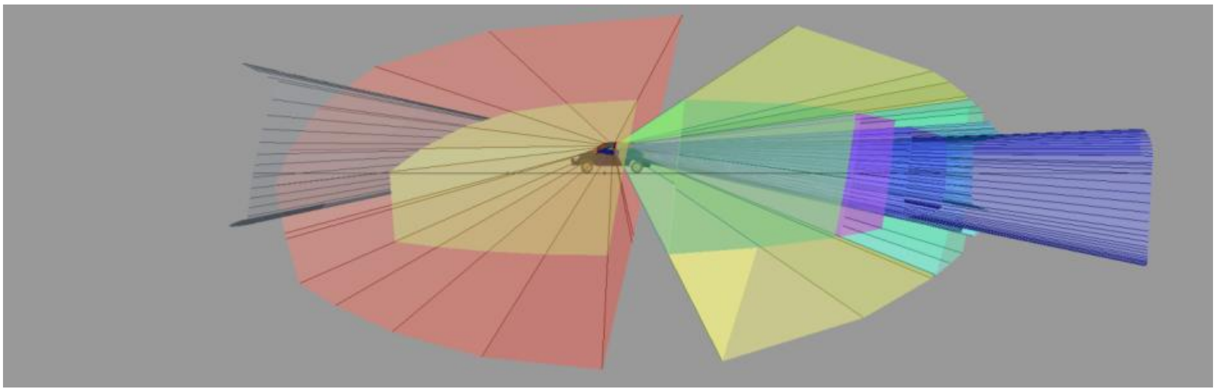

Figure 222. 360° visibility projections – left elevation

Again, three 2D plots are shown in Figure 223, Figure 224 and Figure 225 at three planes: ground plane, ground +1m, and ground +1.56m. The plots show three visual areas: green is the area of visibility from direct vision through window apertures; blue is indirect vision through mirrors; and red is the area not visible to the driver.

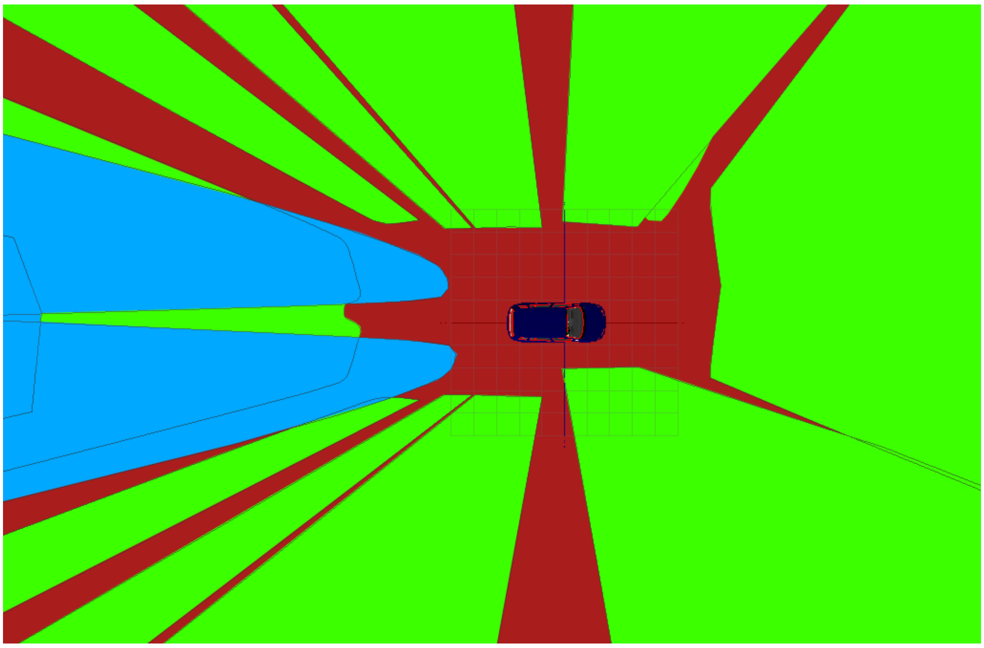

Figure 223. 360° visibility projections – ground plane

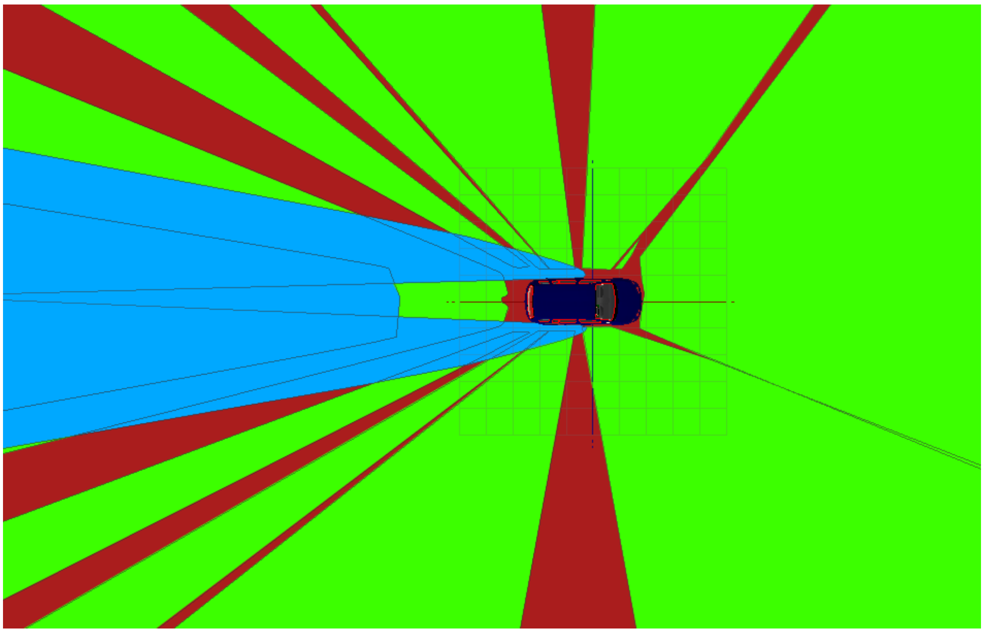

Figure 224. 360° visibility projections – ground +1m plane

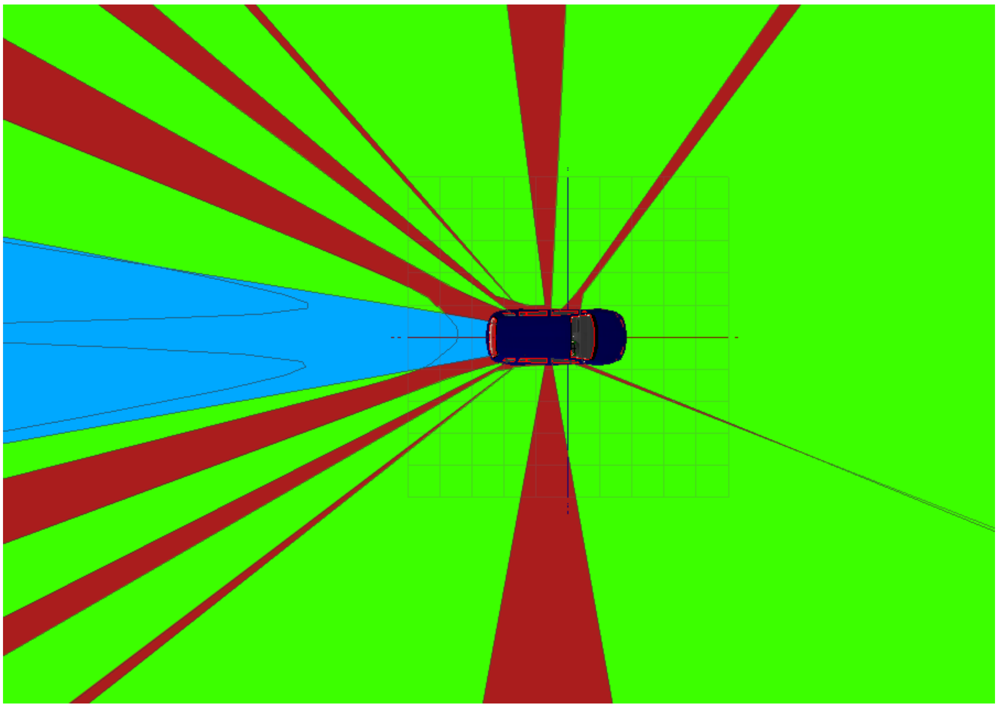

Figure 225. 360° visibility projections – ground +1.56m plane

The pattern observed with the Golf is repeated here with the blind spots significant on the ground plane but shrinking at +1m. There is a clearly identifiable zone directly rearwards of the vehicle that is obscured but this time the uppermost plane projection is the one in which the obscuration is removed. More detail on this particular issue is available in WP3. B pillar obscuration is noticeably greater than in the Golf. In addition, the A-pillar obscuration is greater in the Touran over that seen in the Golf, particularly for the near (left) side. The impact of the split A-pillar window is very small with only a small area visible through glazed aperture on the near side, there is no visibility through the offside.

3.5.1.2.2 35th %ile UK female

The postures adopted for direct forward (windscreen) and indirect rearward (Class I and Class III mirrors), direct rearward (rear window), and direct left and right (side windows) views are shown in Figure 226, Figure 227, Figure 228 and Figure 229 below.

Figure 226. Forwards view posture (35th%ile UK female)

Figure 227. Rearwards view posture (35th%ile UK female)

Figure 228. Left view posture (35th%ile UK female)

Figure 229. Right view posture (35th%ile UK female)

Figure 230, Figure 231, Figure 232, Figure 233 and Figure 234 show the full 360° volumetric projections from the windows as well as the two Classes of mirror fitted.

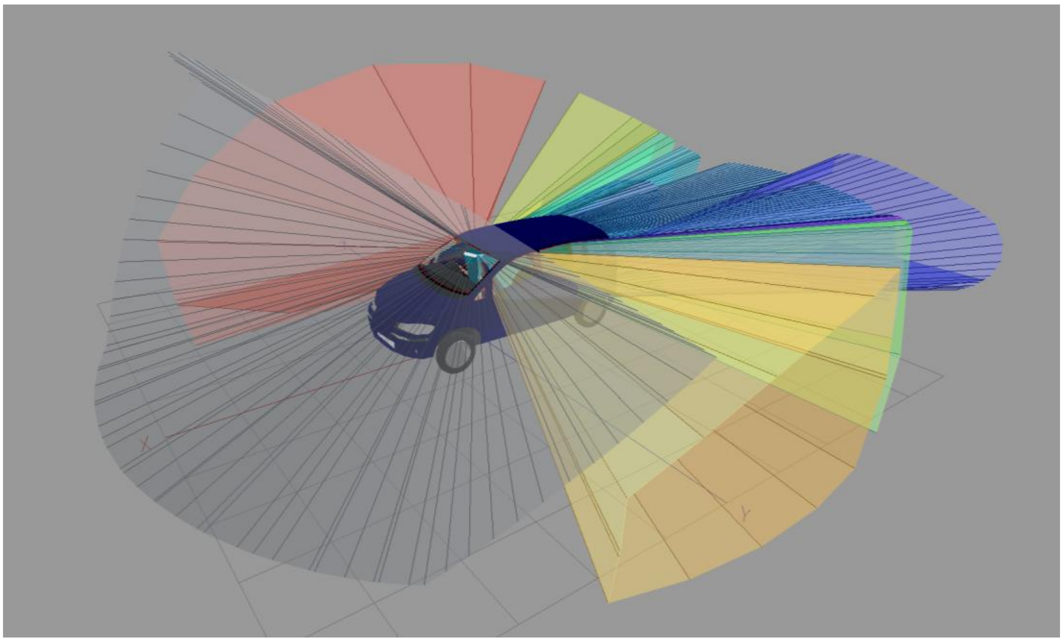

Figure 230. The projected volumes that demonstrate the 360° visibility (view from front left)

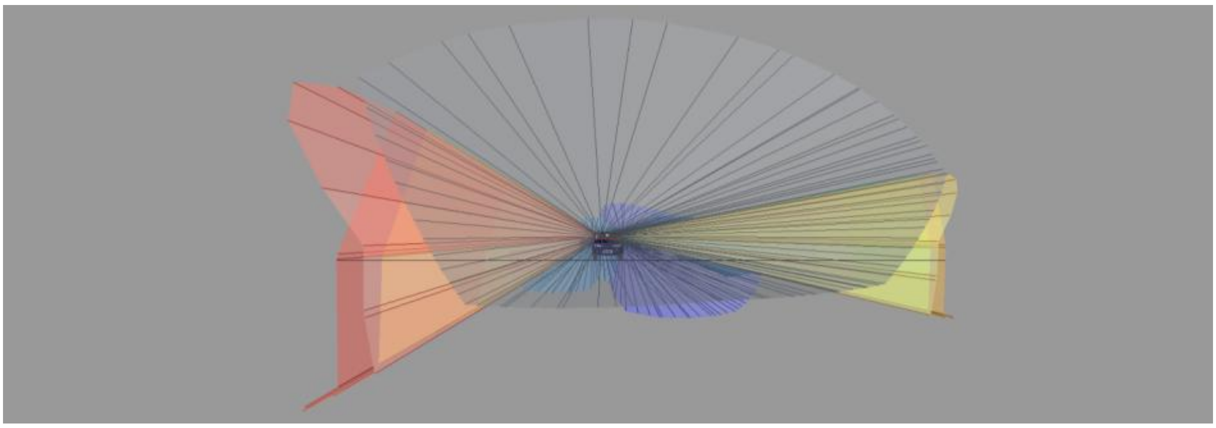

Figure 231. 360° visibility projections – front elevation

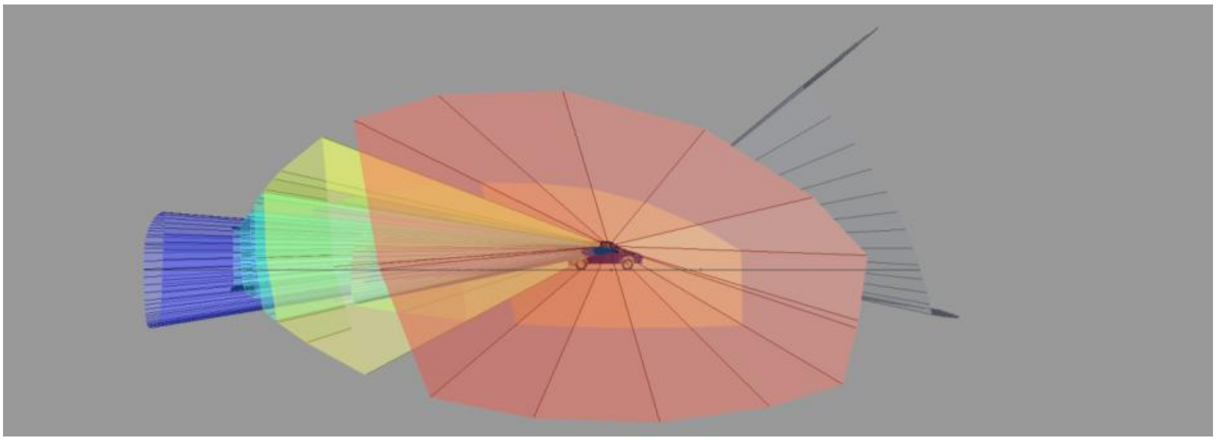

Figure 232. 360° visibility projections – right elevation

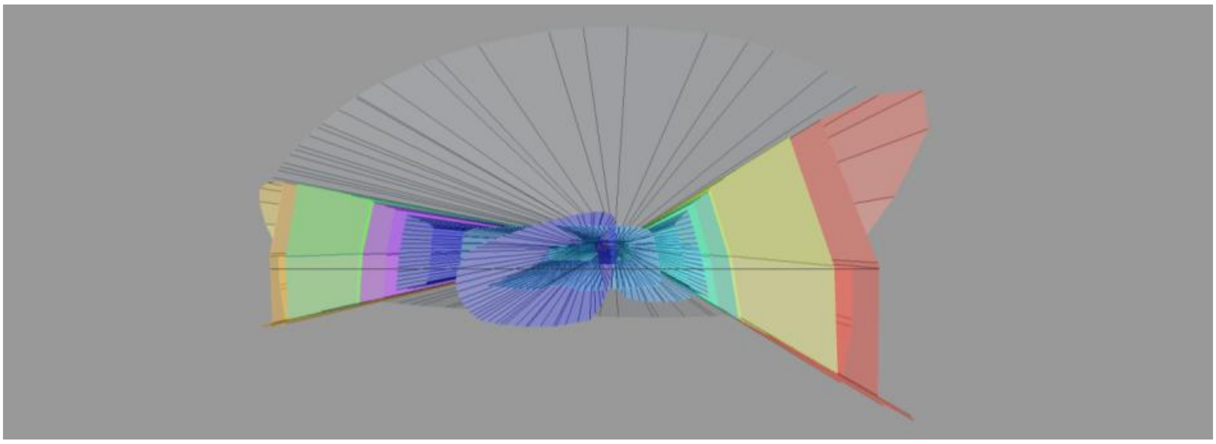

Figure 233. 360° visibility projections – rear elevation

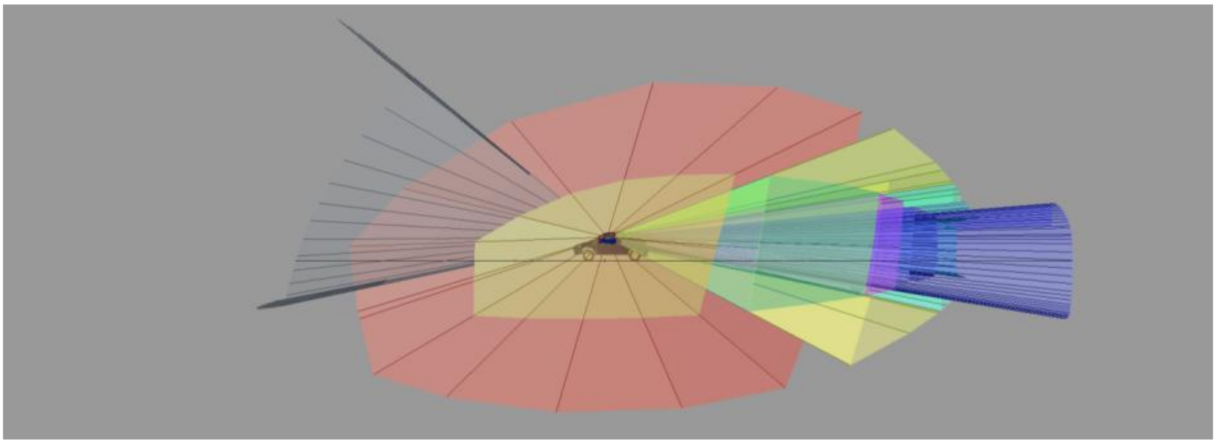

Figure 234. 360° visibility projections – left elevation

Again, three 2D plots are shown in Figure 235, Figure 236 and Figure 237 at three planes: ground plane, ground +1m, and ground +1.56m. The plots show three visual areas: green is the area of visibility from direct vision through window apertures; blue is indirect vision through mirrors; and red is the area not visible to the driver.

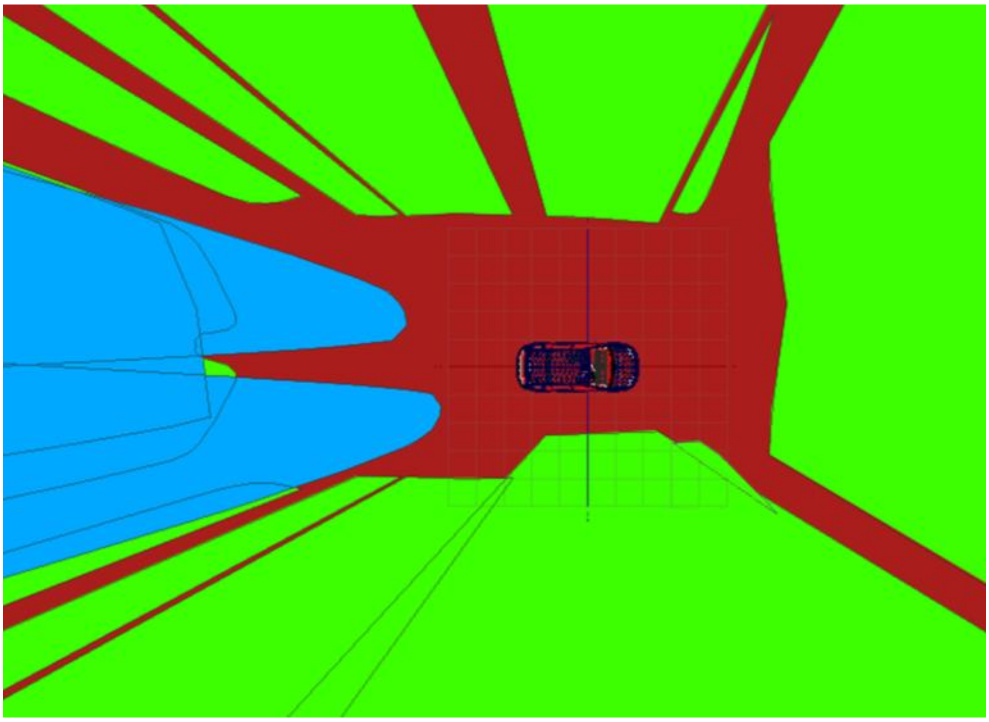

Figure 235. 360° visibility projections – ground plane

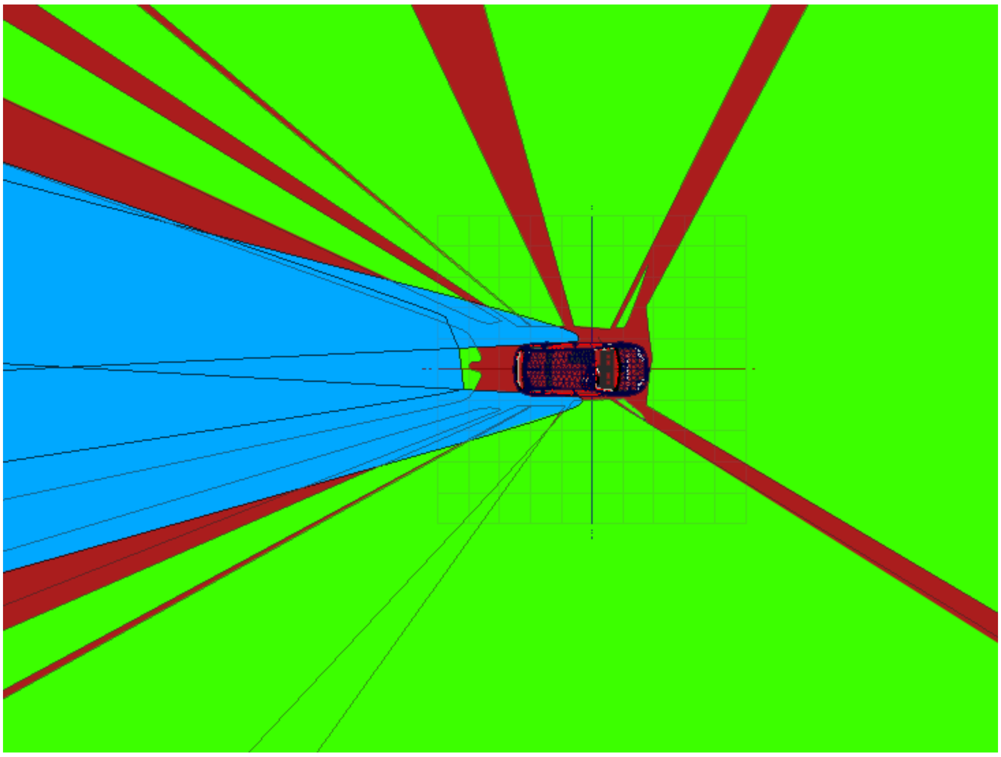

Figure 236. 360° visibility projections – ground +1m plane

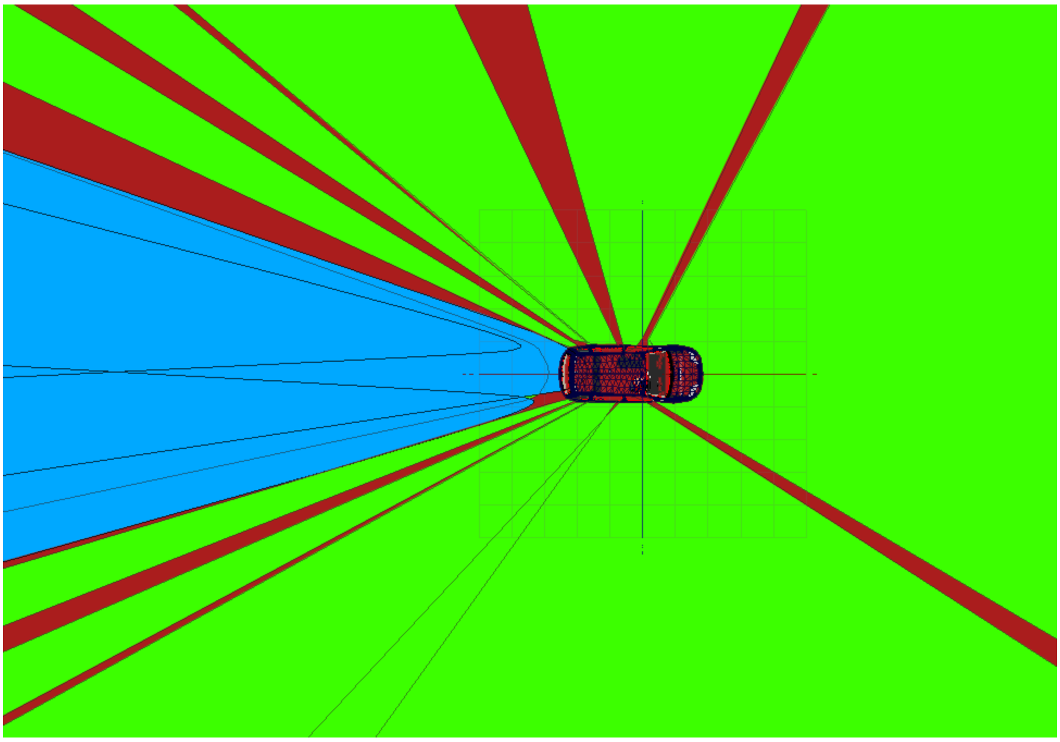

Figure 237. 360° visibility projections – ground +1.56m plane

For the smaller driver the eye point now produces a number of interesting differences over the Dutch male driver, and over the plots observed for the Golf. There are strong areas of obscuration for A, B and C-pillars on the nearside that continue to the horizon. However, on the offside the obscuration from the B-pillar is removed. The impact of the A-pillar obscuration, in particular, is explored in more detail later.

3.5.1.3 M_1 – Hyundai i10

3.5.1.3.1 99th %ile Dutch male

The postures adopted for direct forward (windscreen) and indirect rearward (Class I and Class III mirrors), direct rearward (rear window), and direct left and right (side windows) views are shown in Figure 238, Figure 239, Figure 240 and Figure 241 below.

Figure 238. Forwards view posture (99th%ile Dutch male)

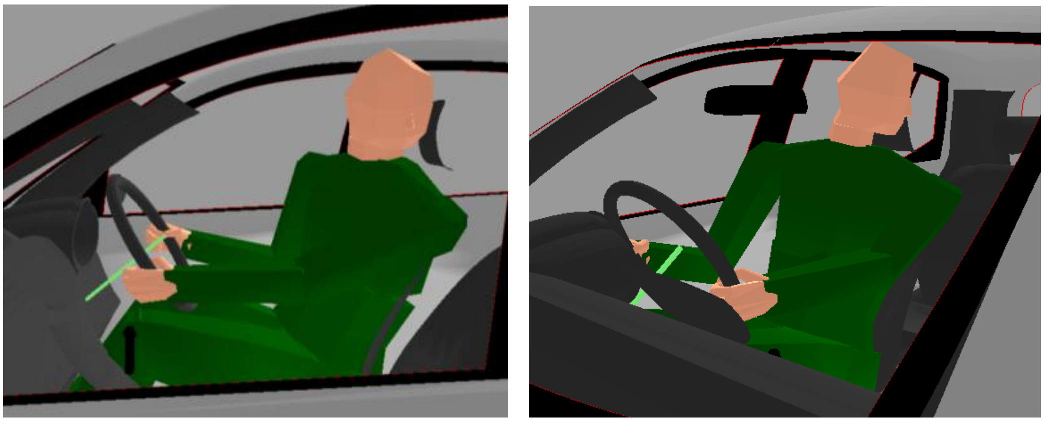

Figure 239. Rearwards view posture (99th%ile Dutch male)

Figure 240. Left view posture (99th%ile Dutch male)

Figure 241. Right view posture (99th%ile Dutch male)

Figure 242, Figure 243, Figure 244, Figure 245 and Figure 246 show the full 360° volumetric projections from the windows as well as the two Classes of mirror fitted.

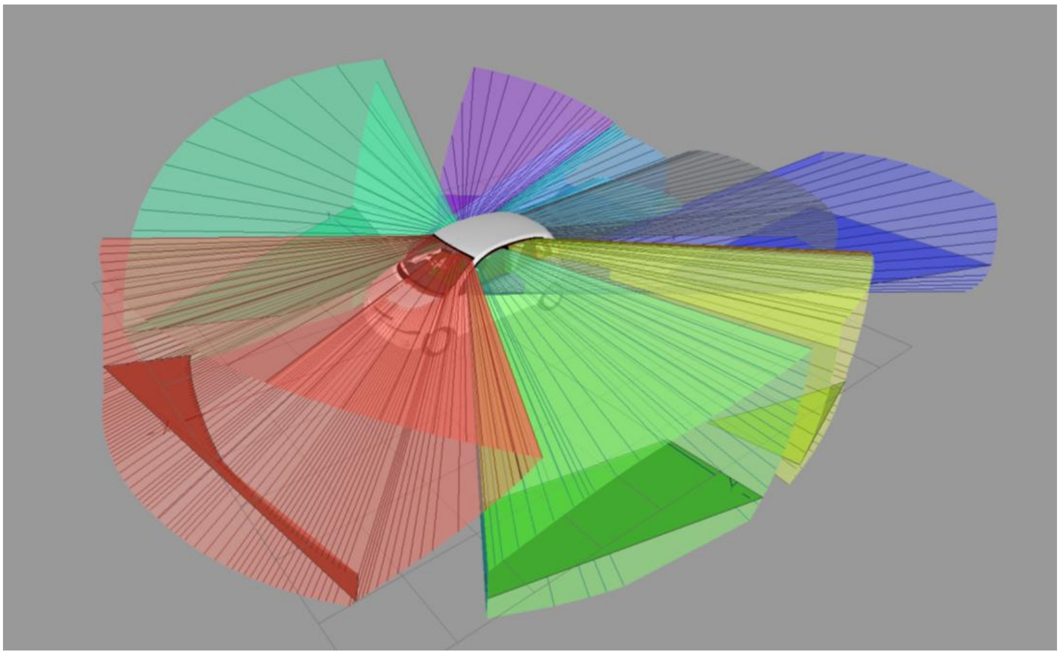

Figure 242. The projected volumes that demonstrate the 360° visibility (view from front left)

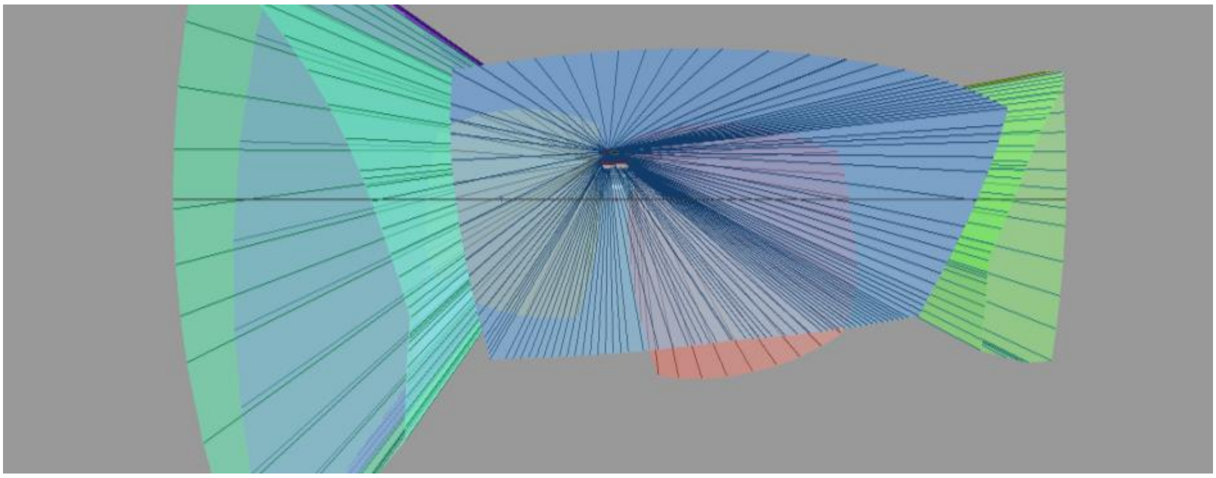

Figure 243. 360° visibility projections – front elevation

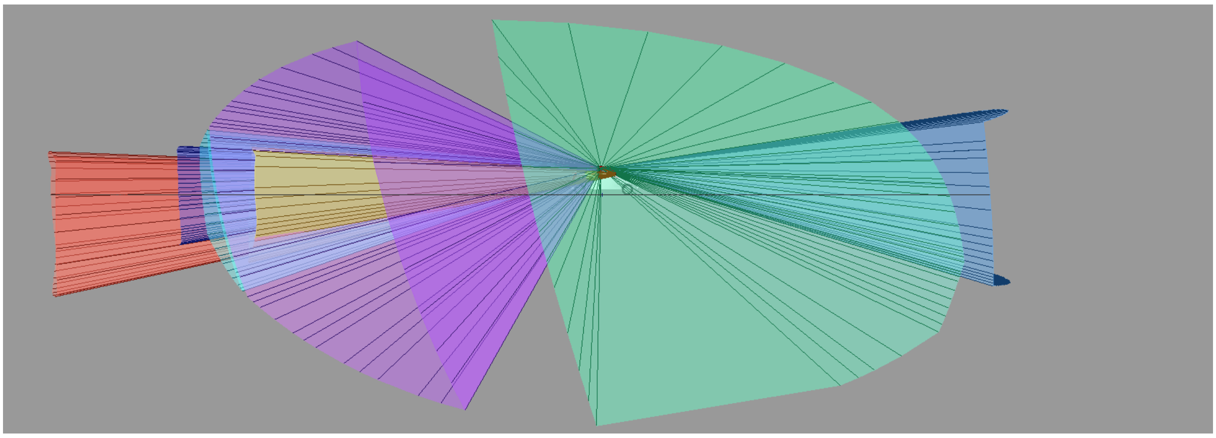

Figure 244. 360° visibility projections – right elevation

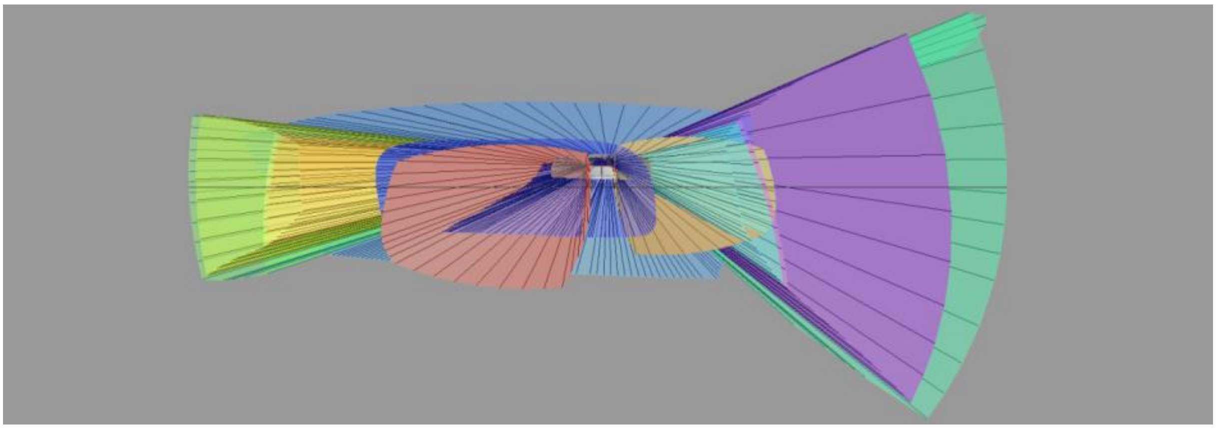

Figure 245. 360° visibility projections – rear elevation

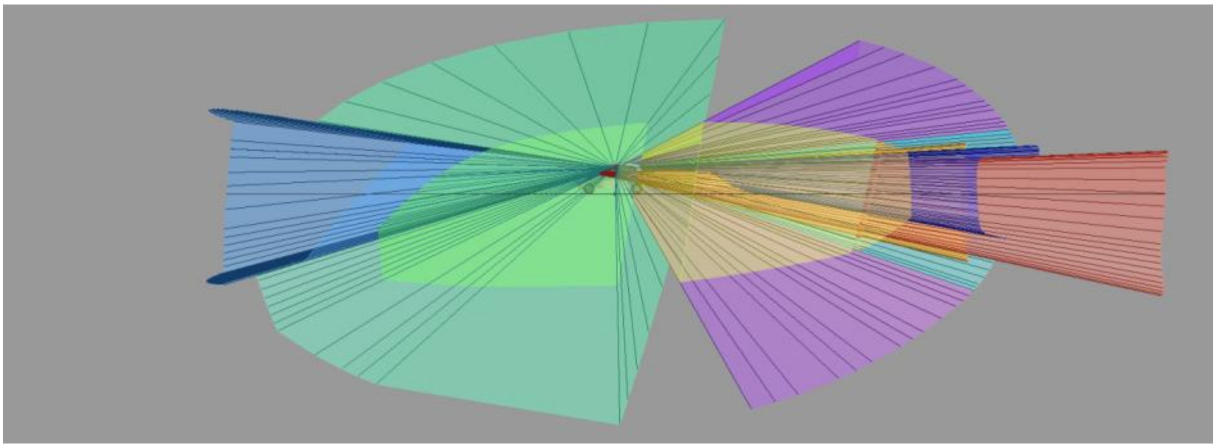

Figure 246. 360° visibility projections – left elevation

Again, three 2D plots are shown in Figure 247, Figure 248 and Figure 249 at three planes: ground plane, ground +1m, and ground +1.56m. The plots show three visual areas: green is the area of visibility from direct vision through window apertures; blue is indirect vision through mirrors; and red is the area not visible to the driver.

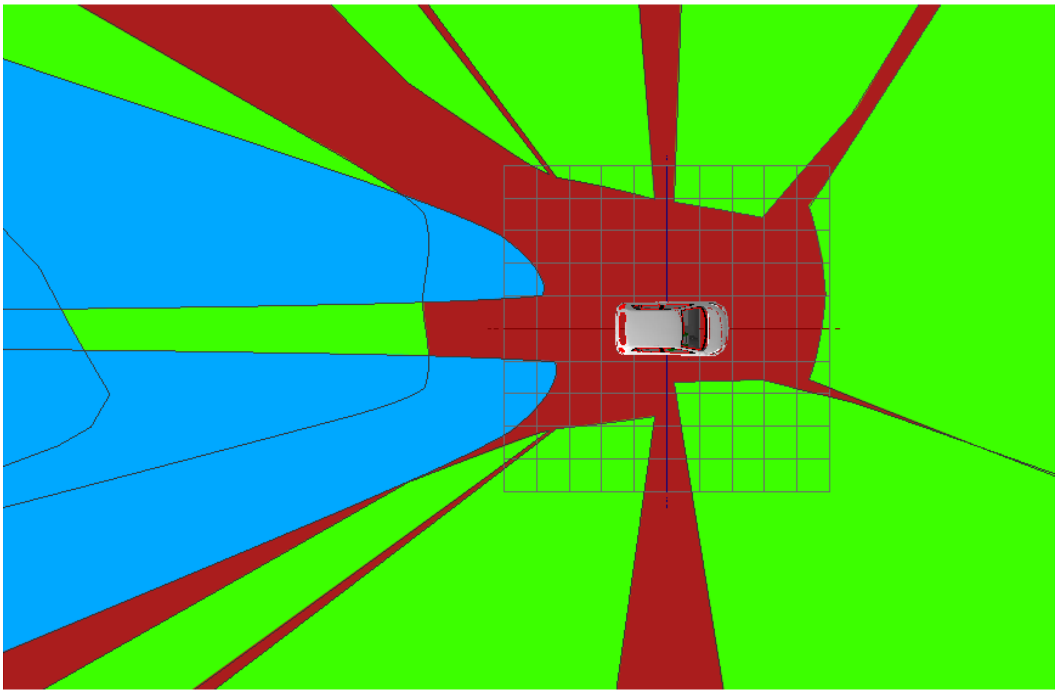

Figure 247. 360° visibility projections – ground plane

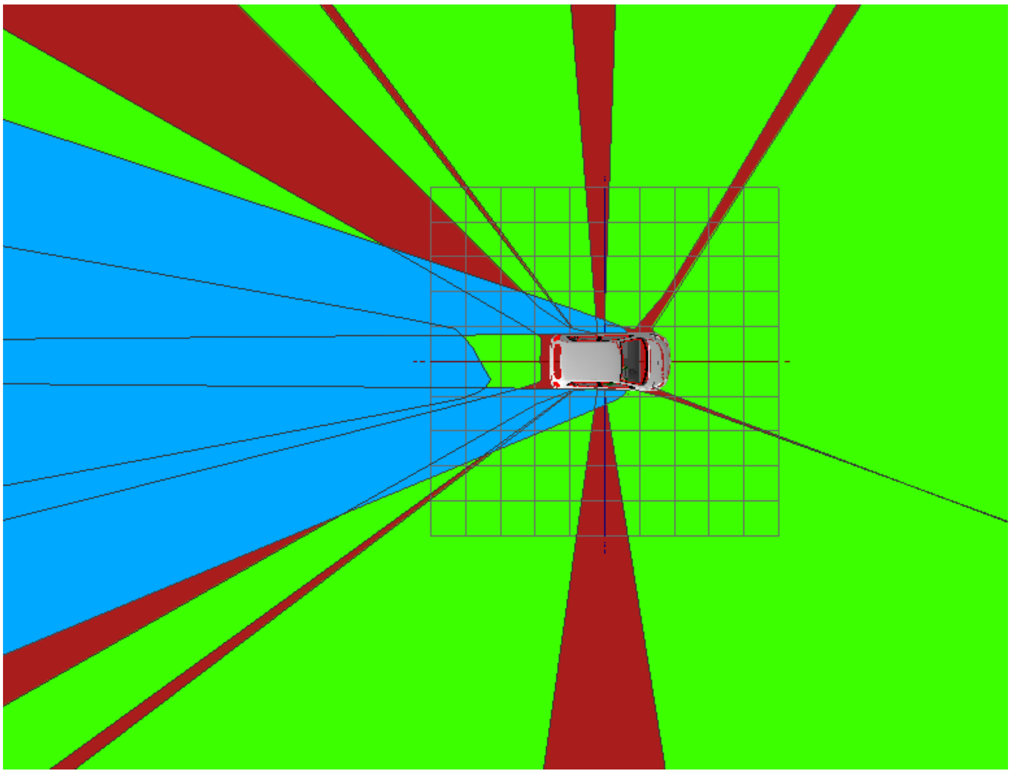

Figure 248. 360° visibility projections – ground +1m plane

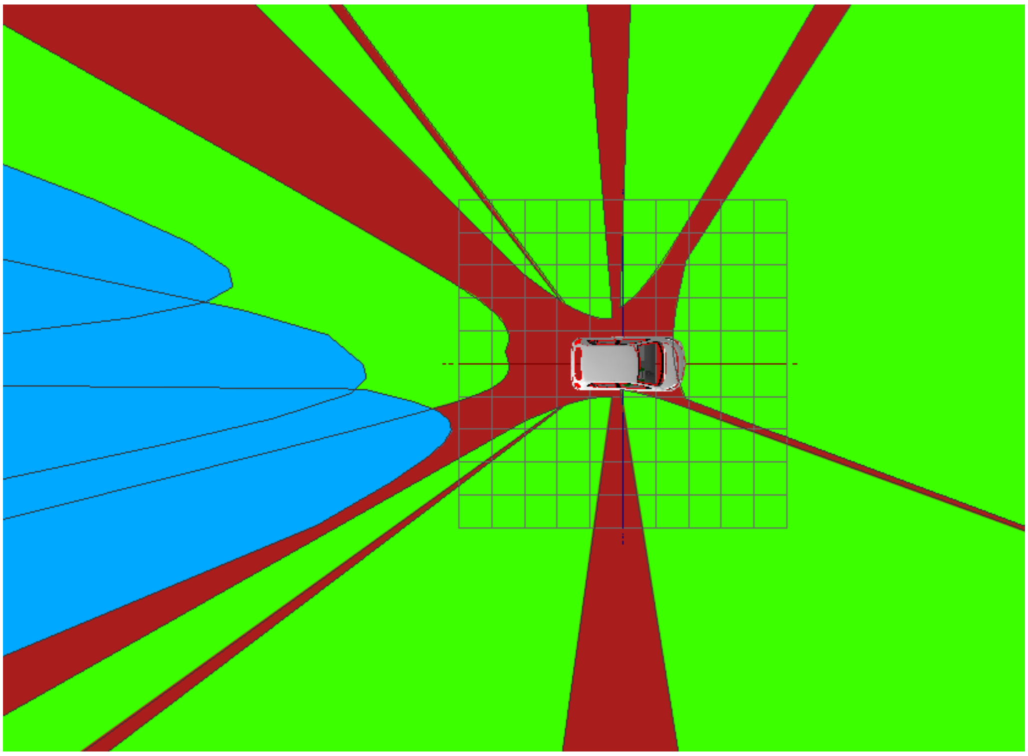

Figure 249. 360° visibility projections – ground +1.56m plane

The general patterns observed previously are again repeated here. There are noticeable blind spots all around the vehicle and obscuration by A, B and C-pillars is consistent and not affected by the variation in head position and posture that is found in the Golf and Touran. C-pillar obscuration is the greatest of all three M_1 vehicles assessed.

3.5.1.3.2 5th %ile UK female

The postures adopted for direct forward (windscreen) and indirect rearward (Class I and Class III mirrors), direct rearward (rear window), and direct left and right (side windows) views are shown in Figure 250, Figure 251, Figure 252 and Figure 253 below.

Figure 250. Forwards view posture (5th%ile UK female)

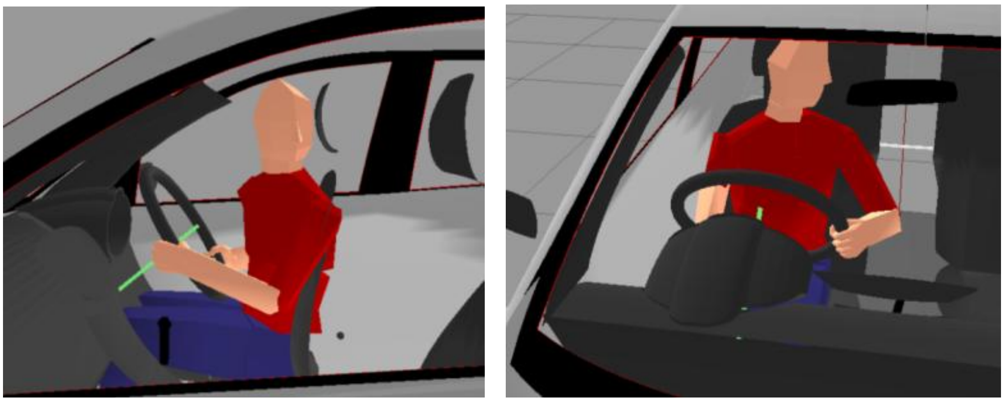

Figure 251. Rearwards view posture (5th%ile UK female)

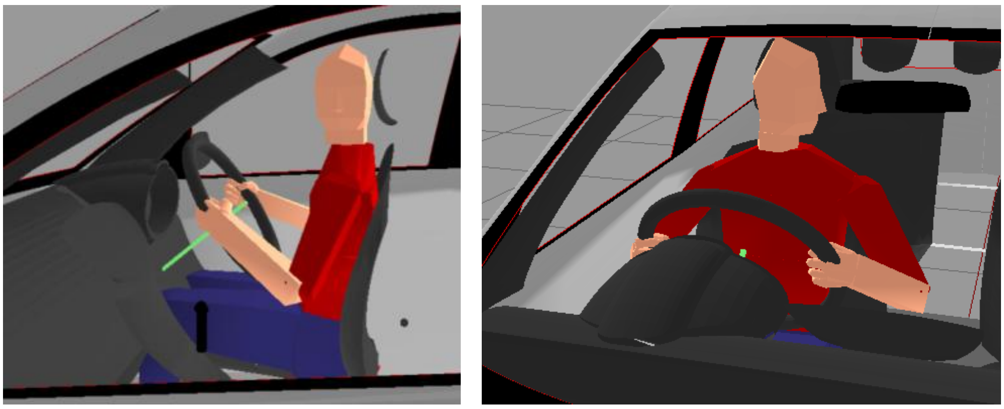

Figure 252. Left view posture (5th%ile UK female)

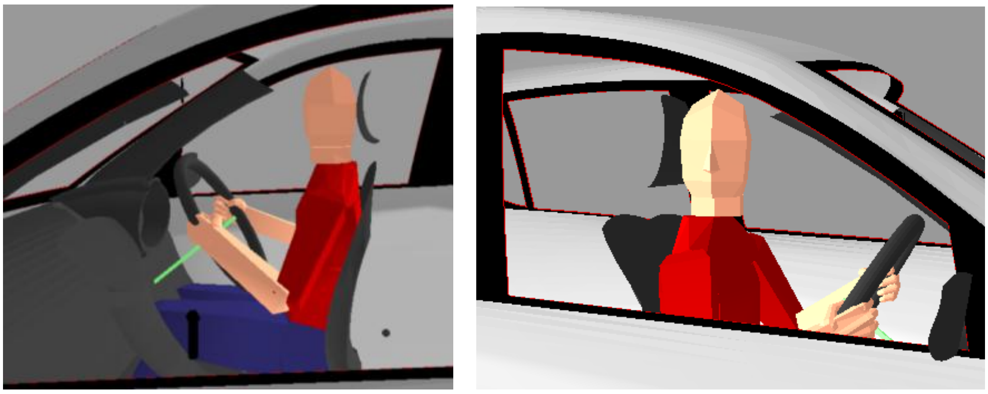

Figure 253. Right view posture (5th%ile UK female)

Figure 254, Figure 255, Figure 256, Figure 257 and Figure 258 show the full 360° volumetric projections from the windows as well as the two Classes of mirror fitted.

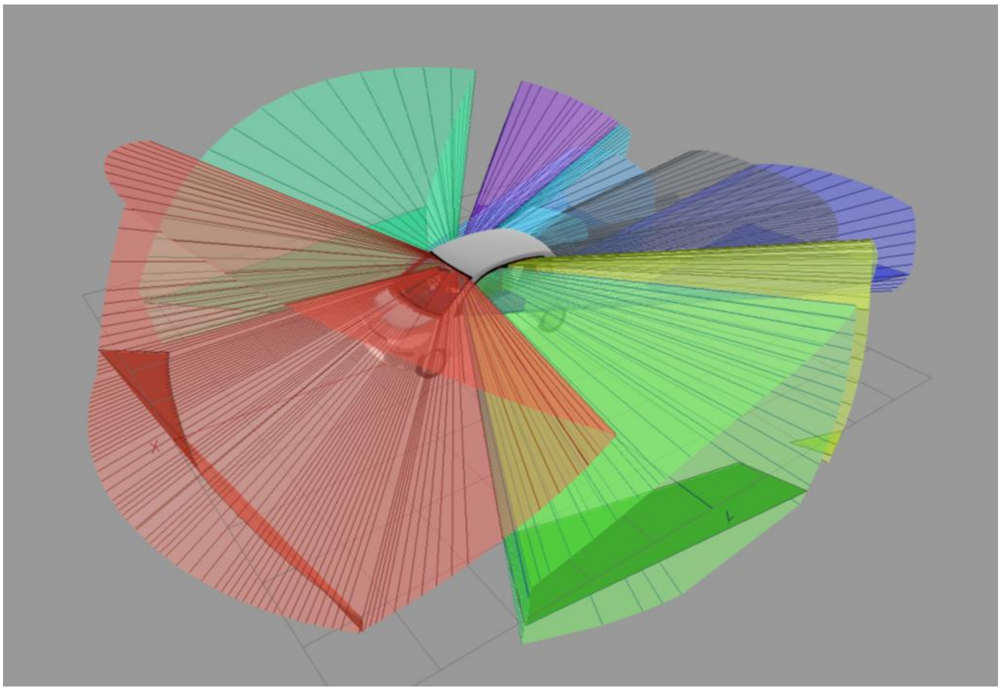

Figure 254. The projected volumes that demonstrate the 360° visibility (view from front left)

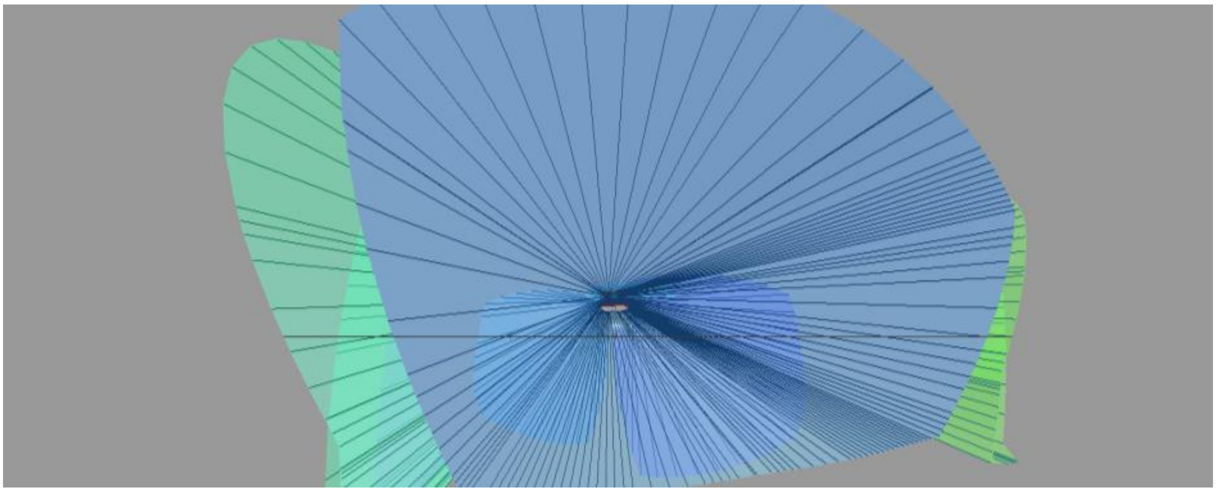

Figure 255. 360° visibility projections – front elevation

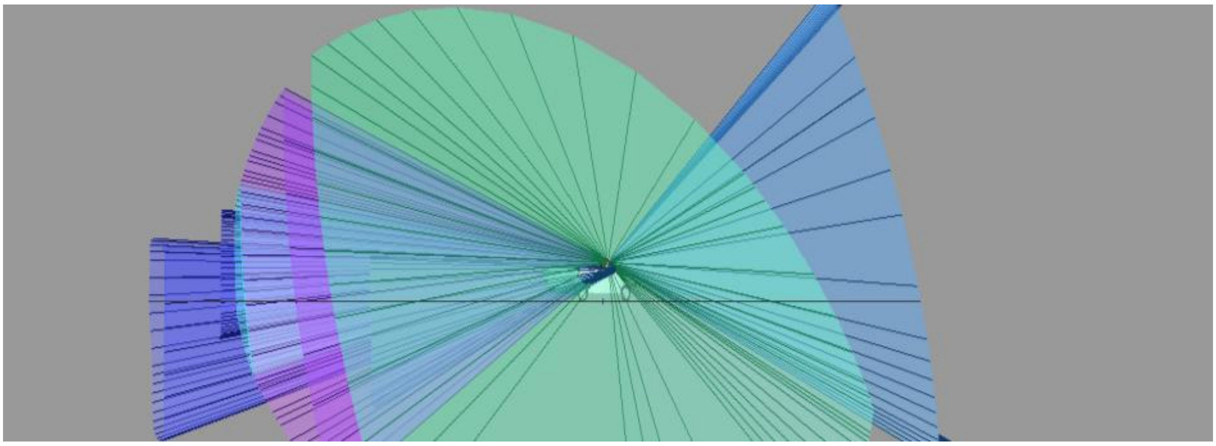

Figure 256. 360° visibility projections – right elevation

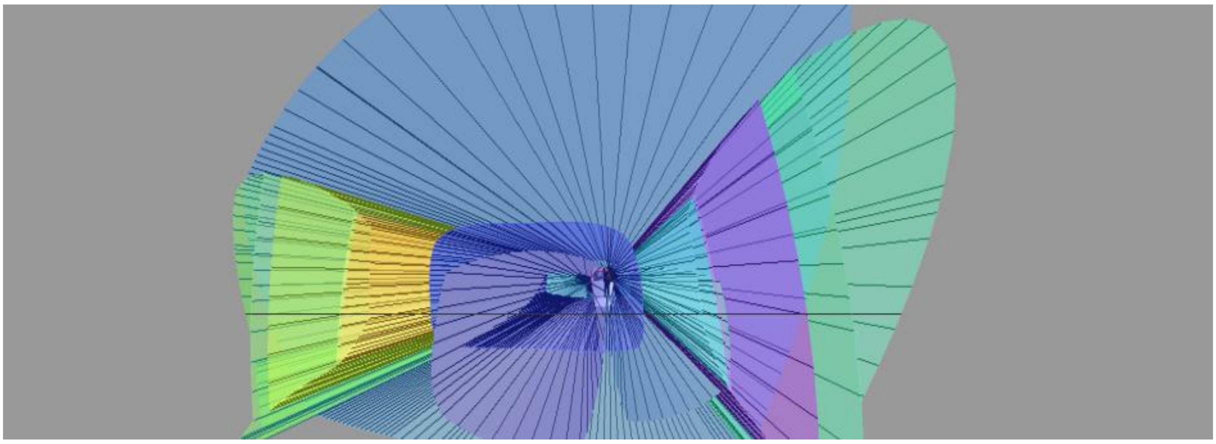

Figure 257. 360° visibility projections – rear elevation

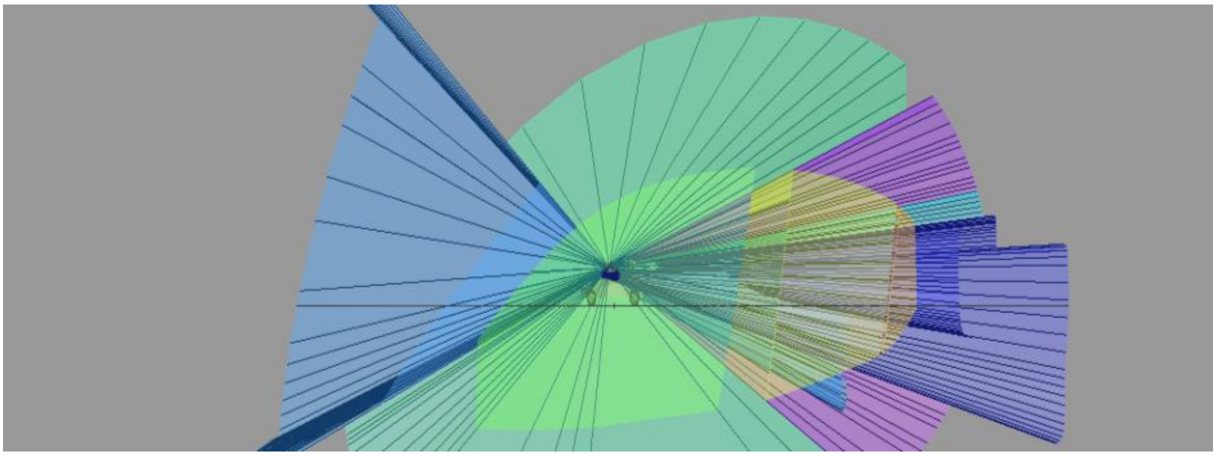

Figure 258. 360° visibility projections – left elevation

As previously, three 2D plots are shown in Figure 259, Figure 260 and Figure 261 at three planes: ground plane, ground +1m, and ground +1.56m. The plots show three visual areas: green is the area of visibility from direct vision through window apertures; blue is indirect vision through mirrors; and red is the area not visible to the driver.

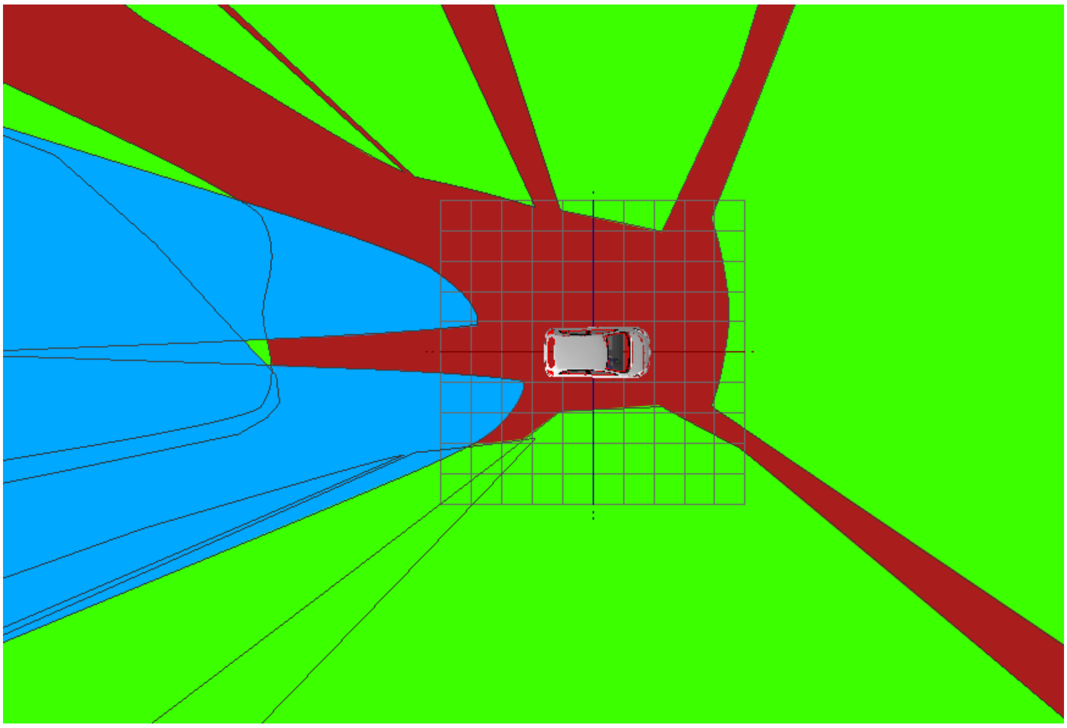

Figure 259. 360° visibility projections – ground plane

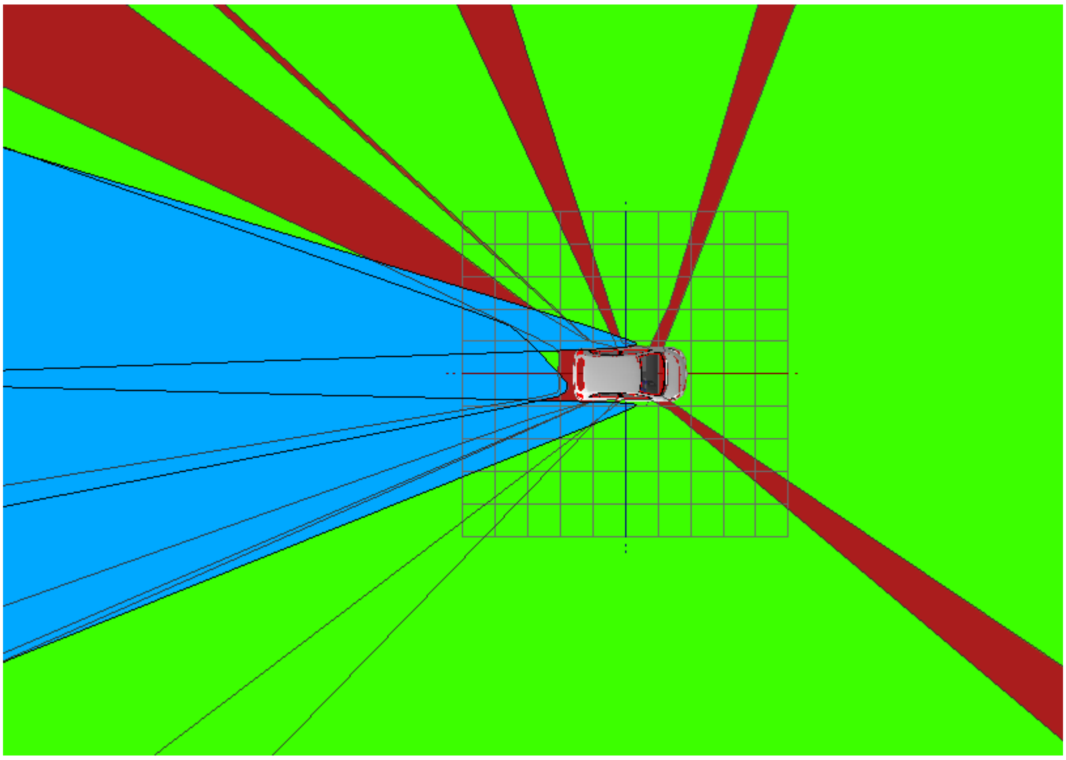

Figure 260. 360° visibility projections – ground +1m plane

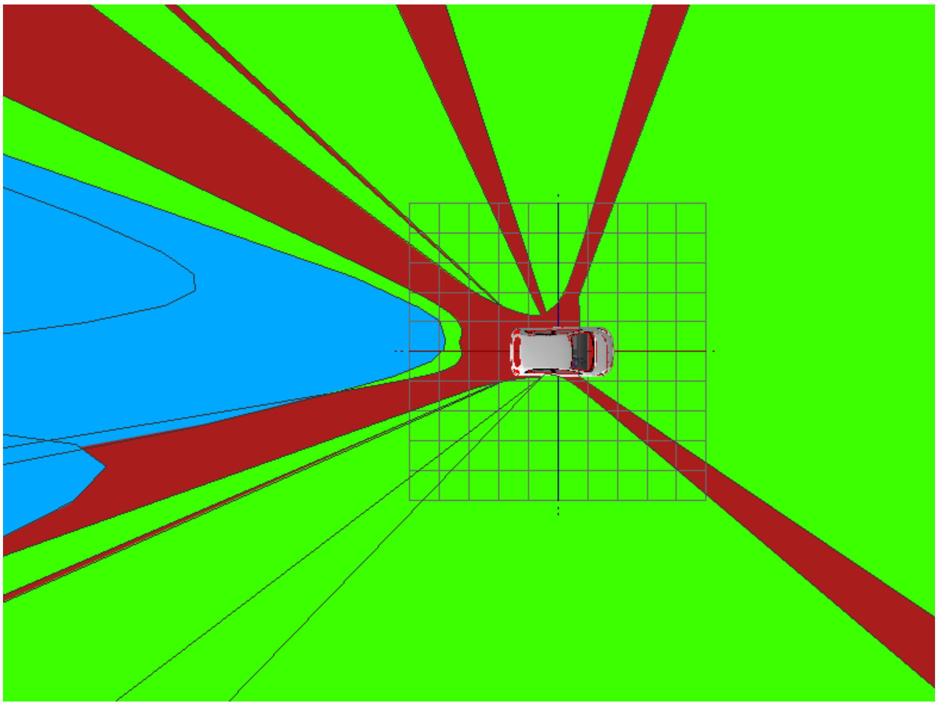

Figure 261. 360° visibility projections – ground +1.56m plane

Obscuration is very significant for the smaller driver, particularly on the nearside for B and C-pillars, and for both A-pillars. A-pillar obscuration is possibly the greatest of all configurations evaluated. However, on the offside, obscuration due to B and C pillars is eliminated on the 1m plane.

3.5.2 Scenario evaluations

3.5.2.1 Mini roundabout OTS case

The following scenario examines the visibility from category M_1 vehicles in a situation where the vehicle (P1V1) has approached a roundabout in lane 2 and come to a complete stop with the intention of exiting the roundabout at exit 2, straight ahead. In the OTS case, the driver of the M_1 category vehicle has pulled off and collided with a scooter (P2V1) already present on the roundabout turning in front of P1V1.

3.5.2.1.1 Scenario setup

The scenario was modelled using the map data provided in the OTS case report (Figure 262). The angle of the junction to the roundabout has the potential to cause difficulty for the category M_1 driver in terms of positioning for optimum visibility in front and to the right of the vehicle to observe vehicles already on the roundabout. The vehicle CAD model that represents P2V1 (a Yamaha Cygnus x) is positioned initially at the entrance to the roundabout opposite P1V1. As detailed, P1V1 is positioned in lane 2 and oriented in a balance between the need to proceed around the roundabout heading for exit 2 and to evaluate the possibility for obscuration of the scooter from the offside A-pillar. A third vehicle is included in the scenario using the same exit as that intended for P1V1 to give an indication of the desired path.

Figure 262. The road layout recreated from the OTS case report

3.5.2.1.2 M_1 – Volkswagen Golf

3.5.2.1.2.1 99th %ile Dutch male

The relative positioning of the vehicles is shown in Figure 263 and Figure 264 below.

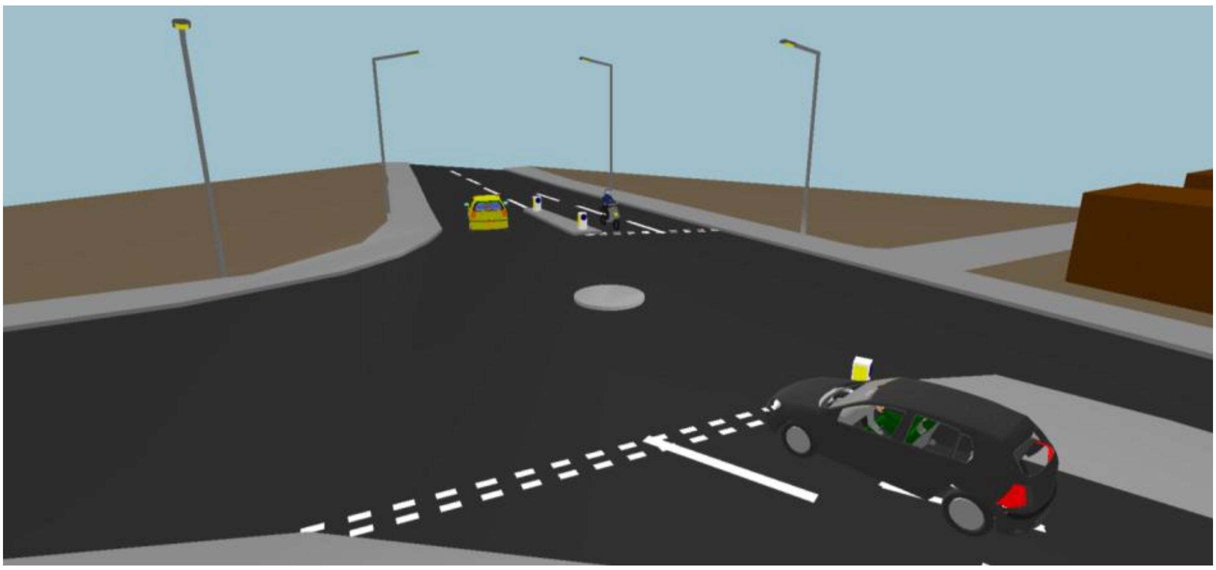

Figure 263. The roundabout layout showing the VW Golf and 99%ile Dutch male driver

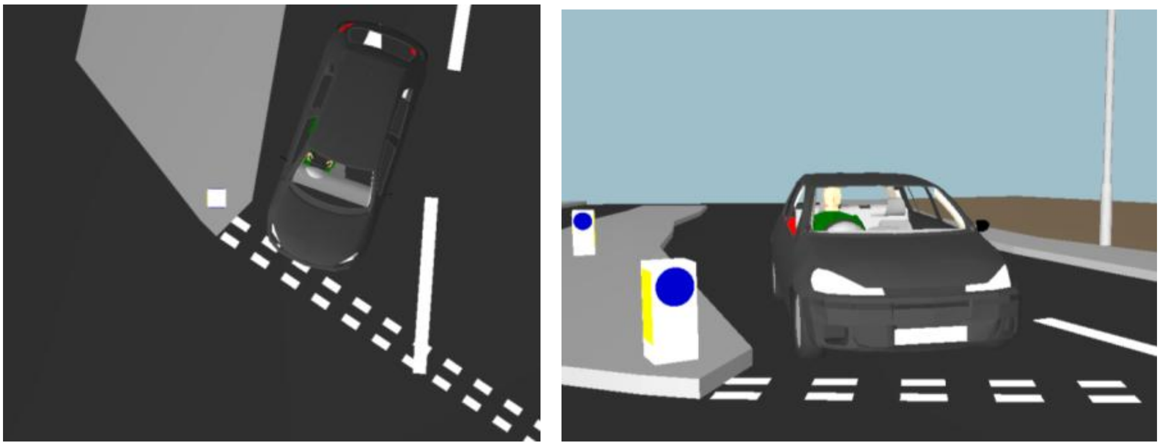

Figure 264. The vehicle positioning at the roundabout

Figure 265 below shows that in this position the scooter and its rider are completely obscured by the A-pillar of the M_1 vehicle. The driver is looking to essentially follow the yellow Fiat Punto off the roundabout.

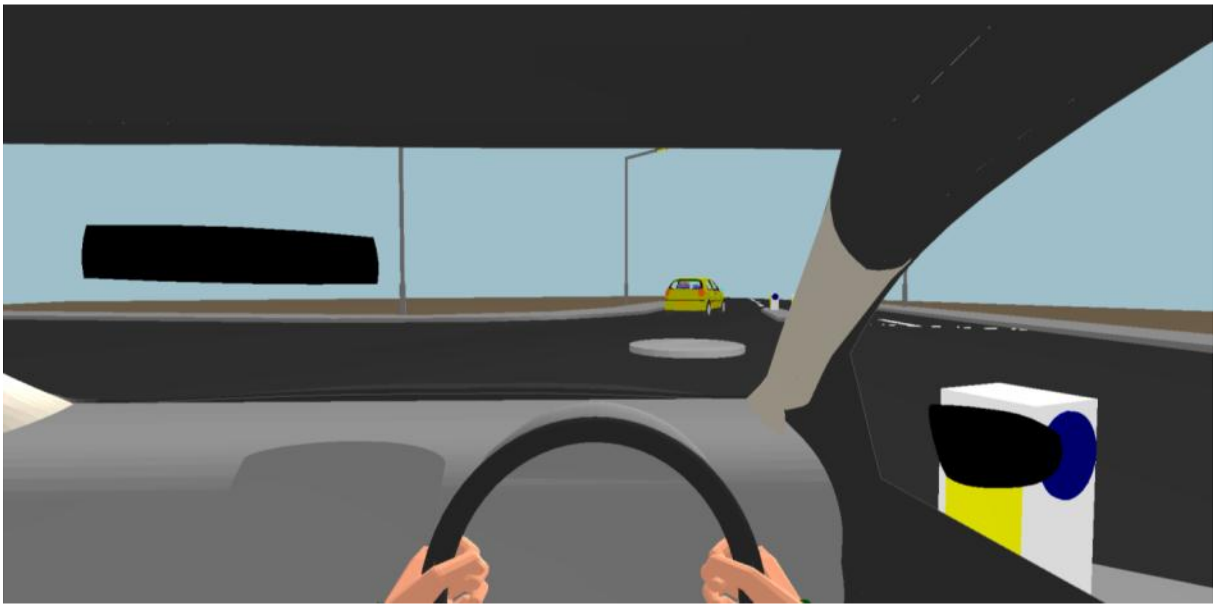

Figure 265. The view of the Dutch male driver

Figure 266. The scooter can be seen if the driver turns their head

Figure 266 above shows that whilst the A-pillar obscuration does mask the scooter and its rider, it is possible for the driver to 'look around' the obscuration if the driver is aware of the blind spot.

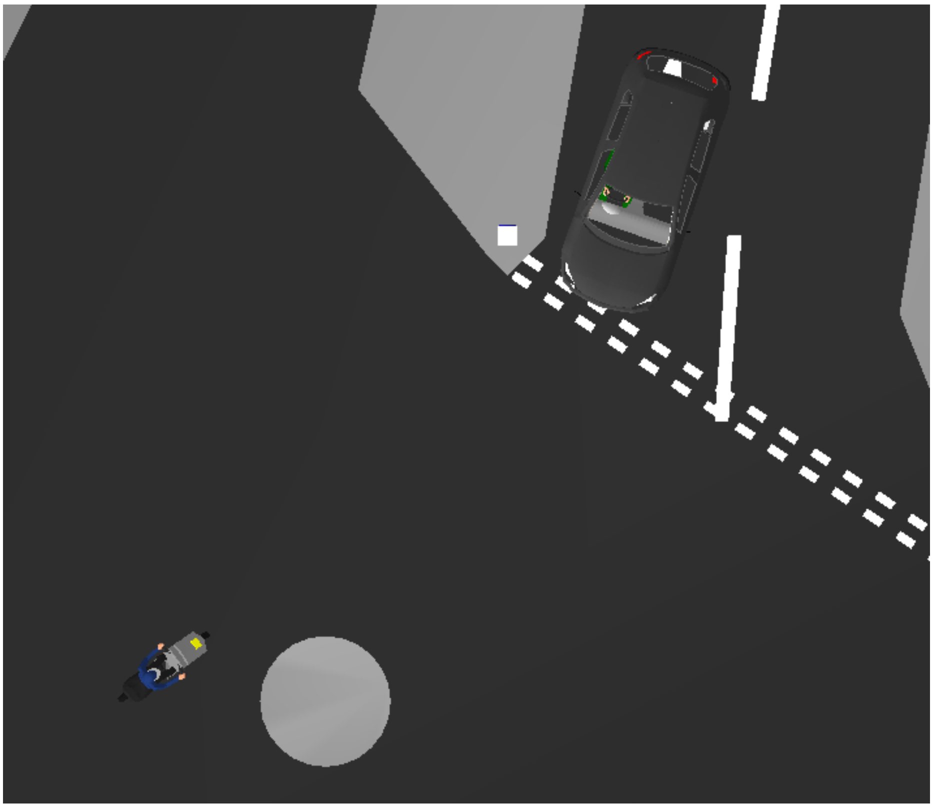

Figure 267. The scooter has proceeded onto the roundabout intending to turn right

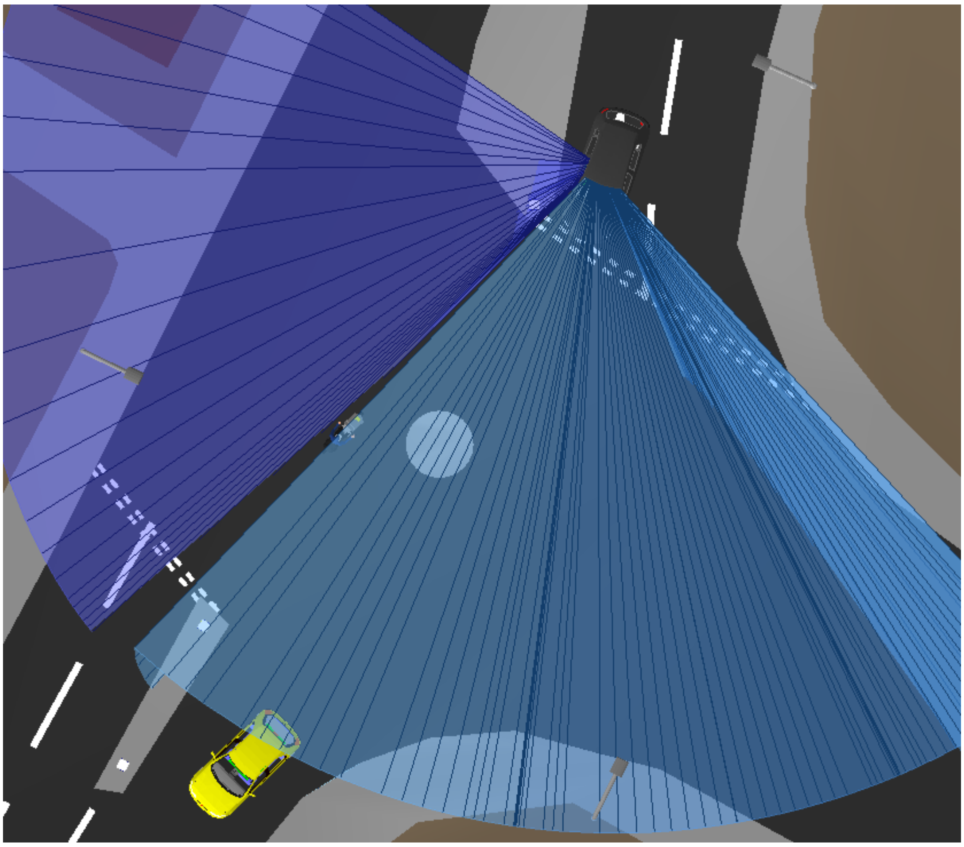

Figure 268. The scooter located within the blind spot caused by the A-pillar

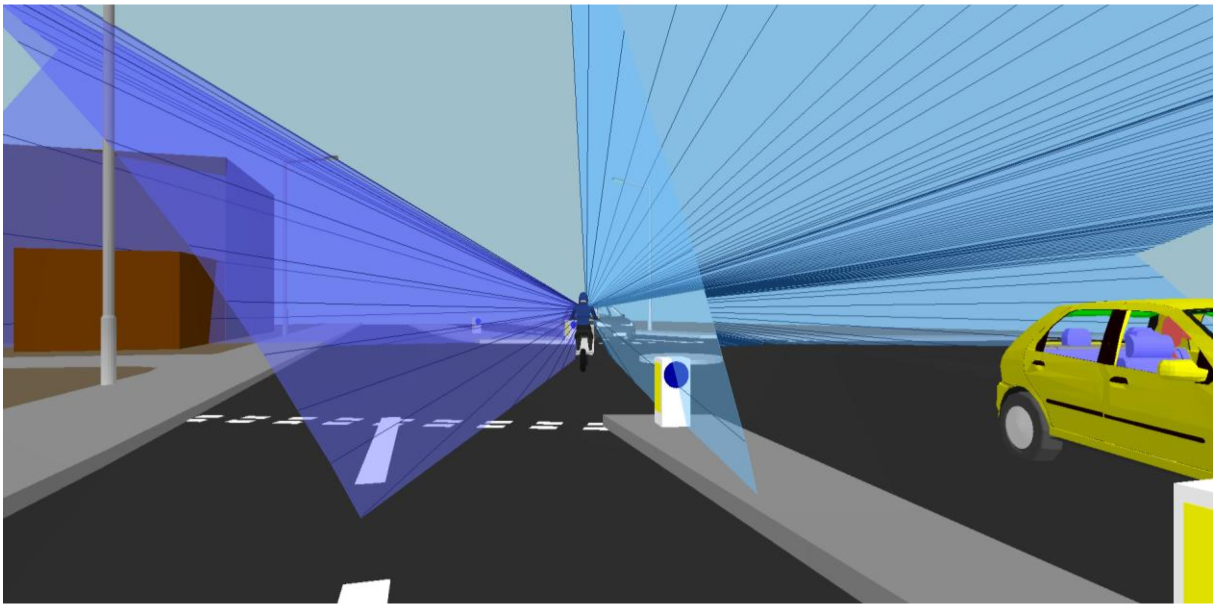

Figure 269. The scooter located within the blind spot caused by the A-pillar (alternative view)

The A-pillar forms a clear 'corridor' of obscured field of view.

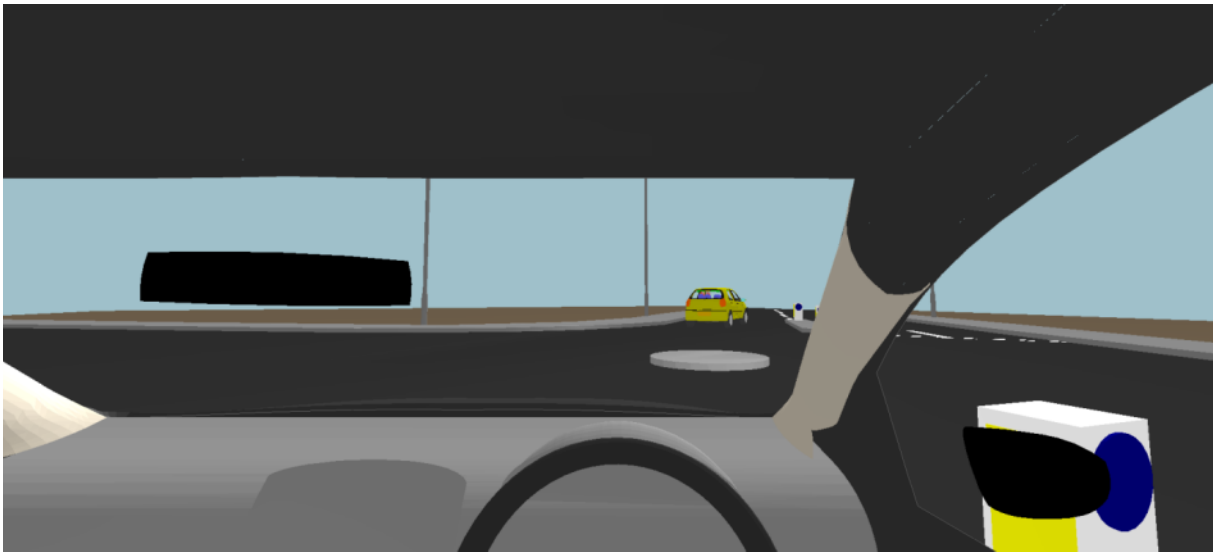

Figure 270. The scooter is still not visible to the M_1 driver

Figure 267, Figure 268 Figure 269, and Figure 270 above show that the scooter could travel down the 'corridor' blind spot caused by the offside (right) a-pillar and thus remain obscured whilst the driver of the M_1 vehicle performs their observations prior to setting off.

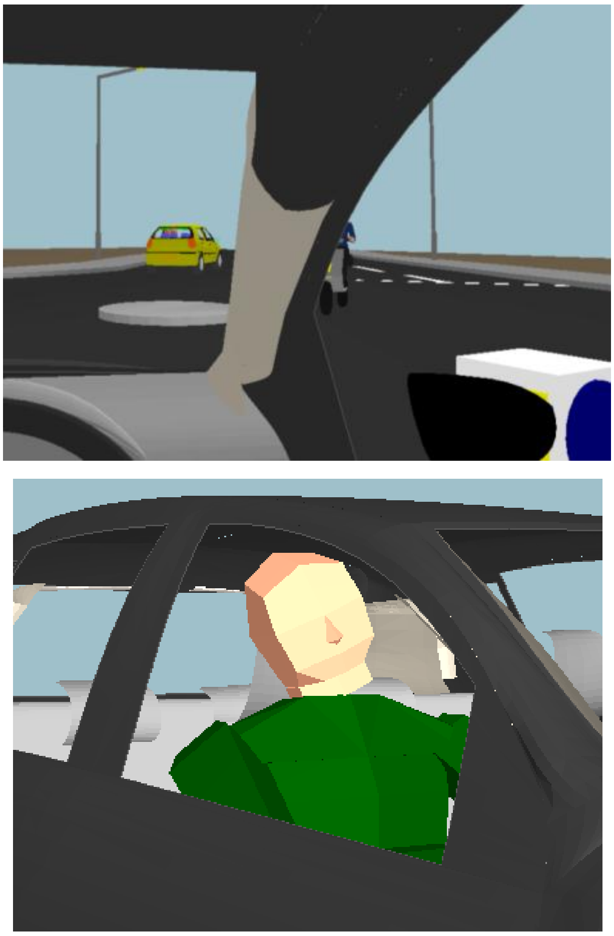

Figure 271. The scooter can be seen if the driver leans their head

Whilst the scooter is obscured by the A-pillar, if the driver is aware of the blind spot it is still possible to 'look around' the obstacle by tilting the head to the side (Figure 271).

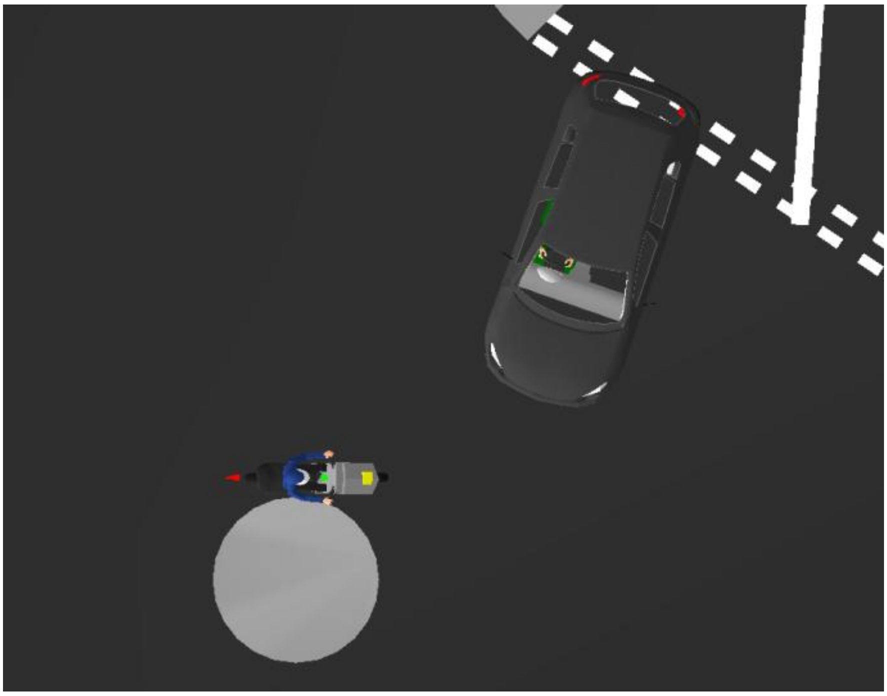

Figure 272. The scooter can effectively travel the whole distance until the point of impact obscured by the M_1 A-pillar

Figure 273. The scooter can effectively travel the whole distance until the point of impact obscured by the M_1 A-pillar – driver's view at point of impact

If the M_1 driver fails to take account of the blind spot, it is possible for the scooter to travel to the centre of the roundabout and for the M_1 vehicle to have set off with the scooter having been obscured for the whole time (Figure 272 and Figure 273).

3.5.2.1.2.2 5^h %ile UK female

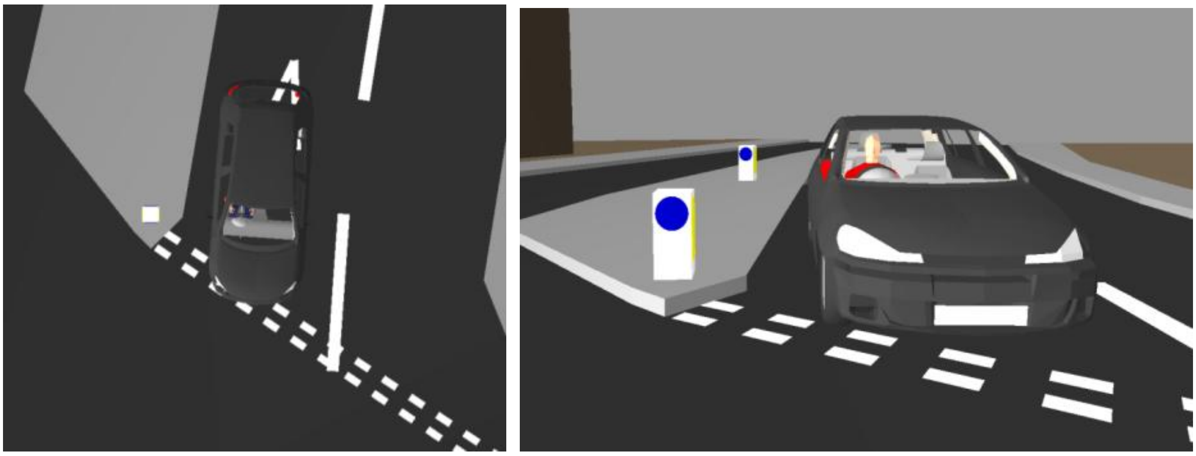

Figure 274. The vehicle positioning at the roundabout

Figure 275 and Figure 276 show that in this position the scooter and its rider are completely obscured by the A-pillar of the M_1 vehicle. The UK female driver's eye point is much closer to the A-pillar than for the Dutch Male and so the pillar appears larger and more to the right, relatively, within the forward field of view. To provide the obscuration the car has to be positioned pointed more to its left, relative to the position for the Dutch male driver, to provide the obscuration (Figure 274).

Figure 275. The view of the UK female driver

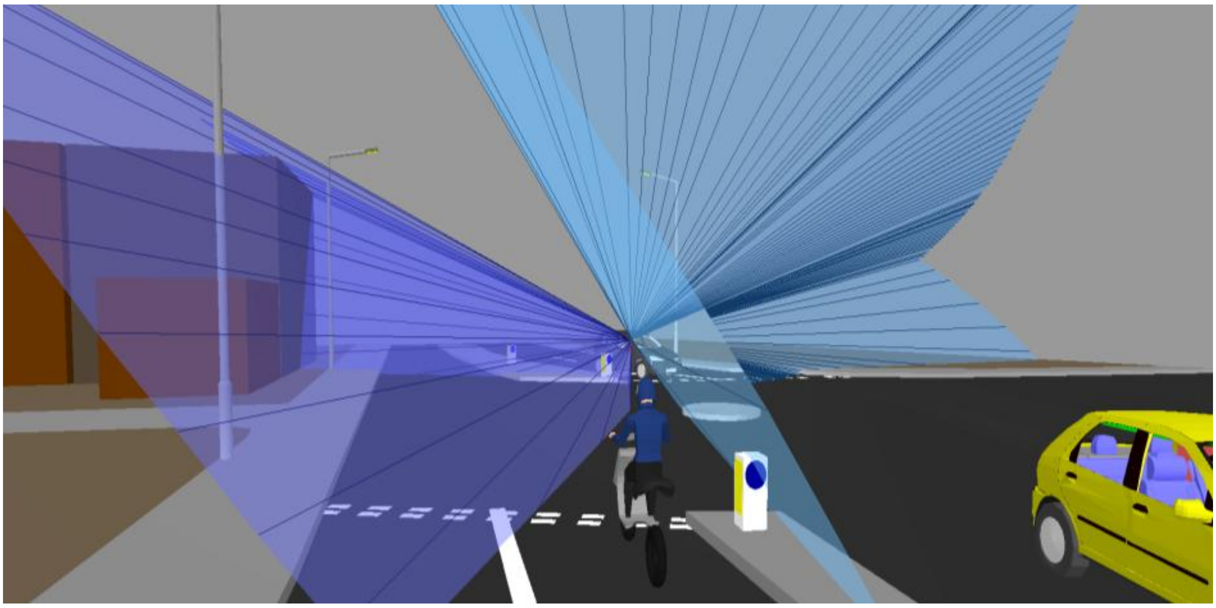

Figure 276. The scooter located within the blind spot caused by the A-pillar

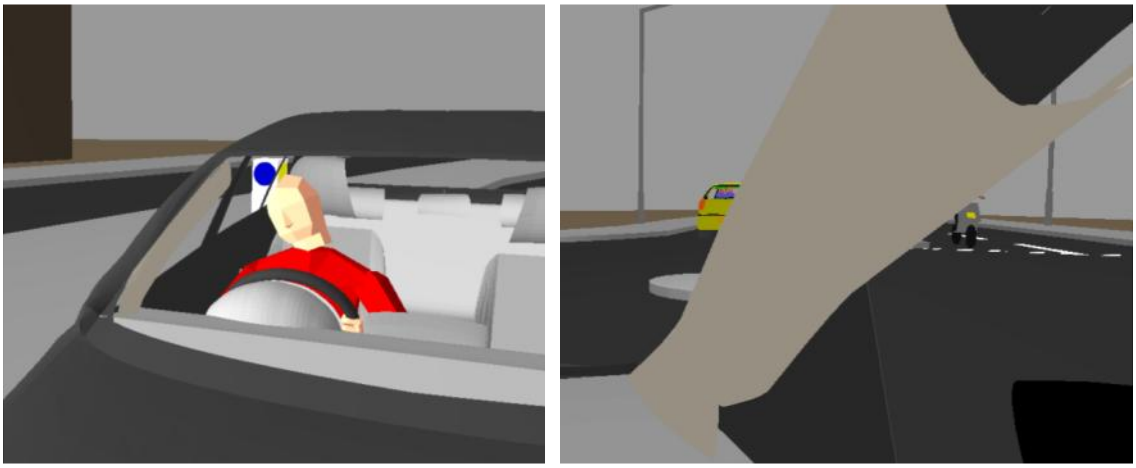

Figure 277. The scooter can be seen if the driver leans their head

Whilst the scooter is obscured by the A-pillar, if the driver is aware of the blind spot it is possible to 'look around' the obstacle by tilting the head to the side (Figure 277).

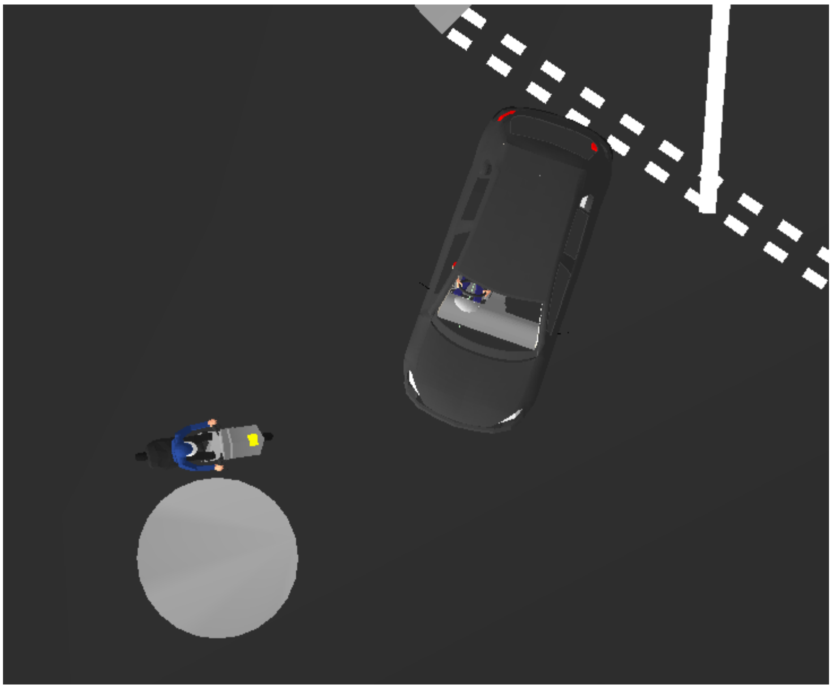

Figure 278. The scooter can effectively travel the whole distance until the point of impact obscured by the M_1 A-pillar

Figure 279. The scooter can effectively travel the whole distance until the point of impact obscured by the M_1 A-pillar – driver's view at point of impact

As with the Dutch Male driver if the M_1 driver fails to take account of the blind spot by changing the position of the head, it is possible for the scooter and M_1 vehicle to travel to the point of impact without the M_1 driver being able to see the scooter (see Figure 278 and Figure 279).

3.5.2.1.3 M_1 – Volkswagen Touran

3.5.2.1.3.1 99th %ile Dutch male

The relative positioning of the vehicles is shown in Figure 280 and Figure 281 below.

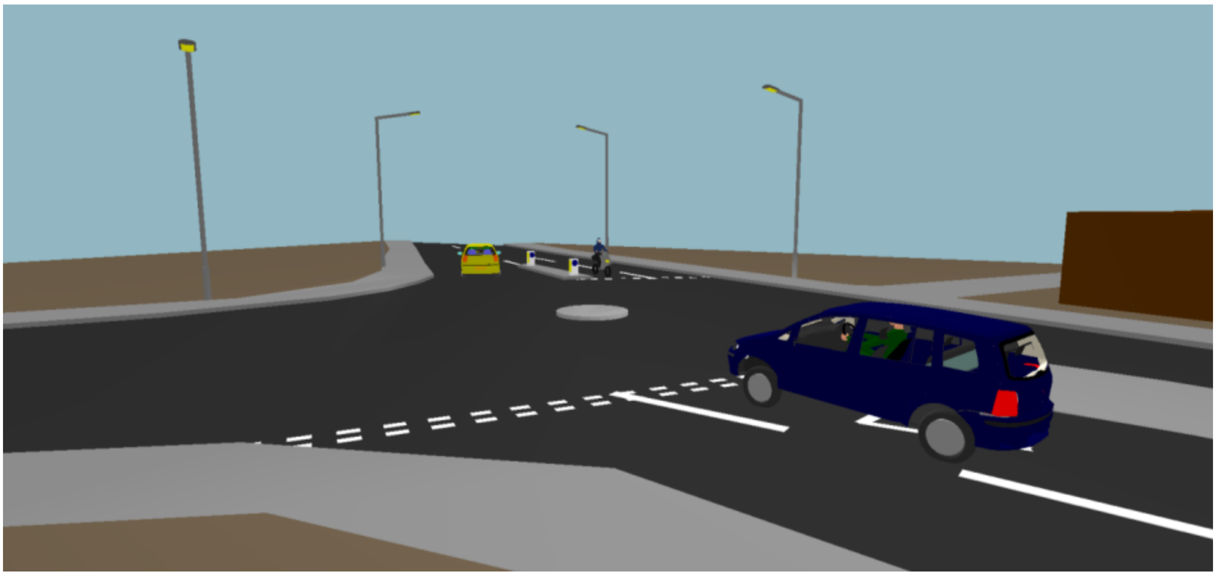

Figure 280. The roundabout layout showing the VW Touran and 99%ile Dutch male driver

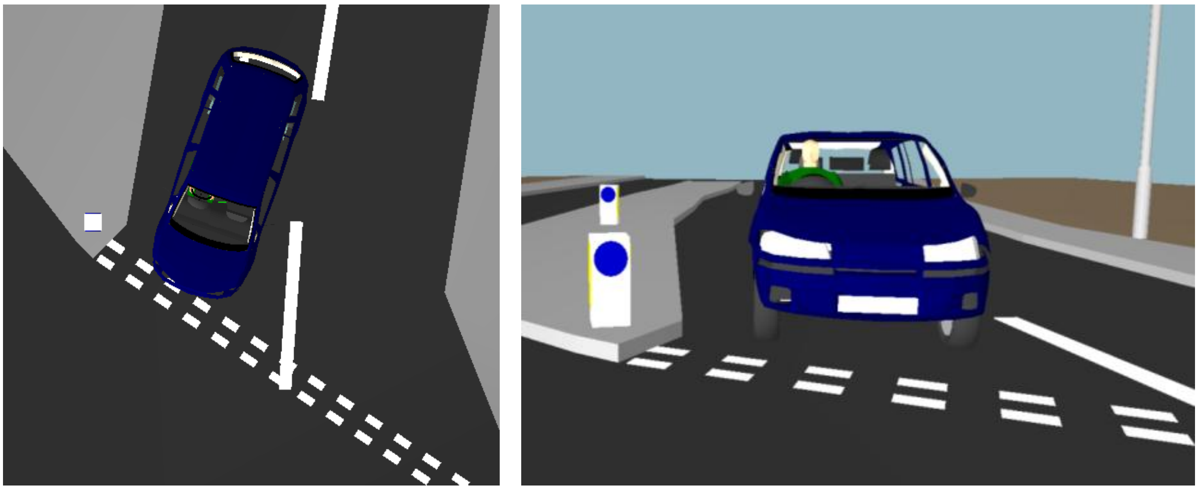

Figure 281. The vehicle positioning at the roundabout

Figure 282, shows that in this position the scooter and its rider are completely obscured by the A-pillar of the M_1 vehicle. The driver is looking to essentially follow the yellow Fiat Punto off the roundabout. The A-pillar is physically larger than that of the Golf, though the colour of the interior trim does make the visual effect greater.

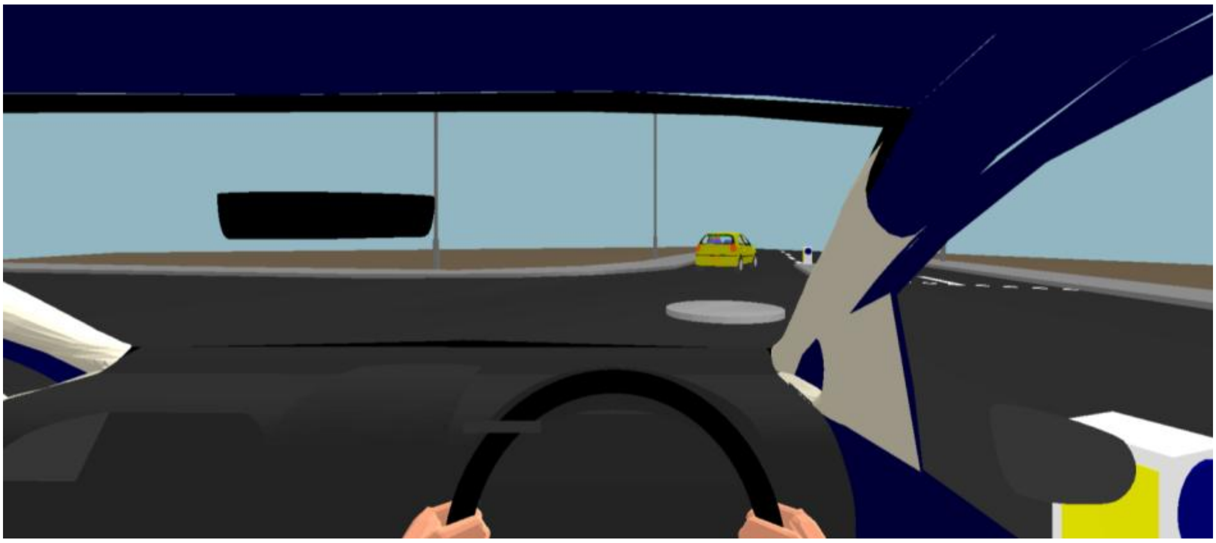

Figure 282. The view of the Dutch male driver

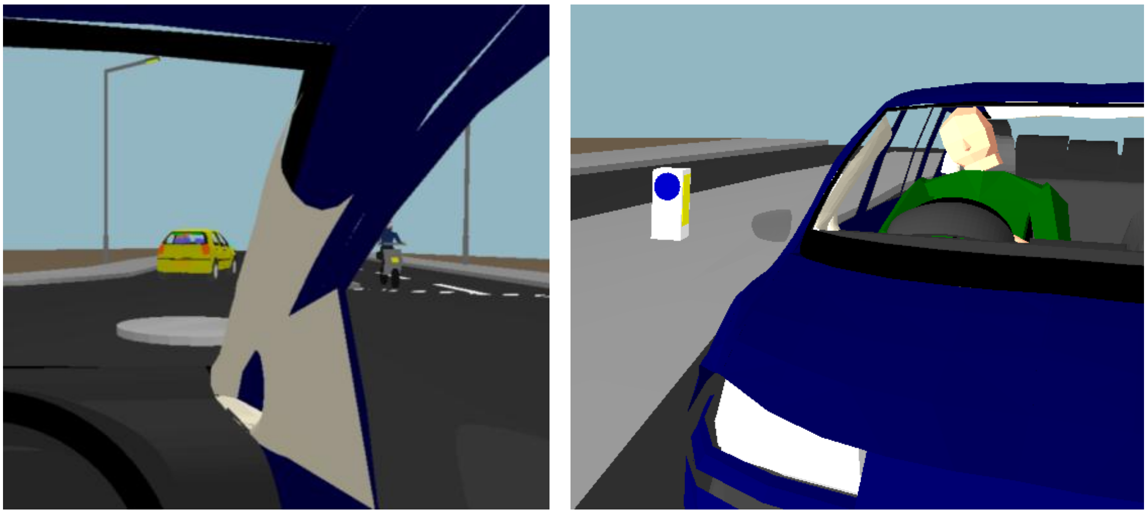

Figure 283. The scooter can be seen if the driver leans their head

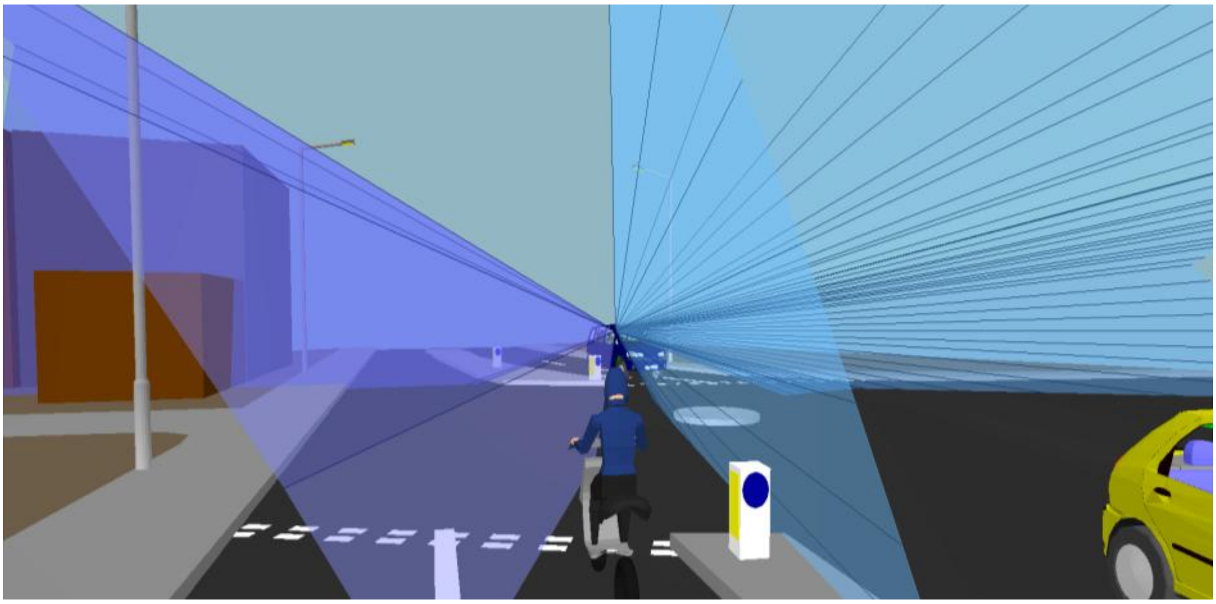

Figure 284. The scooter located within the blind spot caused by the A-pillar

Figure 284, Figure 285 and Figure 286 show that the scooter could travel down the 'corridor' blind spot caused by the offside (right) A-pillar and thus remain obscured whilst the driver of the M_1 vehicle performs their observations prior to setting off. The size of the blind spot is comparable with the Golf for the same size of driver.

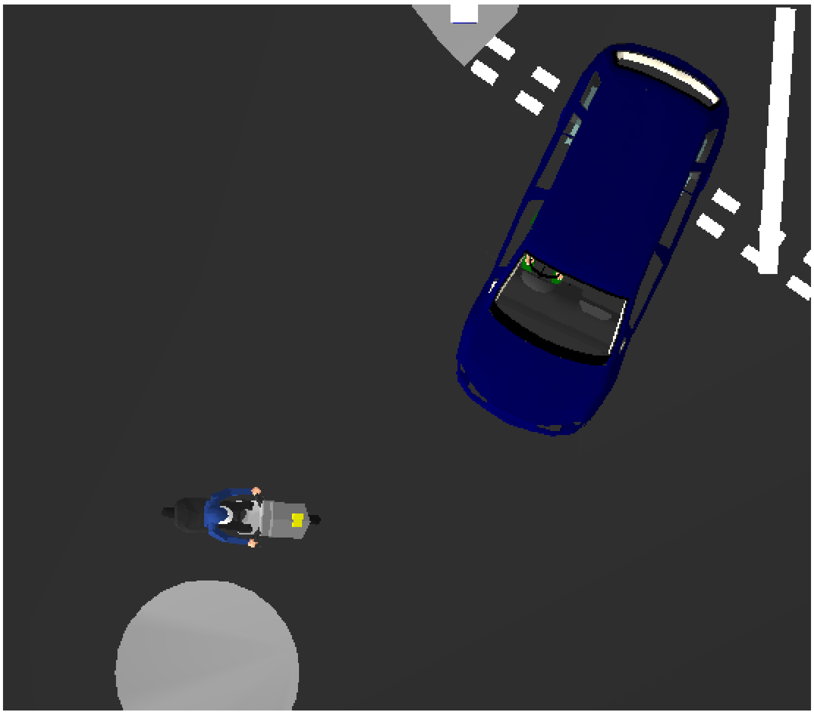

Figure 285. The scooter can effectively travel the whole distance until the point of impact obscured by the M_1 A-pillar

Figure 286. The scooter can effectively travel the whole distance until the point of impact obscured by the M_1 A-pillar – driver's view at point of impact

As with the Golf, if the M_1 driver fails to take account of the blind spot (e.g. Figure 283), it is possible for the scooter to travel to the centre of the roundabout and for the M_1 vehicle to have set off with the scooter having been obscured for the whole time.

3.5.2.1.3.2 35^{h} %ile UK female

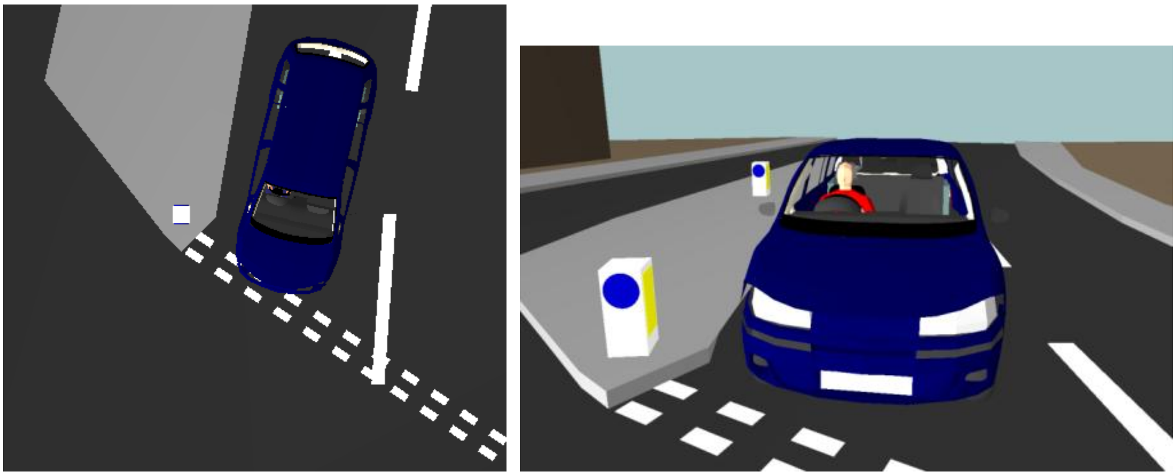

Figure 287. The vehicle positioning at the roundabout

Again with the correct positioning of the M_1 vehicle at the entrance to the roundabout (Figure 287) the scooter and its rider can be completely obscured by the A-pillar of the M_1 vehicle. Here the proximity of the driver's eye point to the A-pillar, and its greater size, makes it a significant obscuration within the driver's field of view (Figure 288). To provide the obscuration the car has to be positioned pointed more to its left, relative to the position for the Dutch male driver, to provide the obscuration. However, it is still possible for the driver to 'look around' the obscuration (Figure 289).

Figure 288. The view of the UK female driver

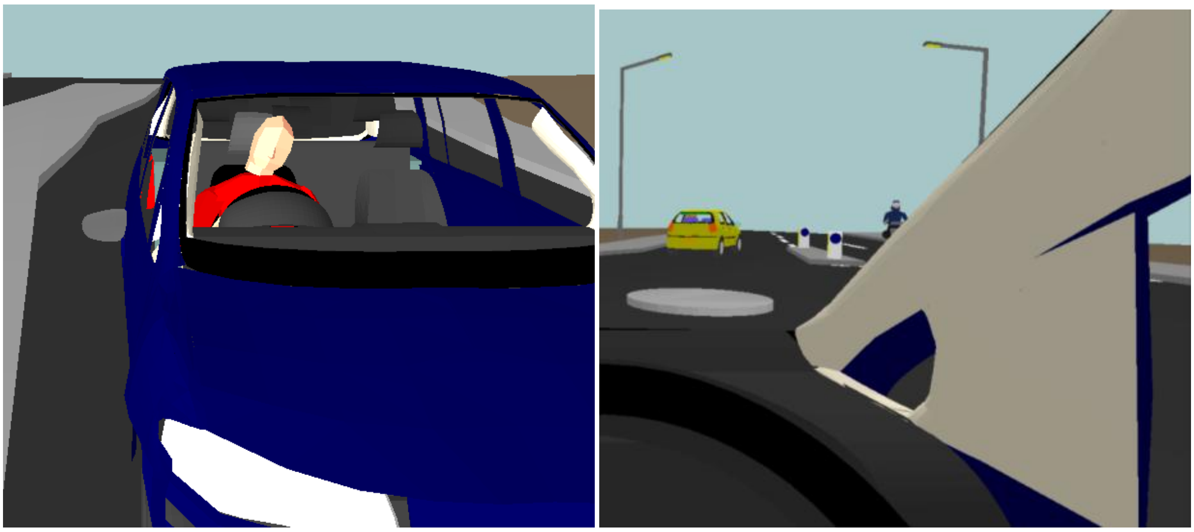

Figure 289. The scooter can be seen if the driver leans their head

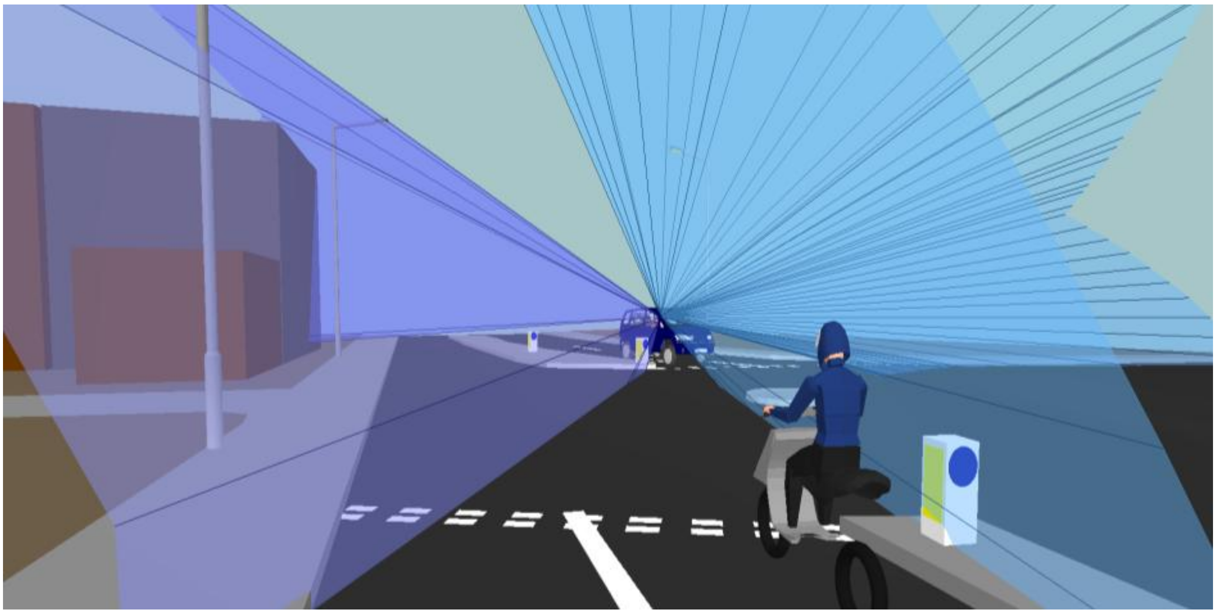

Figure 290. The scooter located within the blind spot caused by the A-pillar

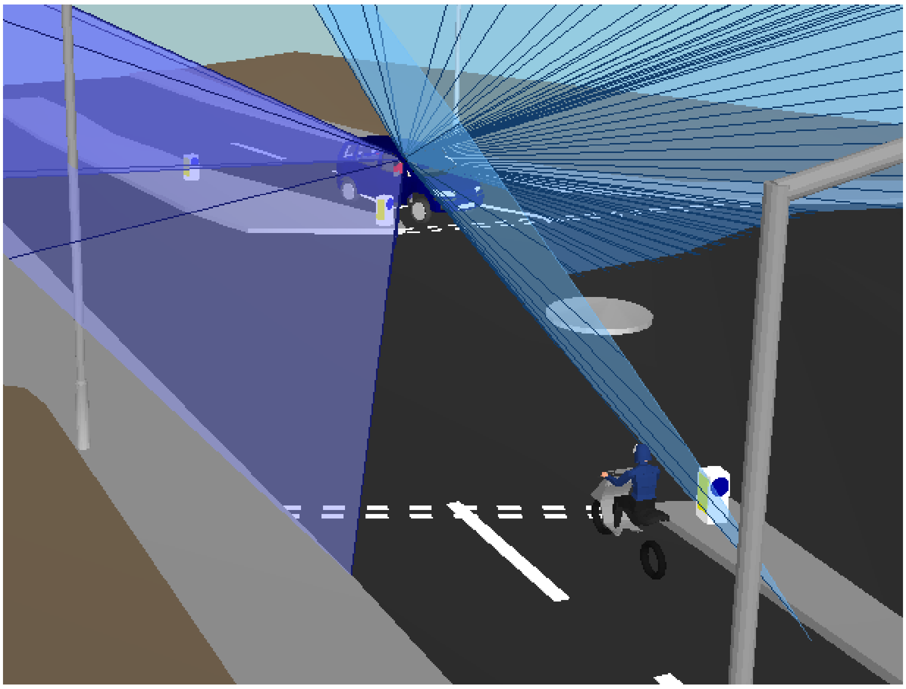

Figure 291. The scooter located within the blind spot caused by the A-pillar (alternative view)

The scooter could easily travel down the 'corridor' blind spot caused by the offside (right) A-pillar and thus remain obscured whilst the driver of the M_1 vehicle performs their observations prior to setting off (Figure 290 and Figure 291). The size of the blind spot is very large and significantly larger than those seen thus far. The size of the A-pillar combined with the smaller driver's positioning within the vehicle compounds the effect of the obscuration. Figure 292 and Figure 293 show how ineffective the split A-pillar's configuration with the glazed aperture is in dealing with this issue.

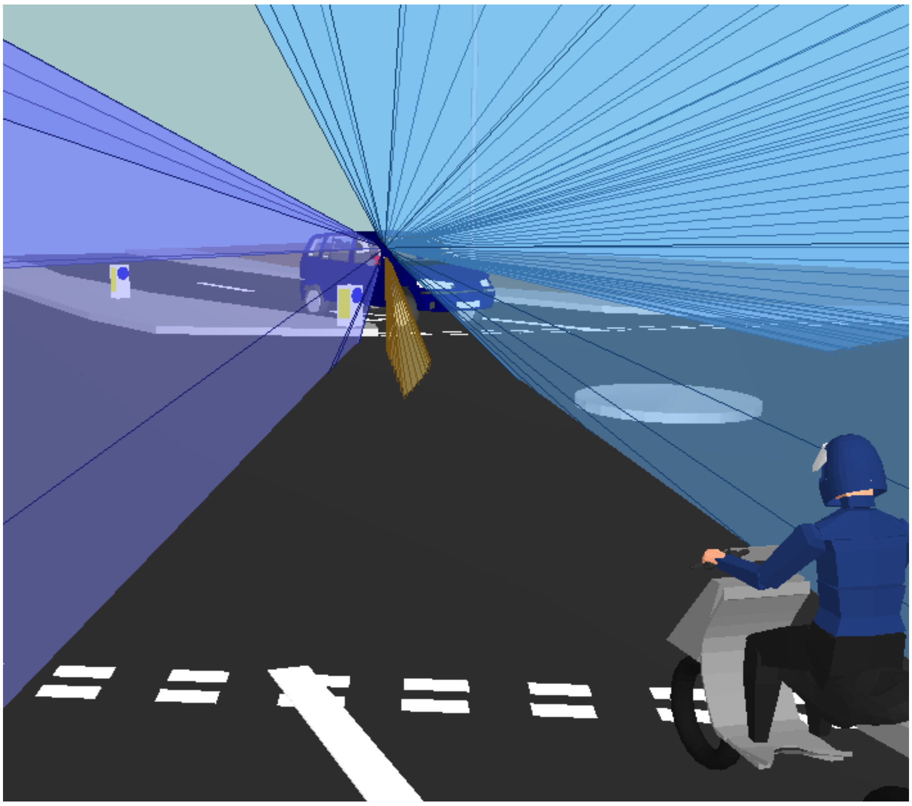

Figure 292. The visibility afforded by the split A-pillar and its glazed aperture is limited (indicated by the yellow projection shown)

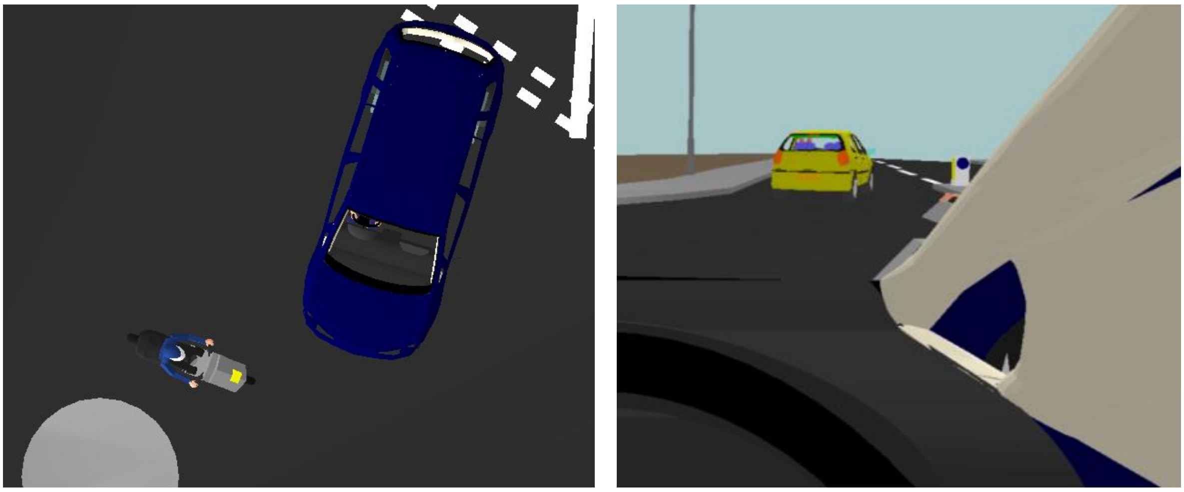

Figure 293. The scooter can effectively travel the whole distance until the point of impact obscured by the M_1 A-pillar

3.5.2.1.4 M_1 – Hyundai i10

3.5.2.1.4.1 99th %ile Dutch male

The relative positioning of the vehicles is shown in Figure 294 and Figure 295 below.

Figure 294. The roundabout layout showing the Hyundai i10 and 99%ile Dutch male driver

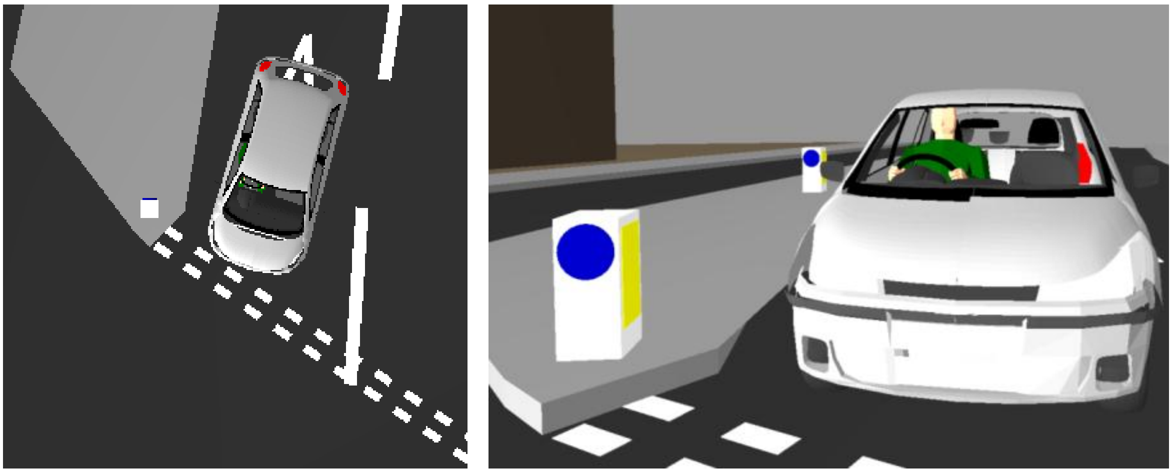

Figure 295. The vehicle positioning at the roundabout

Figure 296 shows that in this position the scooter and its rider are completely obscured by the A-pillar of the M_1 vehicle. However, it is still possible for the driver to 'look around' the obscuration (Figure 297).

Figure 296. The view of the Dutch male driver

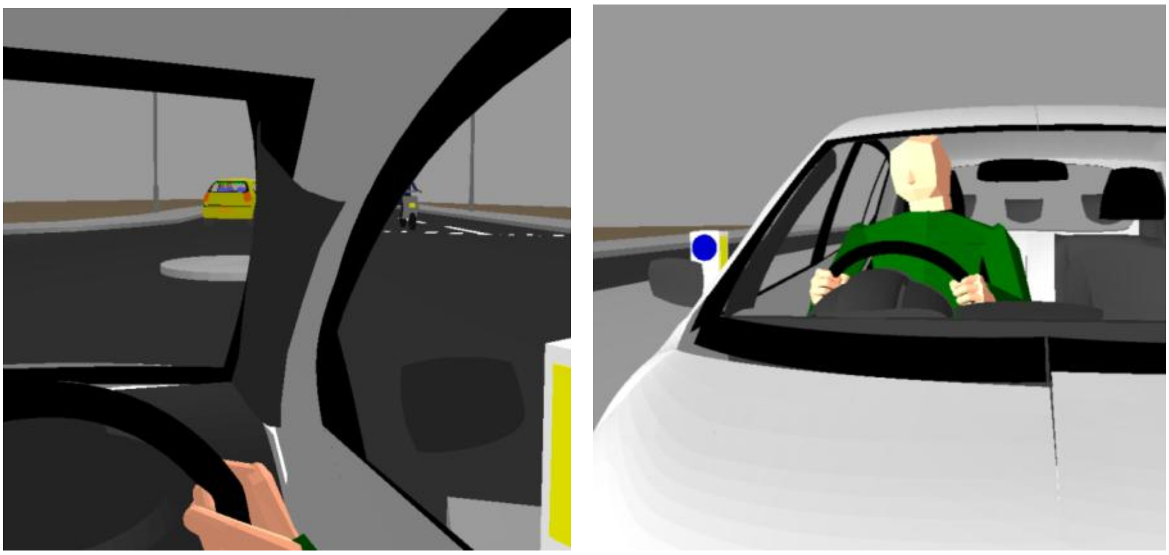

Figure 297. The scooter can be seen if the driver leans their head

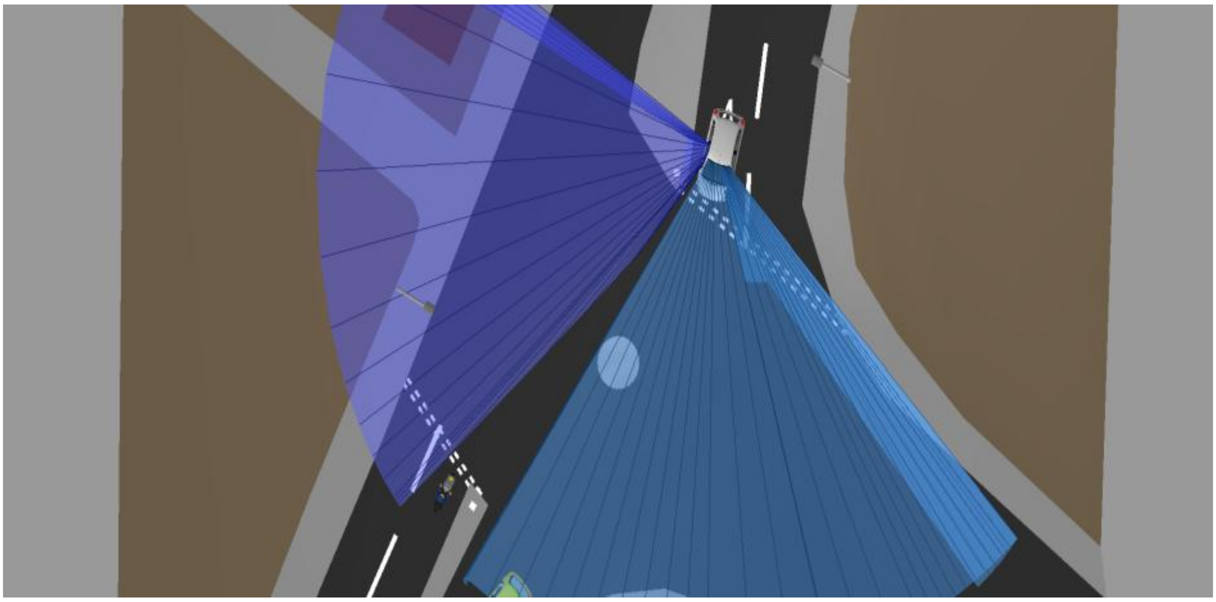

Figure 298. The scooter located within the blind spot caused by the A-pillar

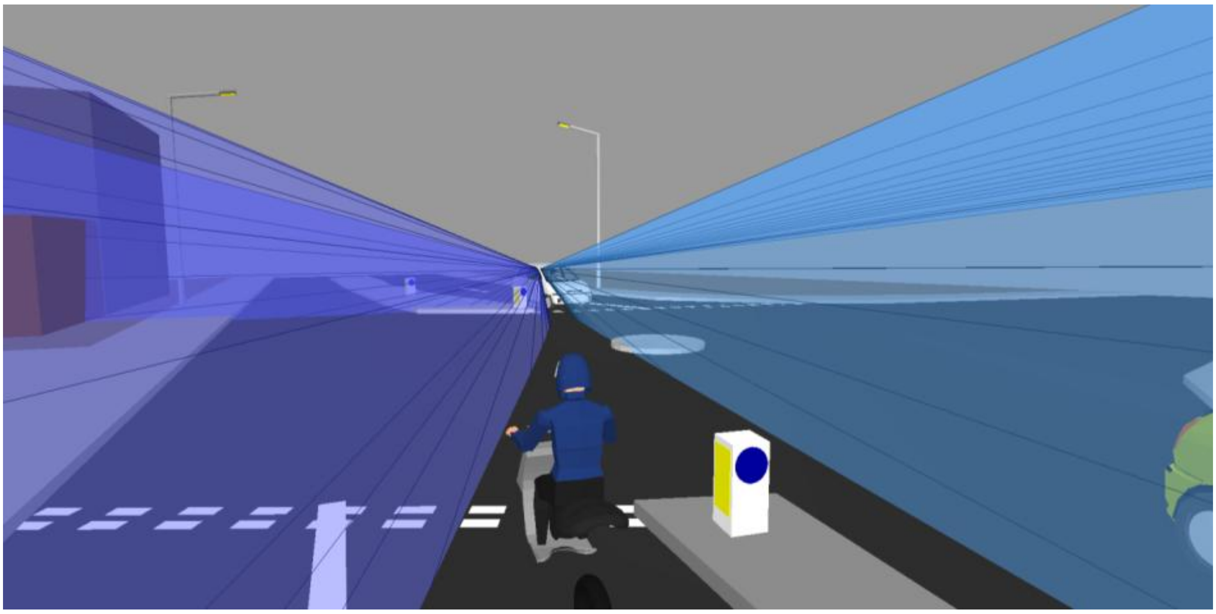

Figure 299. The scooter located within the blind spot caused by the A-pillar

Figure 298 and Figure 300 show again that the scooter could travel down the 'corridor' blind spot caused by the offside (right) a-pillar and thus remain obscured whilst the driver of the M_1 vehicle performs their observations prior to setting off. The size of the blind spot is comparable and possibly slightly larger than that of the Golf and Touran for the same size of driver.

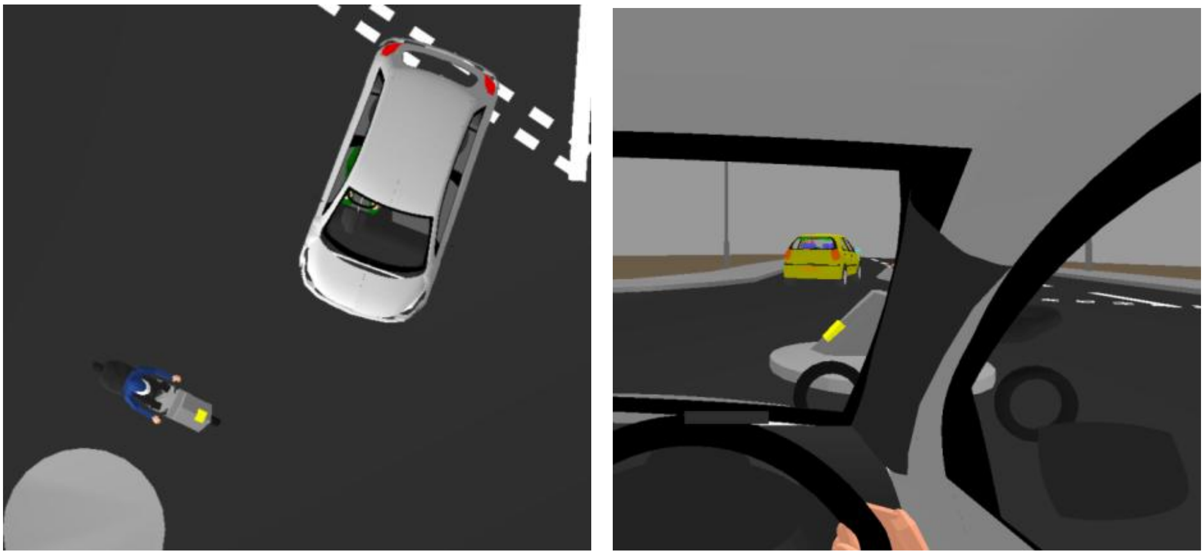

Figure 300. The scooter can effectively travel the whole distance until the point of impact obscured by the M_1 A-pillar

3.5.2.1.4.2 5^h %ile UK female

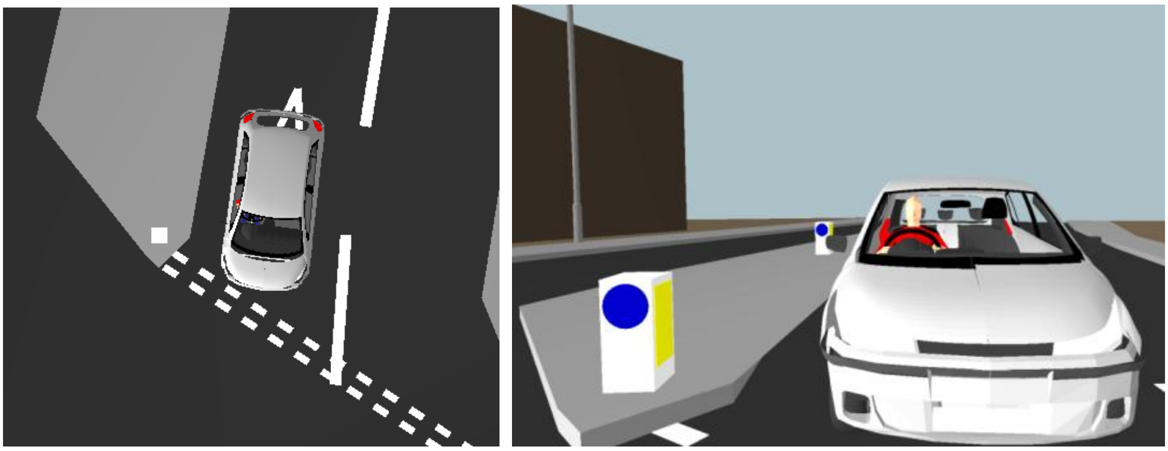

Figure 301. The vehicle positioning at the roundabout

With the correct positioning of the M_1 vehicle at the entrance to the roundabout (Figure 301) the scooter and its rider can be completely obscured by the A-pillar of the M_1 vehicle (Figure 302). Here the proximity of the driver's eye point to the A-pillar and its greater size makes it a significant obscuration within the driver's field of view. As with the other M_1 vehicles the car has to be positioned pointed more to its left, relative to the position for the Dutch male driver, to provide the obscuration.

Figure 302. The view of the UK female driver

Figure 303. The scooter can be seen if the driver leans their head (to the left)

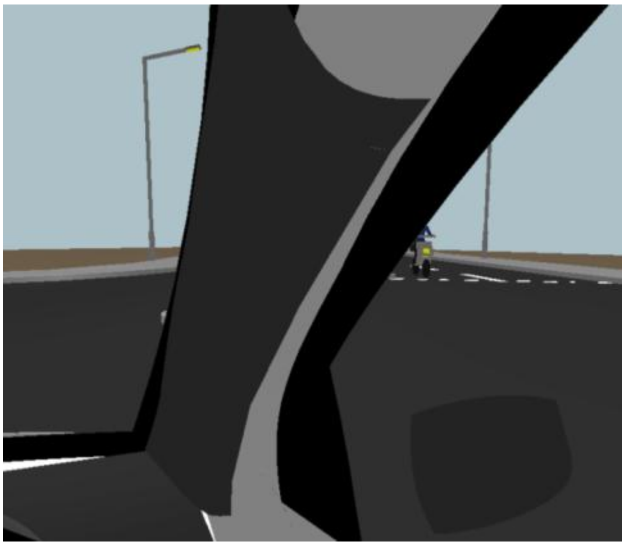

Figure 304. The scooter can be seen if the driver leans their head (to the right)

As with all vehicles in this scenario, if the driver is aware of the blind spot it is possible to 'look around' the obstacle by tilting the head to the side. However due to the significance of the obscuration the posture to 'look around' the A-pillar is not a simple glance to the side but requires a very deliberate lean of the head or lean forward of the torso to either side (Figure 303 and Figure 304).

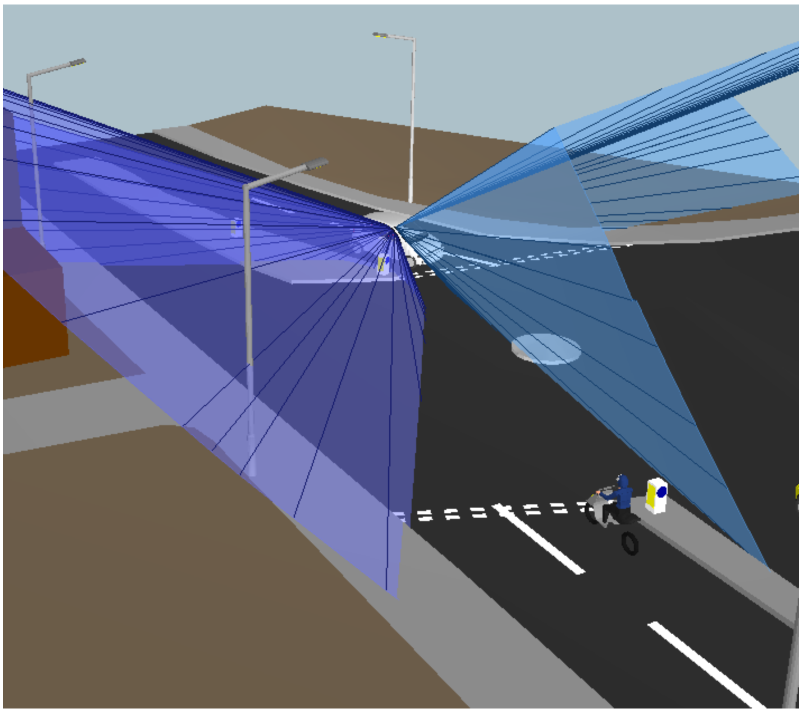

Figure 305. The scooter located within the blind spot caused by the A-pillar

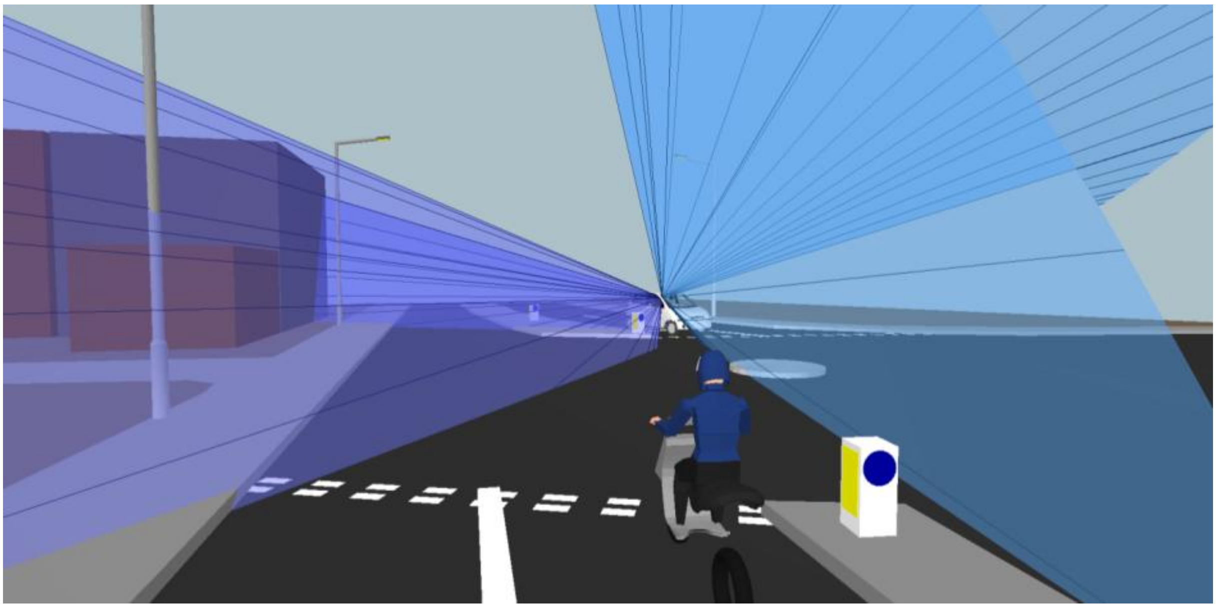

Figure 306. The scooter located within the blind spot caused by the A-pillar (alternative view)

Figure 305 and Figure 306 show that the scooter, and indeed the whole opposite entrance to the roundabout, could be obscured by the A-pillar. The size of the blind spot is the largest seen in these evaluations. The result of this blind spot is that the scooter could get all the way to the impact point without being seen by the driver of the M_1 vehicle (Figure 307).

Figure 307. The scooter can effectively travel the whole distance until the point of impact obscured by the M_1 A-pillar

3.5.2.1.5 Roundabout summary

For all of the assessed M_1 vehicles there is an effective 'corridor' blind spot caused by the A-pillar. This blind spot is greater for the smaller drivers of each vehicle as the angle subtended by the eye has to be greater to clear the A-pillar obscuration due to the eye point being closer to the pillar. It is possible that whilst the M_1 driver is performing their observations prior to setting off that the scooter could have travelled the length of this corridor and be in the process of turning to their right, across the front of the M_1 vehicle. If the scooter rider was focused on their direction of travel and exit from the roundabout and had reached the critical point where the M_1 vehicle was no longer visible, it is possible that the M_1 vehicle could set off and cause the collision. This sequence of events would need very particular timing but Figure 308, Figure 309, Figure 310, Figure 311 and Figure 312 below give an indication of how this may come together to cause the accident.

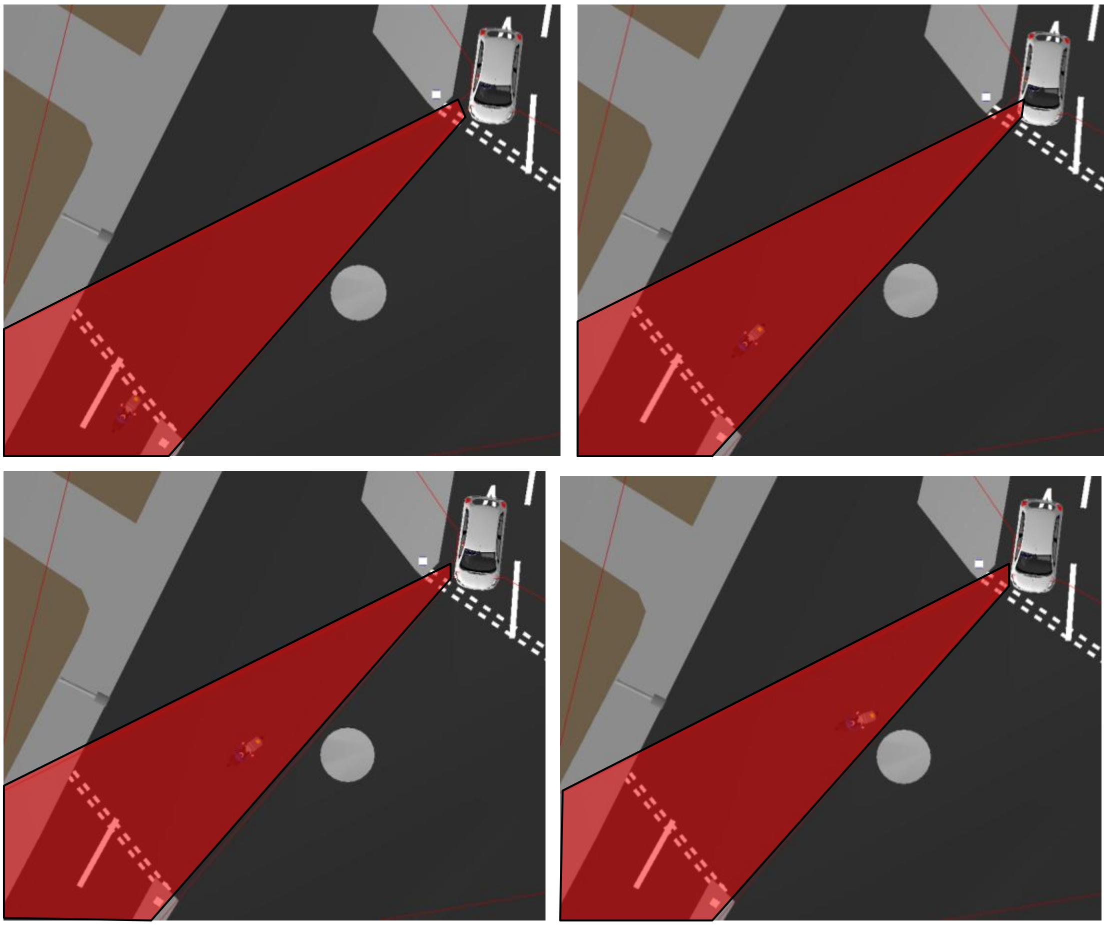

Figure 308. The scooter travels along the blind spot whilst the M_1 driver performs observations

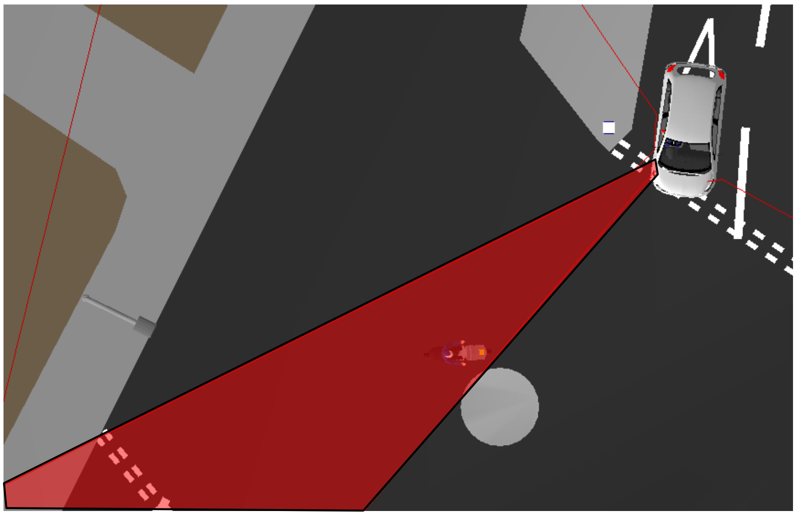

Figure 309. At this point the scooter rider is focused on their exit and is no longer aware of the M_1 vehicle

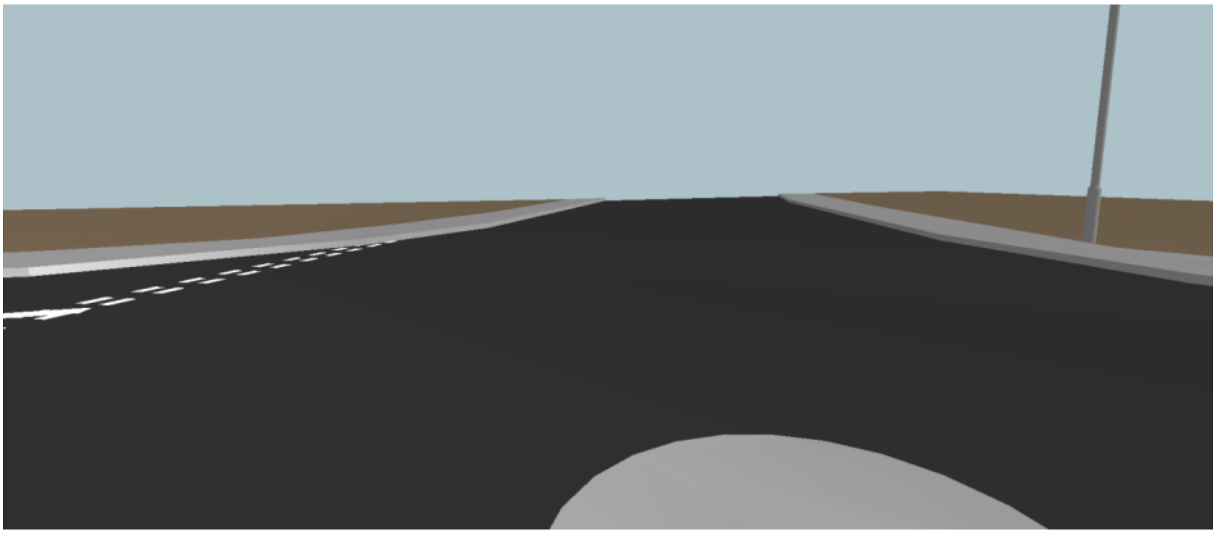

Figure 310. At this point the scooter rider is focused on their exit and is no longer aware of the M_1 vehicle – Rider's view

Figure 309 / Figure 310: the scooter rider is still obscured by the A-pillar and critically the rider is no longer aware of the M_1 vehicle as they are focused on their exit from the roundabout.

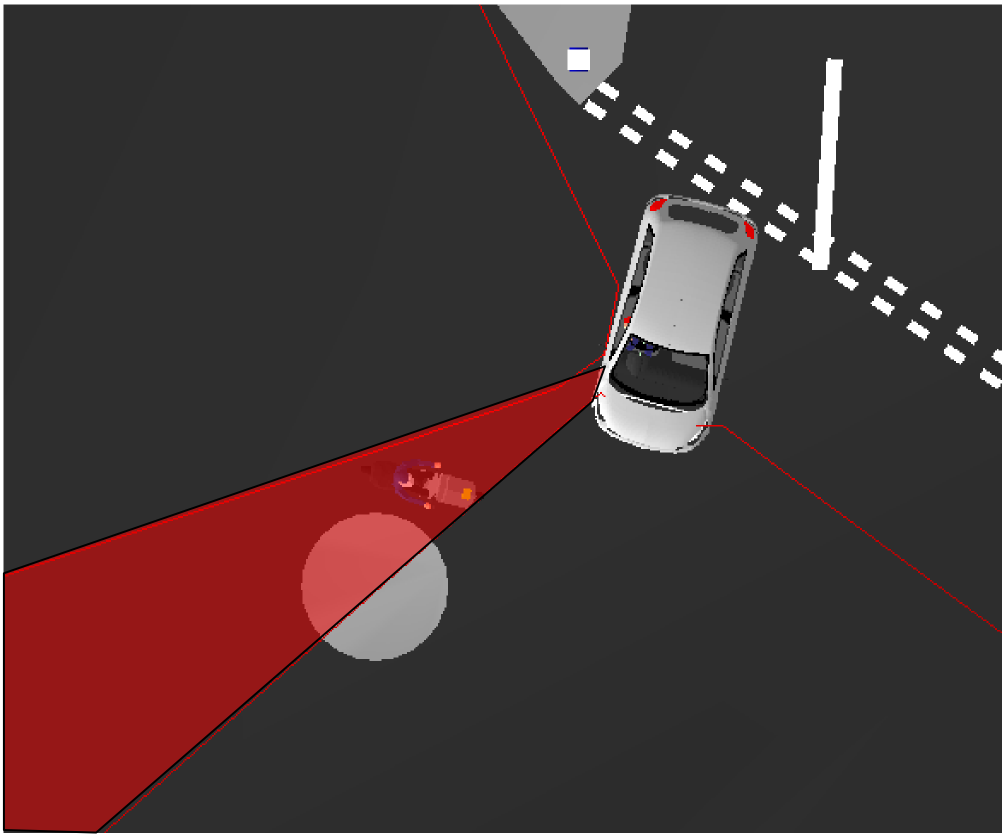

Figure 311. The M_1 vehicle has now set off and the scooter is still obscured

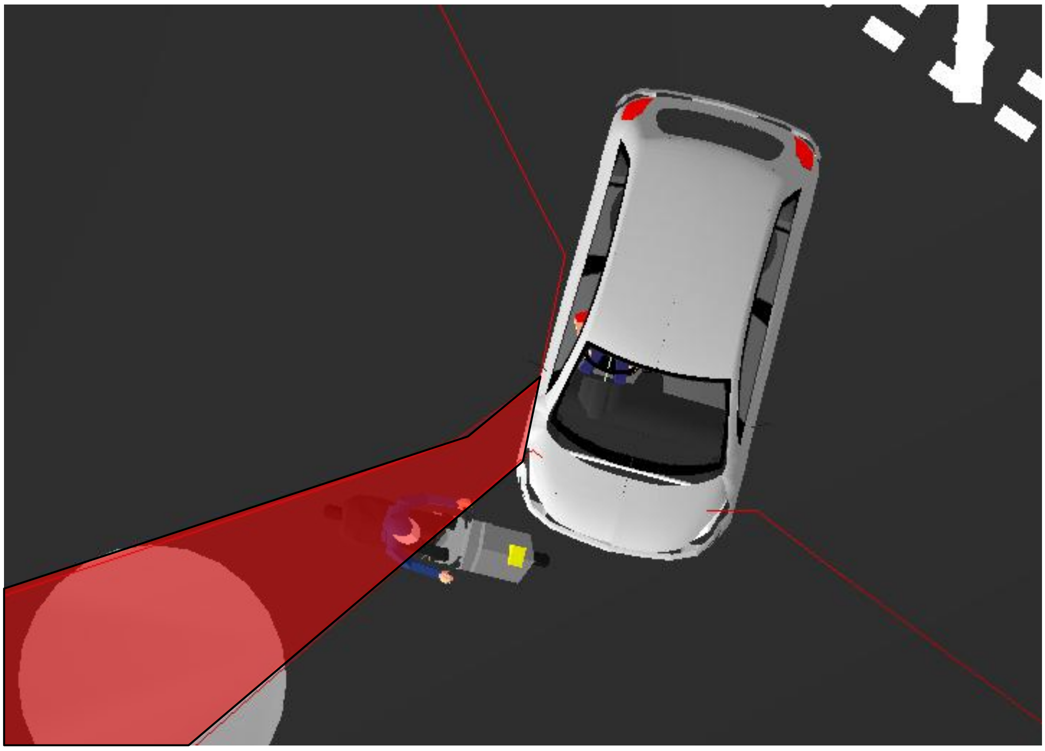

Figure 312. The point of impact

Figure 312: the scooter finally becomes visible at the point of impact and would appear to 'come out of nowhere' to the driver of the M_1 vehicle.

All three vehicles are potentially capable of being involved in this form of incident but the Hyundai i10 and Volkswagen Touran have noticeably larger blind spots (Figure 313). In addition, smaller drivers are universally less able to see 'around' the A-pillar when compared to the larger driver. Proximity to the pillar appears to be as large a contributory factor as pillar size itself with the Touran having a much larger pillar but being further away from the driver than in the smaller pillared Hyundai.

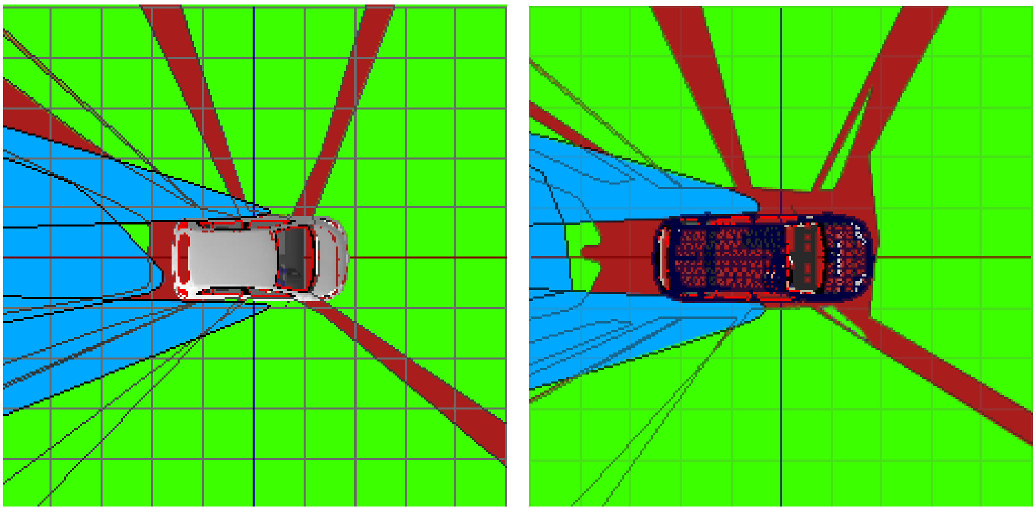

Figure 313. The similarity of the Hyundai i10 and Volkswagen Touran offside A-pillar obscuration

3.5.2.2 T-Junction OTS case

The following scenario examines the visibility from category M_1 vehicles in a situation where the vehicle (P1V1) is turning left at a T-Junction from a shop car park into a major road. In the OTS case, the driver of the M_1 category vehicle has pulled out of the junction and a pedal cycle (P2V1) collided with the side of the vehicle.

3.5.2.2.1 Scenario setup

The scenario was modelled using the map data provided in the OTS case report (Figure 314). The angle of the junction from the car park to the main road has the potential to cause difficulty for the category M_1 driver in terms of positioning for optimum visibility to the right of the vehicle to observe vehicles already on the main road travelling from right to left. The vehicle CAD model that represents P2V1 (a pedal cycle of unknown type) is positioned travelling along the main road from right to left across the path of the M_1 vehicle. P1V1 is positioned to make the turn to the left as smooth as possible by aligning the front of the vehicle relatively to the left as opposed to perpendicular to the main road.

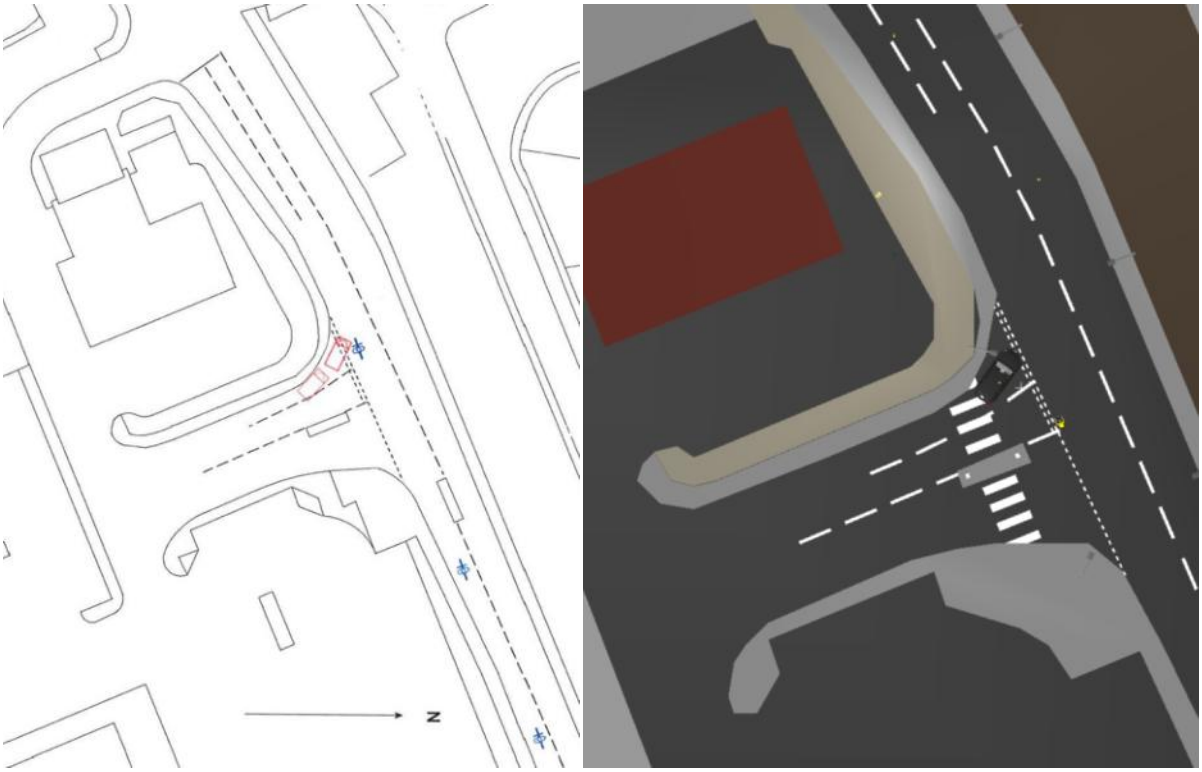

Figure 314. The road layout recreated from the OTS case report

3.5.2.2.2 M_1 – Volkswagen Golf

3.5.2.2.2.1 99th %ile Dutch male

The relative positioning of the vehicles is shown in Figure 315 and Figure 316 below.

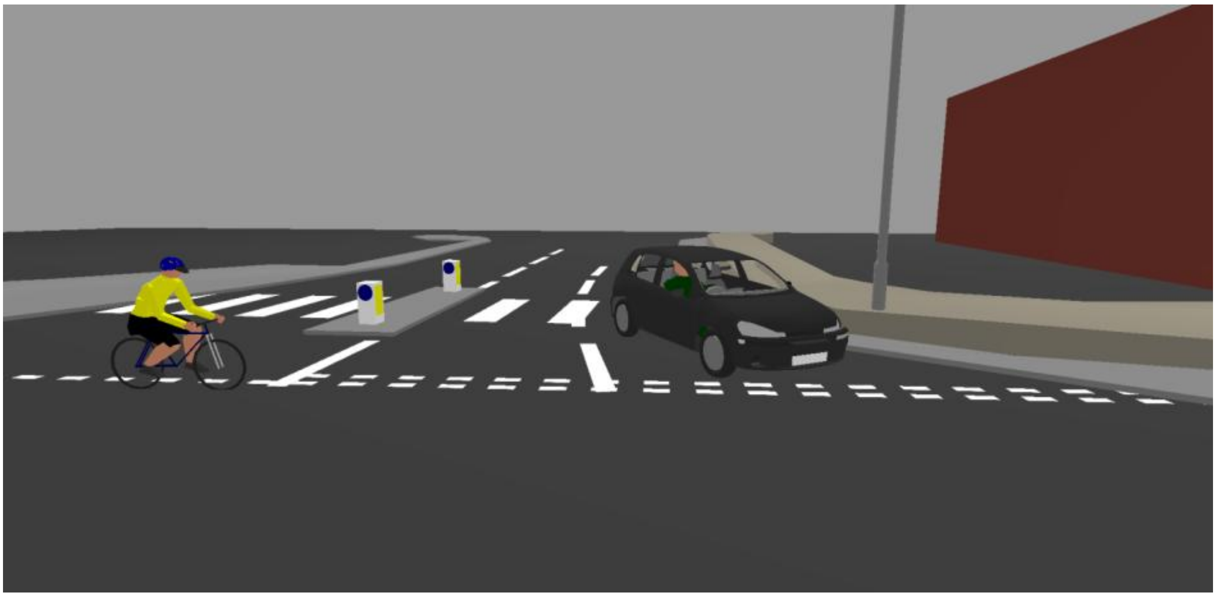

Figure 315. The T-Junction layout showing the VW Golf and 99%ile Dutch male driver

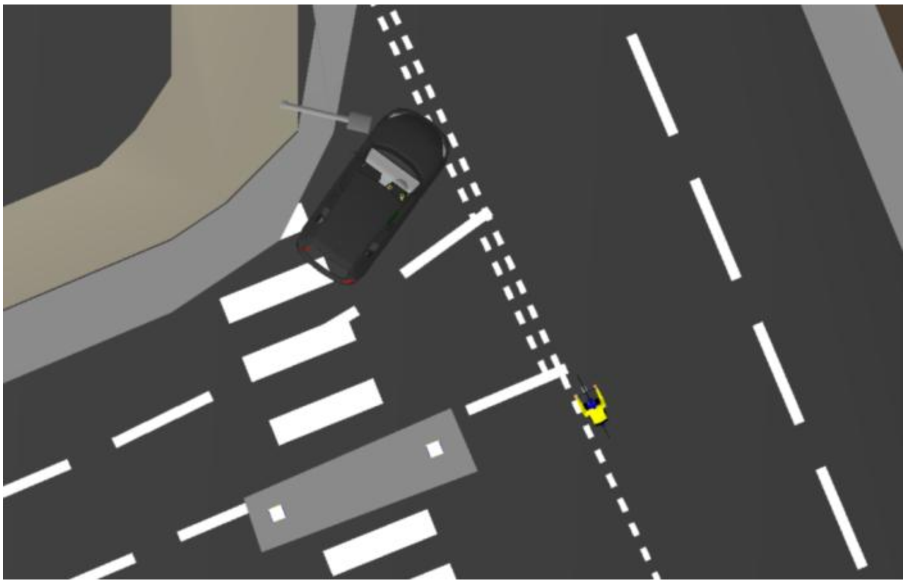

Figure 316. The vehicle positioning at the junction

Figure 317 shows that in this position the cyclist is completely obscured by the B-pillar of the M_1 vehicle. The driver is looking to the right to check the coast is clear prior to pulling off.

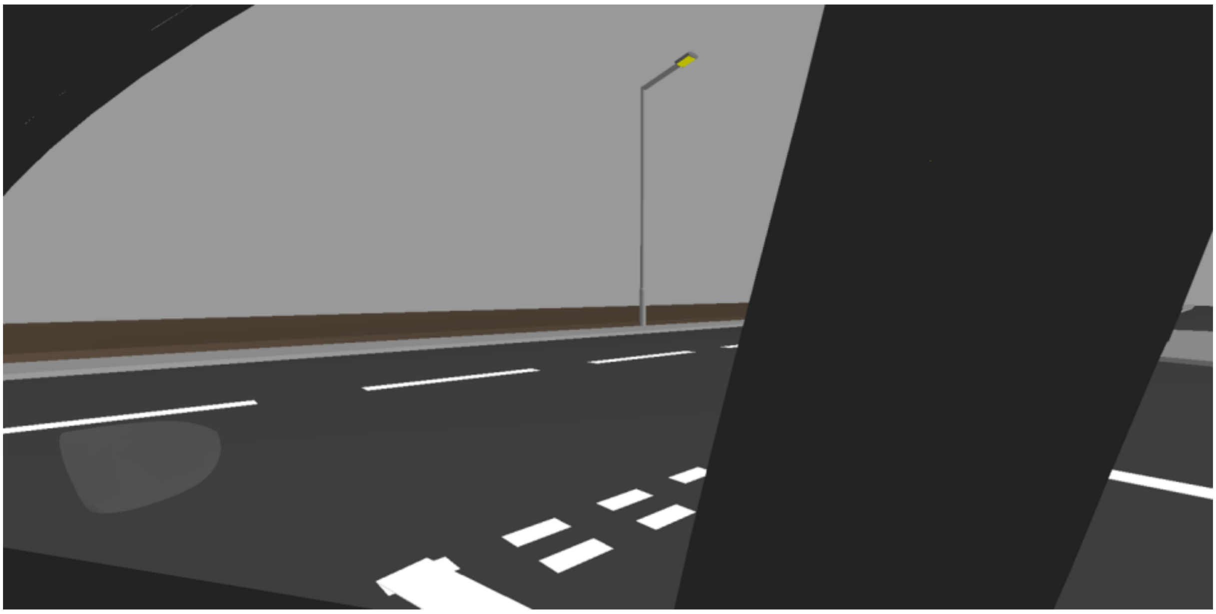

Figure 317. The view of the Dutch male driver

Figure 318. The cyclist can be seen if the driver leans their head

Figure 318 above shows that whilst the B-pillar obscuration does mask the cyclist, it is possible for the driver to 'look around' the obscuration if the driver is aware of the blind spot.

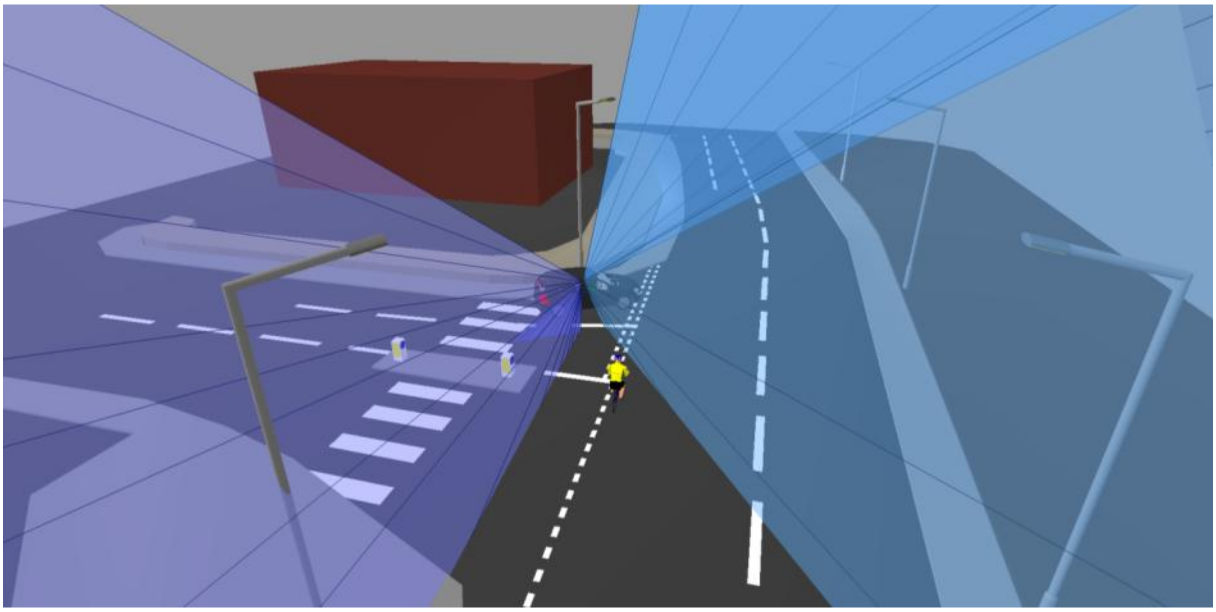

Figure 319. The cyclist located within the blind spot caused by the B-pillar

The B-pillar forms a clear and significant 'corridor' of obscured field of view in the direction of the oncoming traffic (Figure 319).

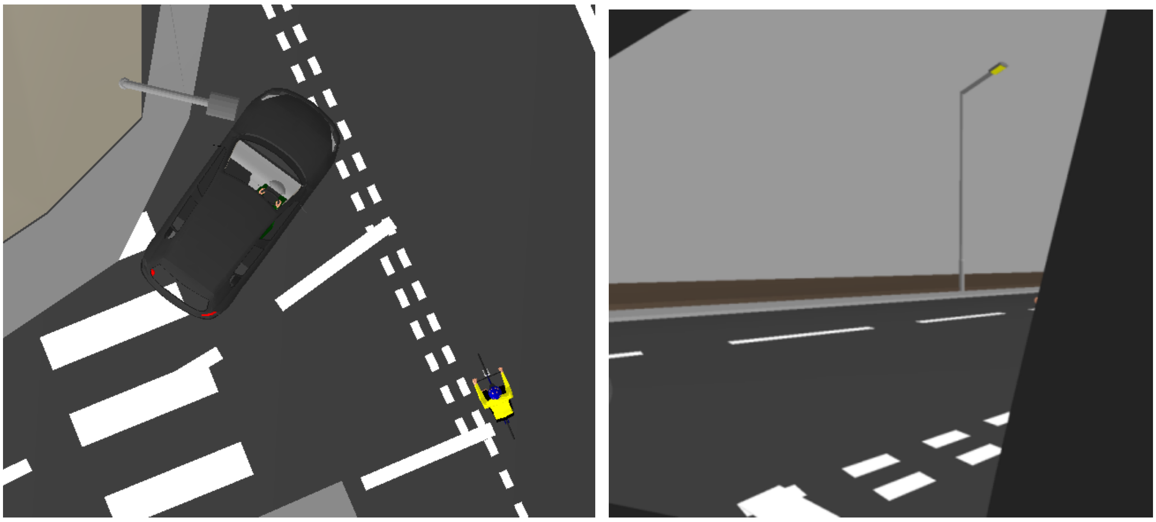

Figure 320. The cyclist can get within 4.5m of the M_1 whilst obscured by the B-pillar

Figure 320 shows the closest the cyclist can get to the M_1 vehicle whilst still being within the blind spot caused by the B-pillar. The cyclist is approximately 4.5m from the front of the M_1 vehicle and when travelling at a relatively modest 14mph they could cover this distance in 0.719s. It is clear the driver could look and not see the cyclist and then pull out in front of the oncoming cyclist

3.5.2.2.2.2 5^{h} %ile UK female

The relative positioning of the vehicles is shown in Figure 321 and Figure 322 below.

Figure 321. The T-Junction layout showing the VW Golf and 5%ile UK female driver

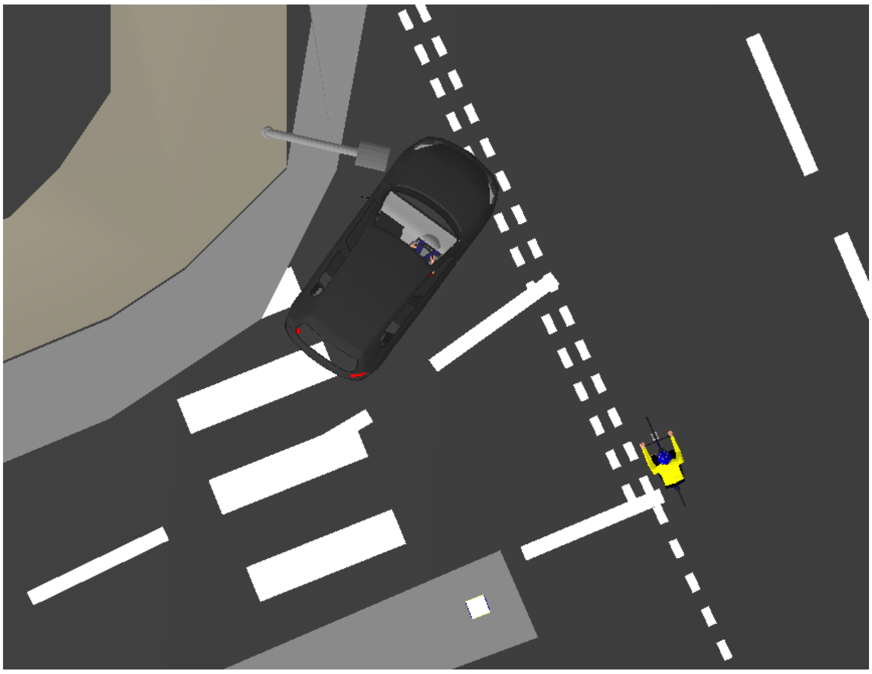

Figure 322. The vehicle positioning at the junction

Figure 323 and Figure 324 show that in this position the cyclist is completely visible through the offside (right) front window. Due to the driver's eye point being further forwards in the vehicle in comparison to the Dutch male, the B-pillar is relatively rearward of the eye point and thus its obscuration does not affect this scenario setup. There is a clear view of the road for a considerable distance.

Figure 323. The view of the UK female driver

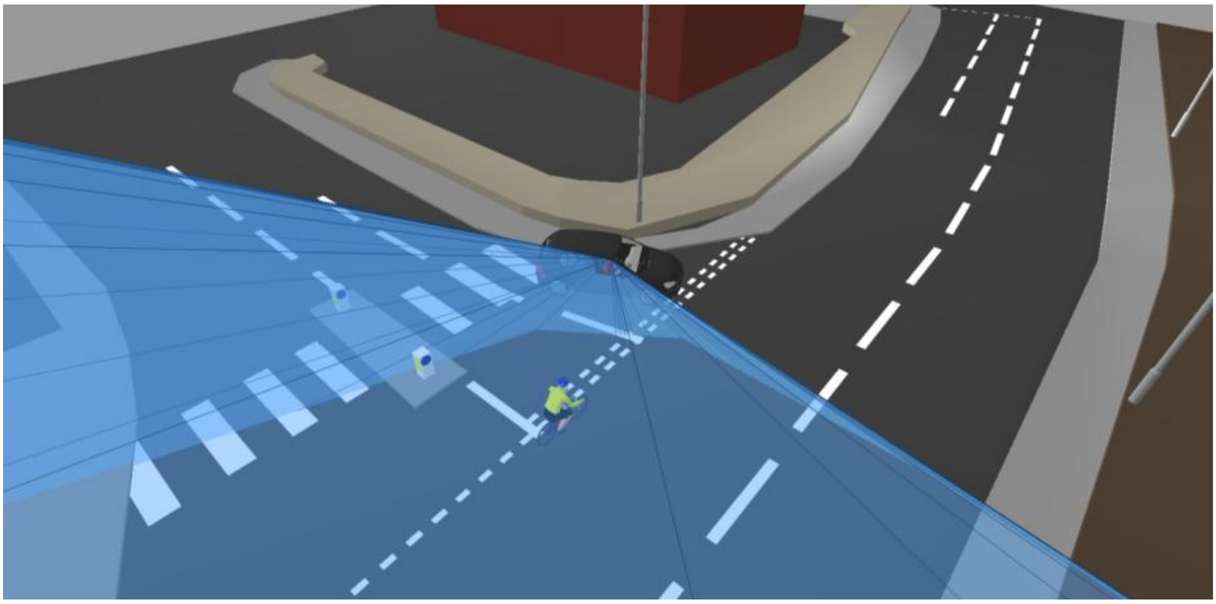

Figure 324. The cyclist located within the field of view through the offside (right) front window

Figure 325 below aims to evaluate whether the A-pillar could pose a sufficient obscuration for the UK female driver in this scenario. The images clearly show that the A-pillar is very unlikely to be the reason for the driver to have failed to see the cyclist.

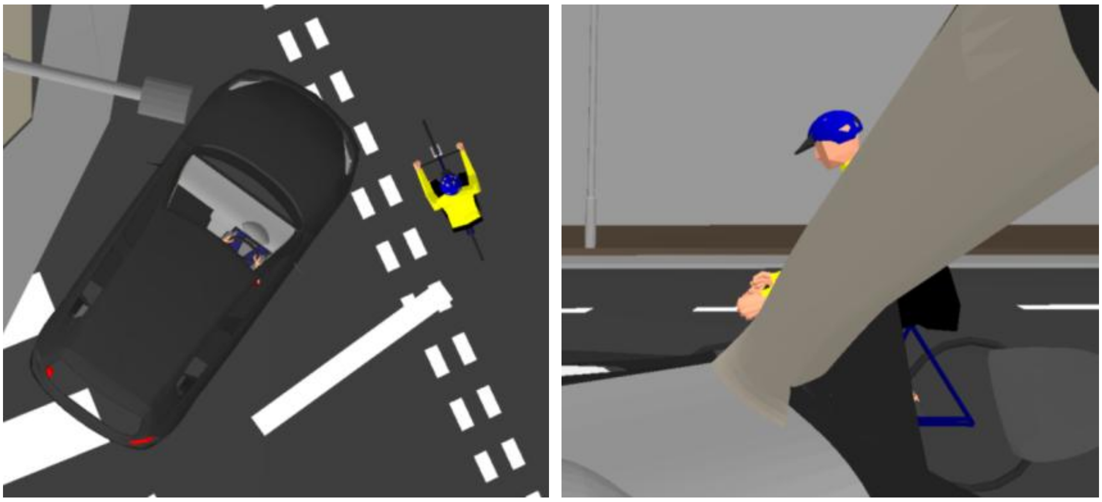

Figure 325. Evaluating the possibility of A-pillar obscuration for this scenario

3.5.2.2.3 M_1 – Volkswagen Touran

3.5.2.2.3.1 99th %ile Dutch male

The relative positioning of the vehicles is shown in Figure 326 and Figure 327 below.

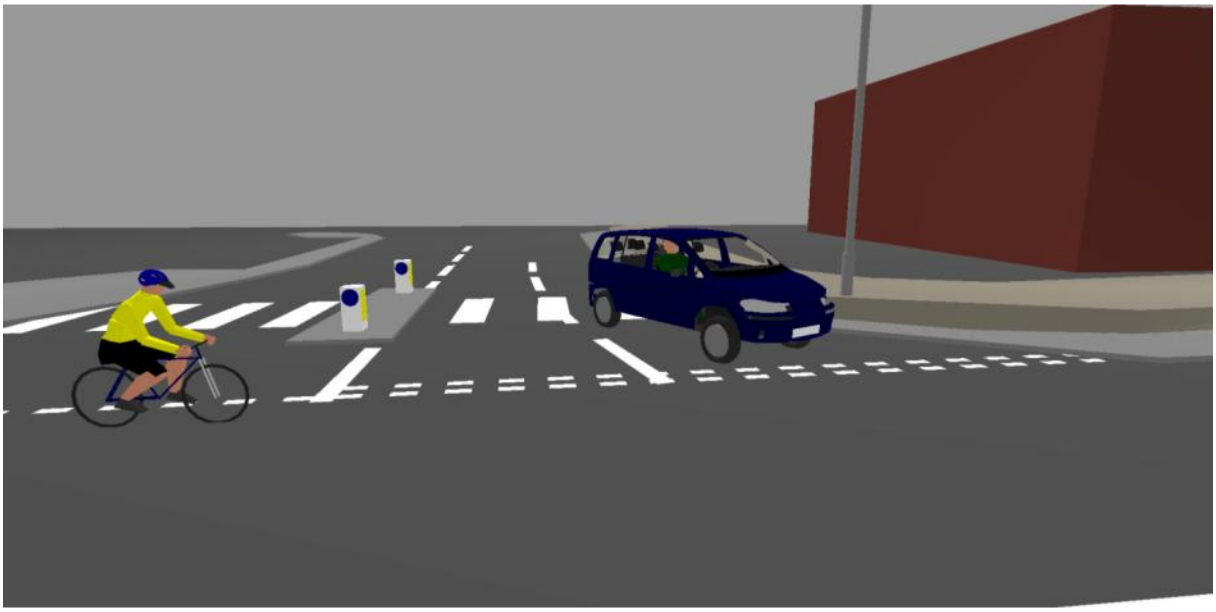

Figure 326. The T-Junction layout showing the VW Touran and 99%ile Dutch male driver

Figure 327. The vehicle positioning at the junction

Figure 328 shows that in this position the cyclist is again completely obscured by the B-pillar of the M_1 vehicle.

Figure 328. The view of the Dutch male driver

Figure 329. The cyclist can be seen if the driver leans their head

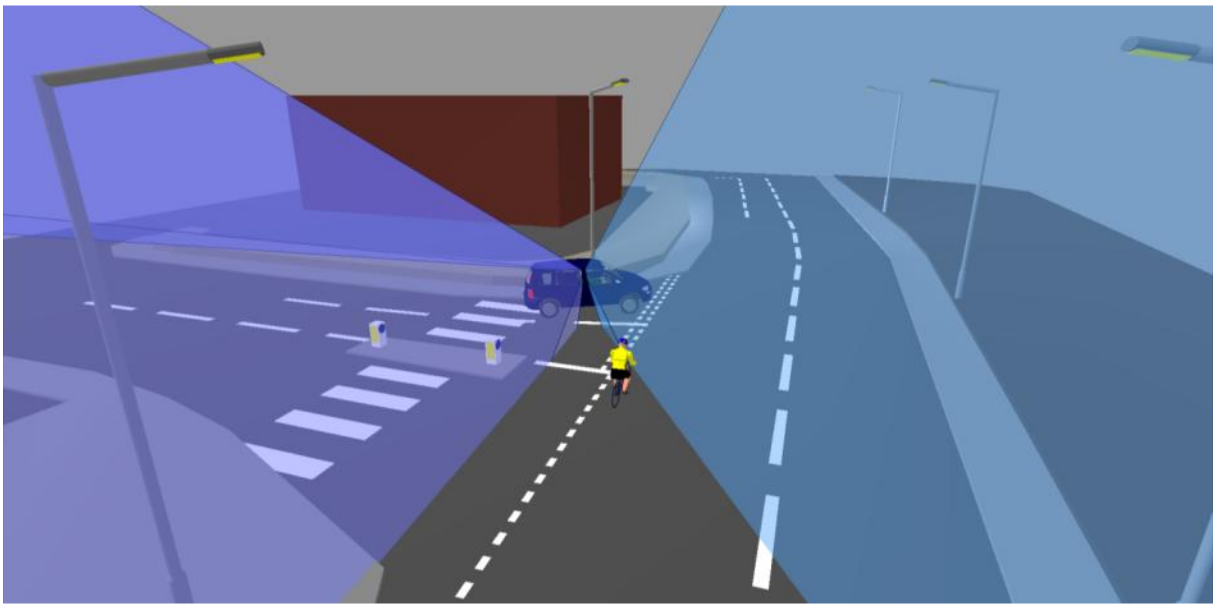

Figure 330. The cyclist located within the blind spot caused by the B-pillar

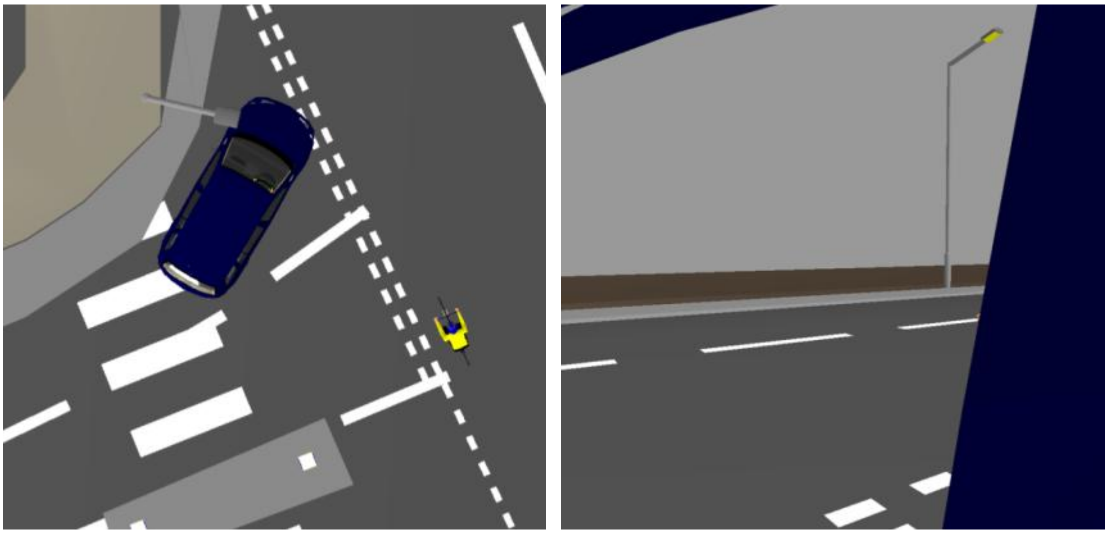

Figure 331. The cyclist can get within 4.5m of the M_1 whilst obscured by the B-pillar

If the driver fails to look around the obscuration (Figure 329), it is possible for the cyclist to get to within 4.5m of the M_1 vehicle whilst still being within the blind spot caused by the B-pillar (Figure 330 and Figure 331). At 4.5m from the front of the M_1 vehicle (the same as for the Golf) and travelling at a relatively modest 14mph they could cover this distance in 0.719s. It is clear the driver could look and not see the cyclist and then pull out in front of the oncoming cyclist.

3.5.2.2.3.2 35^h %ile UK female

The relative positioning of the vehicles is shown in Figure 332 and Figure 333 below.

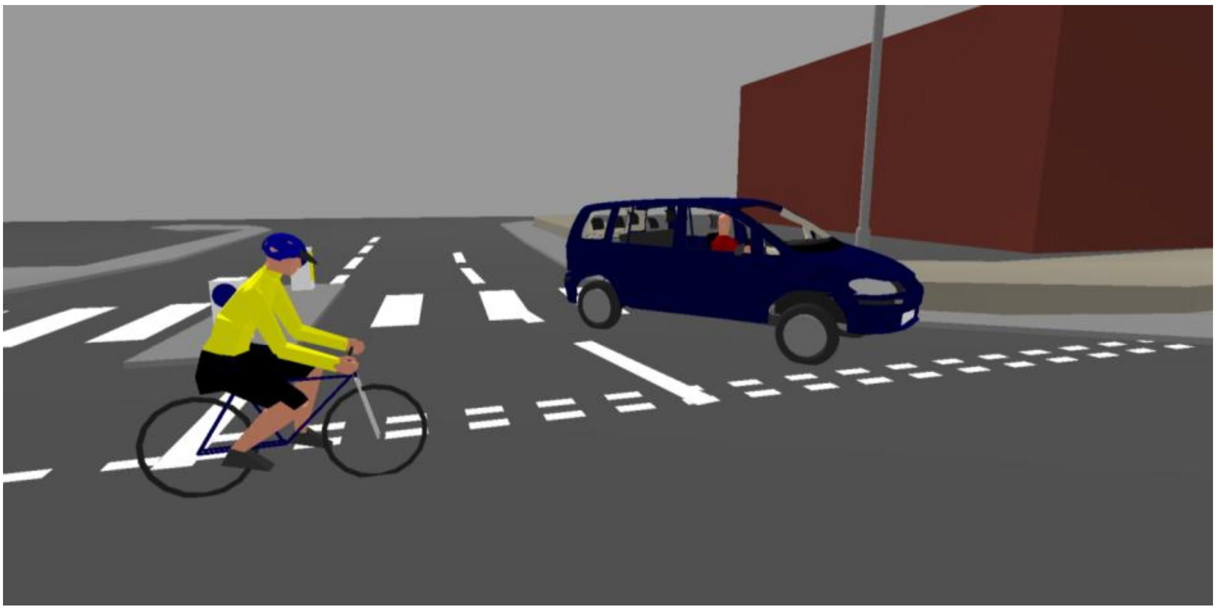

Figure 332. The T-Junction layout showing the VW Touran and 35%ile UK female driver

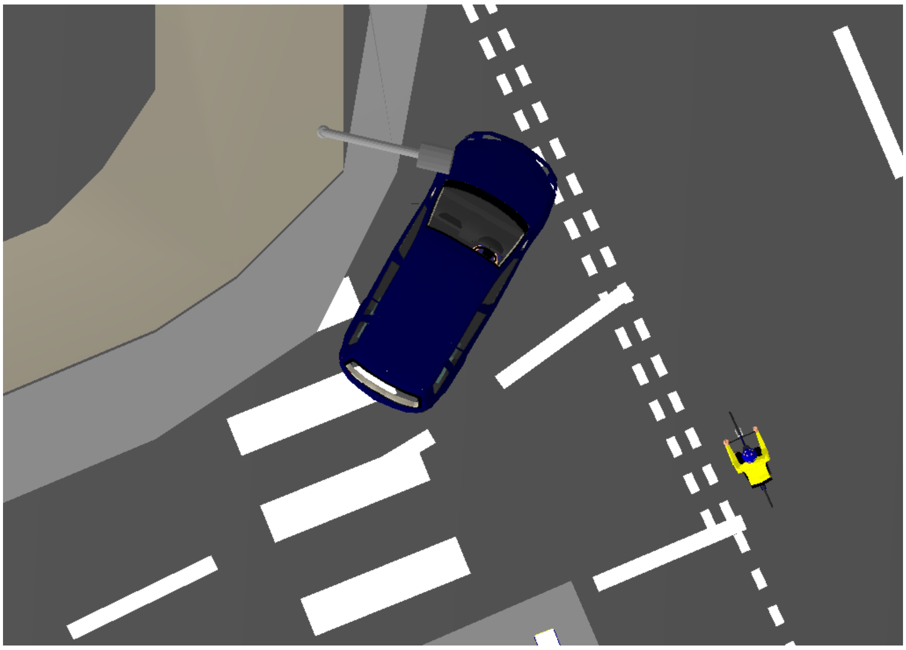

Figure 333. The vehicle positioning at the junction

Figure 334 and Figure 335 show that in this position the cyclist is completely visible through the offside (right) front window. Due to the driver's eye point being further forwards in the vehicle in comparison to the Dutch male, the B-pillar is relatively rearward of the eye point and thus its obscuration does not affect this scenario setup.

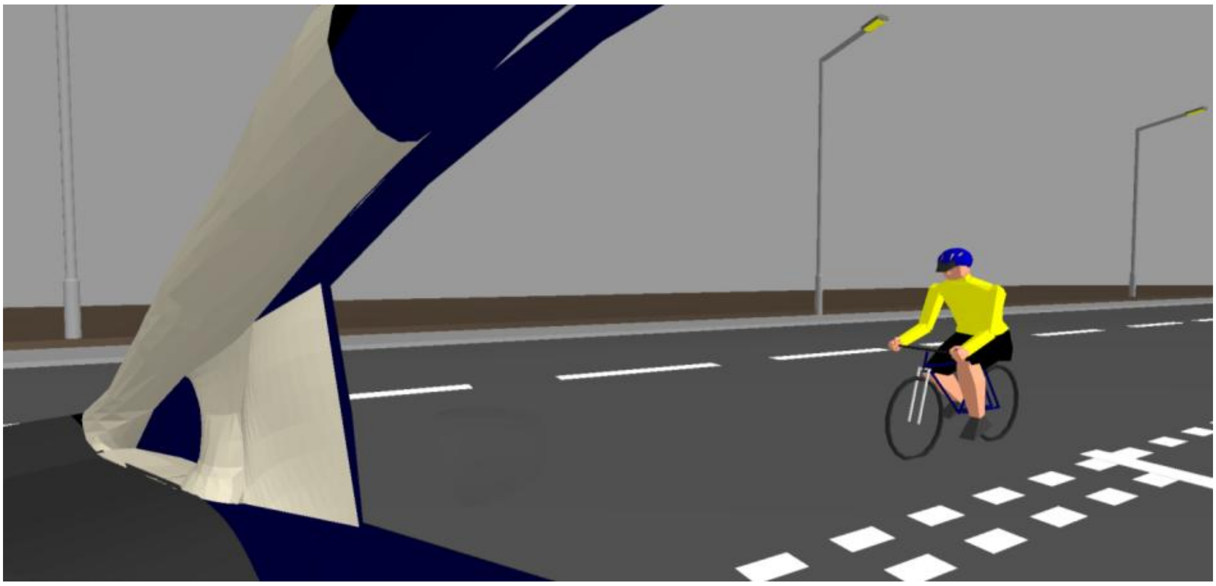

Figure 334. The view of the UK female driver

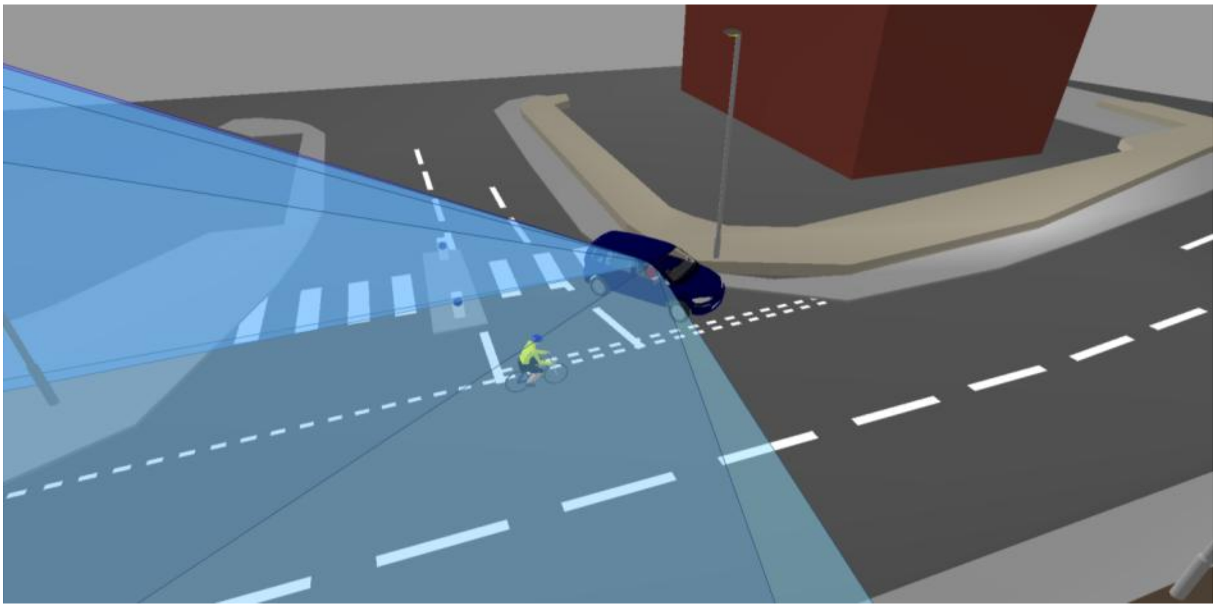

Figure 335. The cyclist located within the field of view through the offside (right) front window

Figure 336 evaluates whether the A-pillar could pose a sufficient obscuration for the UK female driver in this scenario. The A-pillar does pose a more significant obscuration in comparison to the Golf but is still very unlikely to be the reason for the driver to have failed to see the cyclist.

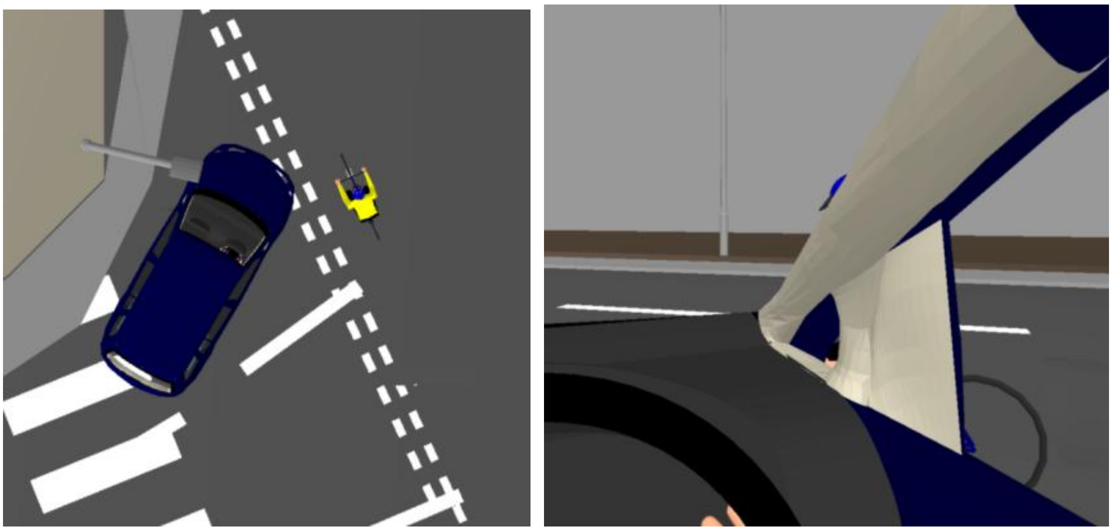

Figure 336. Evaluating the possibility of A-pillar obscuration for this scenario

3.5.2.2.4 M_1 – Hyundai i10

3.5.2.2.4.1 99th %ile Dutch male

The relative positioning of the vehicles is shown in Figure 337 and Figure 338 below.

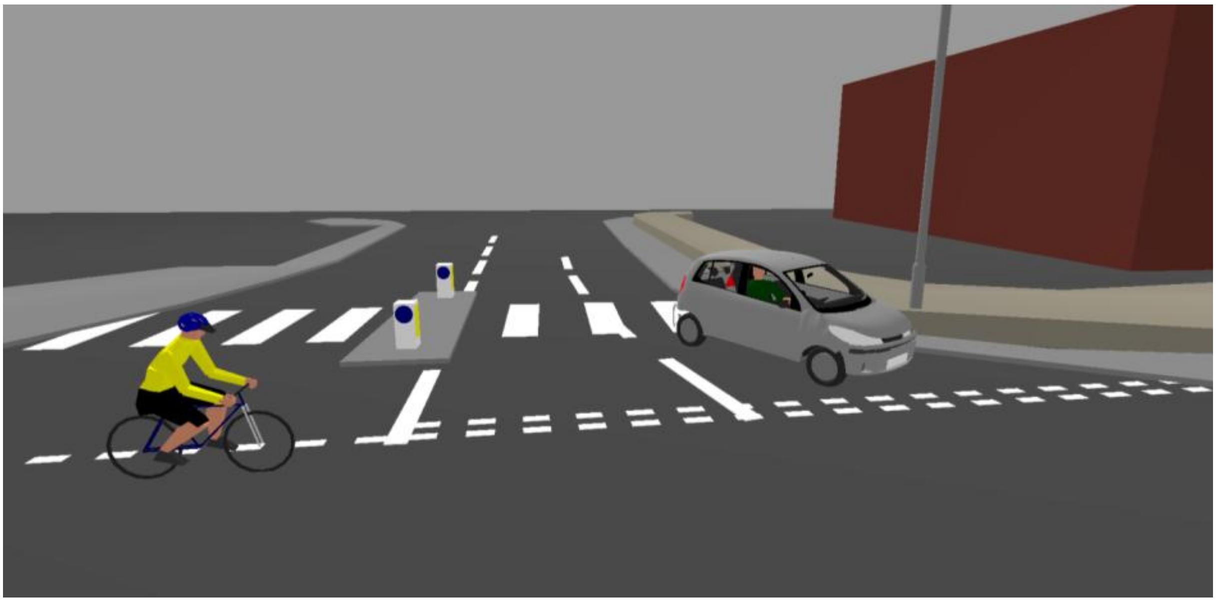

Figure 337. The T-Junction layout showing the Hyundai i10 and 99%ile Dutch male driver

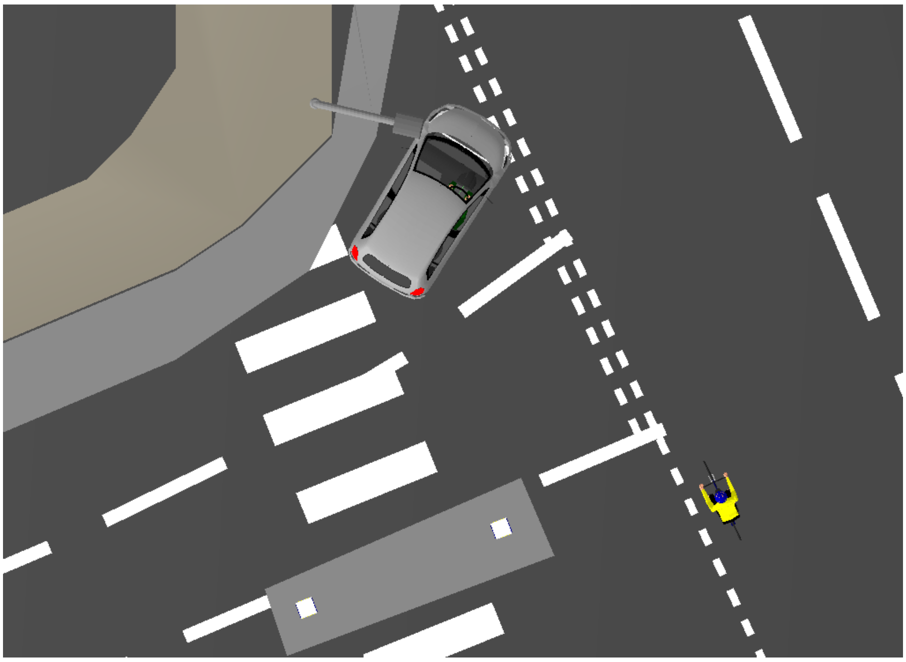

Figure 338. The vehicle positioning at the junction

Figure 339 below shows that in this position the cyclist is again completely obscured by the B-pillar of the M_1 vehicle.

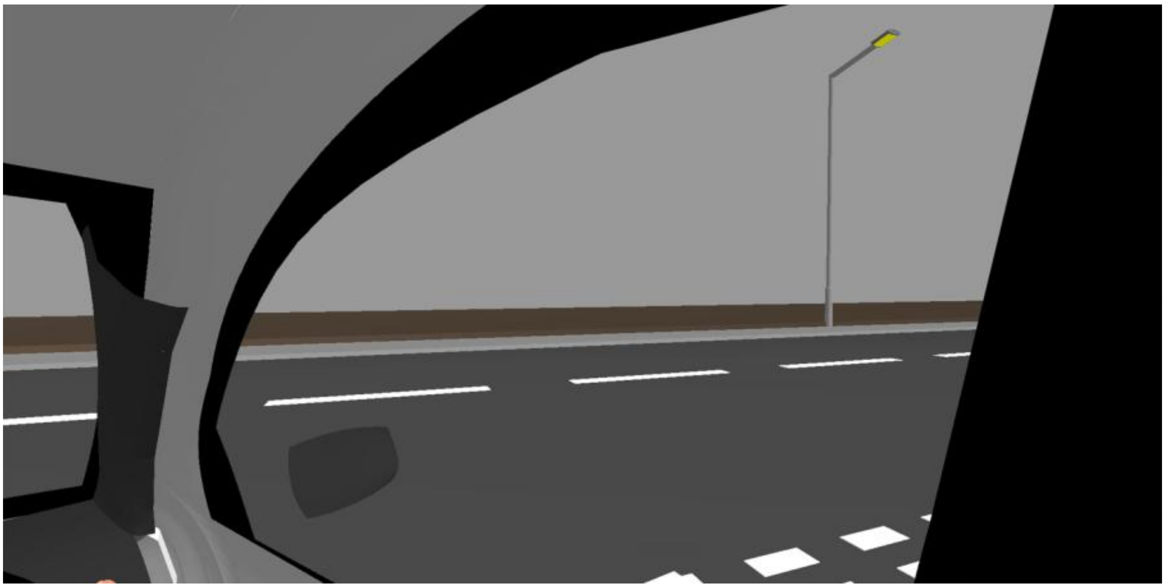

Figure 339. The view of the Dutch male driver

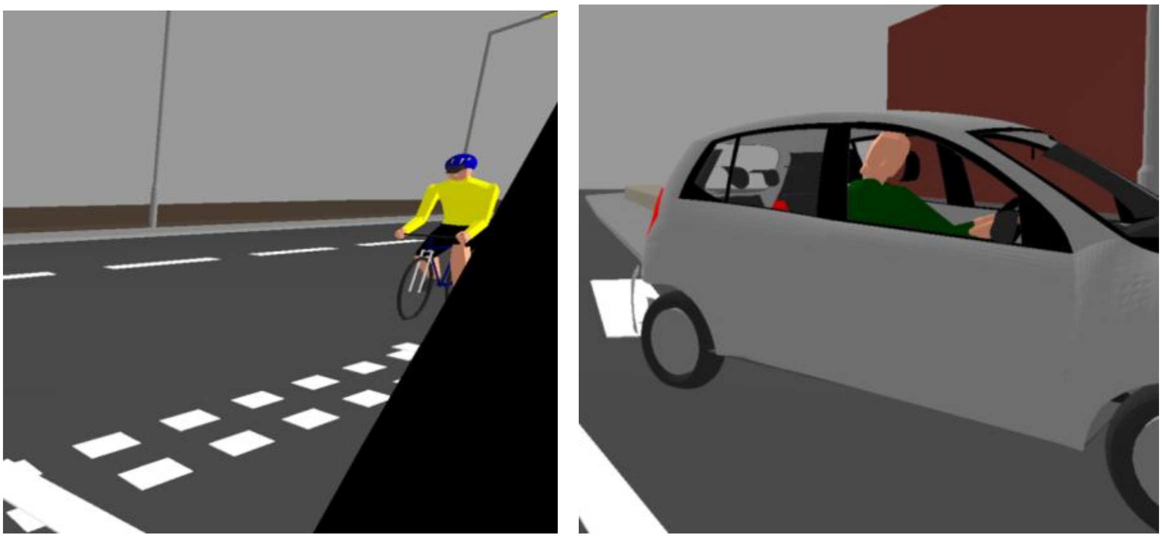

Figure 340. The cyclist can be seen if the driver leans their head

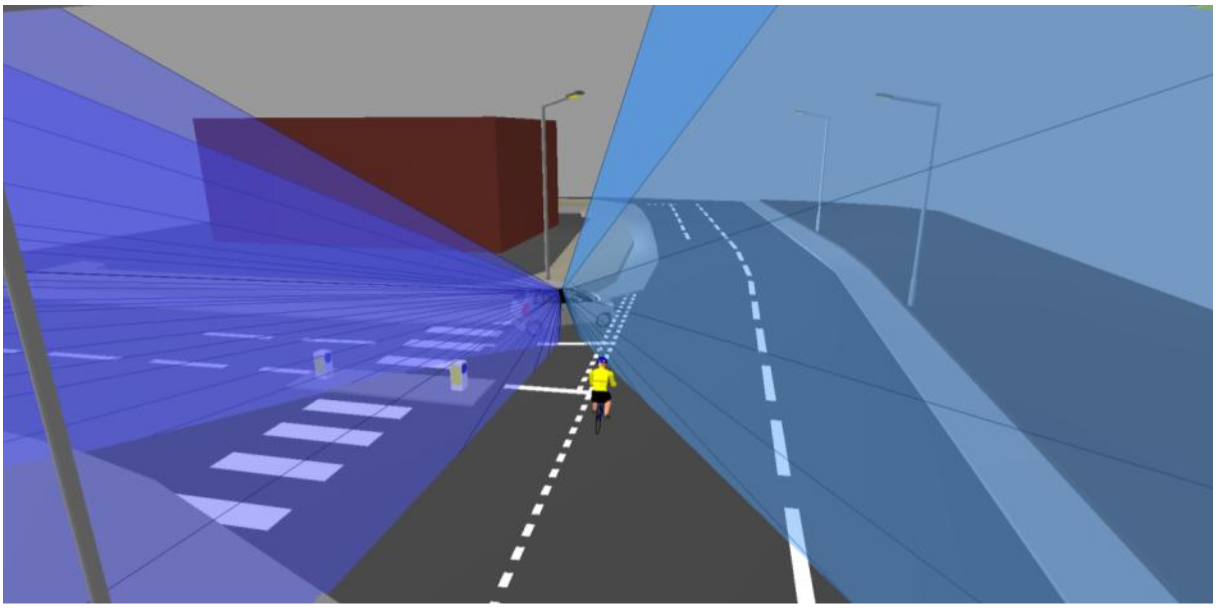

Figure 341. The cyclist located within the blind spot caused by the B-pillar

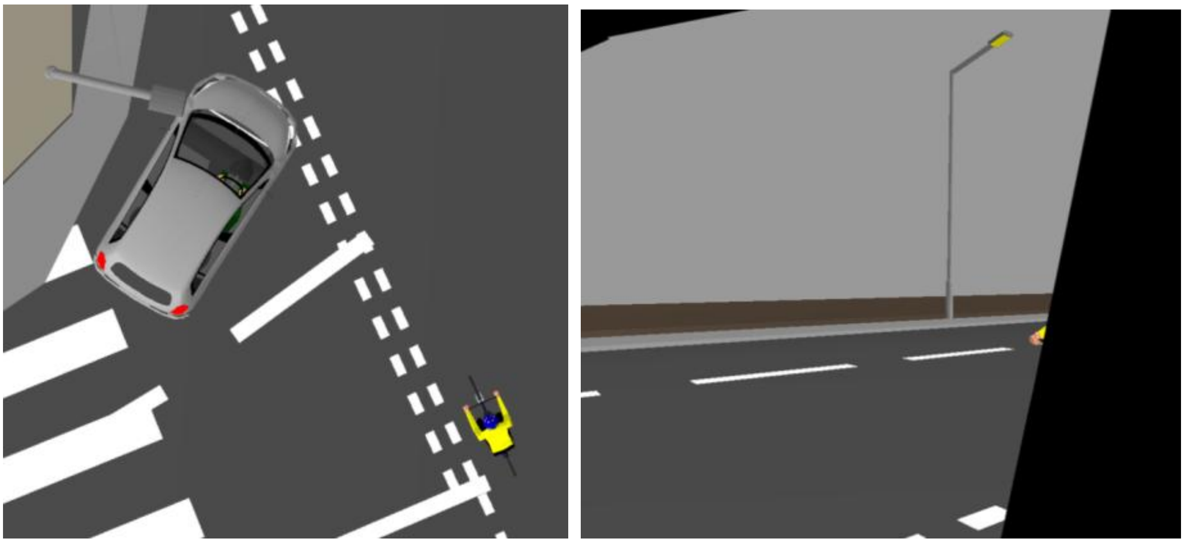

Figure 342. The cyclist can get within 4.5m of the M_1 whilst obscured by the B-pillar

If the driver fails to look around the obscuration (Figure 340), Figure 341 and Figure 342 above show the closest the cyclist can get to the M_1 vehicle whilst still being within the blind spot caused by the B-pillar. The cyclist is again approximately 4.5m from the front of the M_1 vehicle and so the conclusions are the same with the possibility that the B-pillar could be instrumental in the driver looking but failing to see the cyclist.

3.5.2.2.4.2 5^h %ile UK female

The relative positioning of the vehicles is shown in Figure 343 and Figure 344 below.

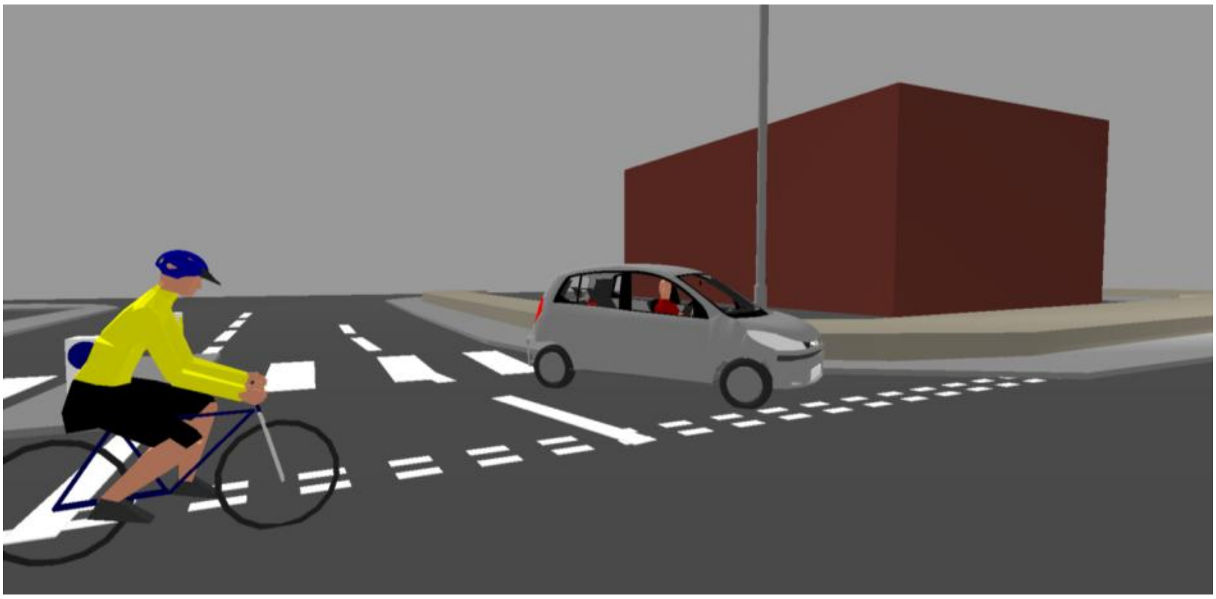

Figure 343. The T-Junction layout showing the Hyundai i10 and 5%ile UK female driver

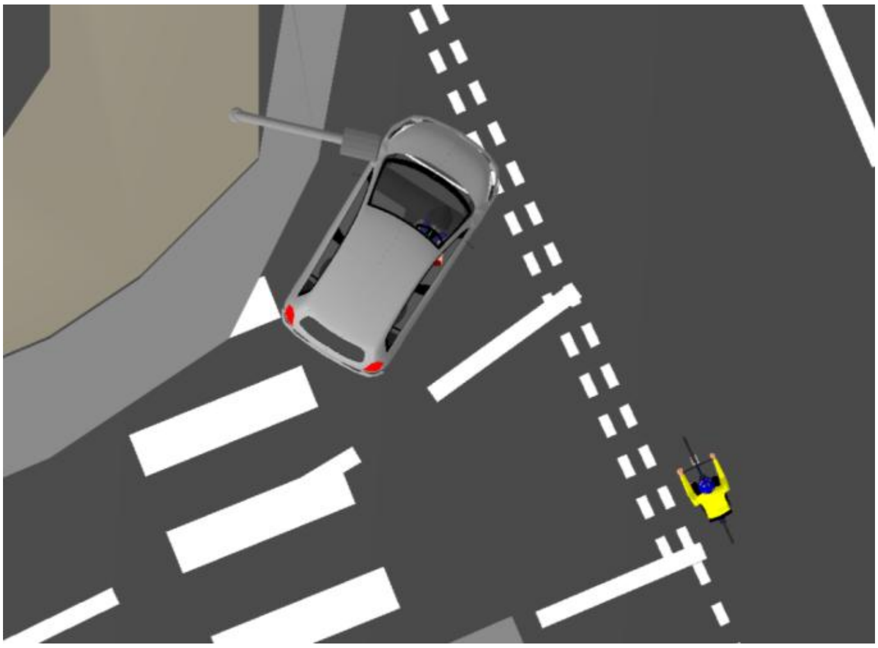

Figure 344. The vehicle positioning at the junction

Figure 345 and Figure 346 show that in this position the cyclist is completely visible through the offside (right) front window.

Figure 345. The view of the UK female driver

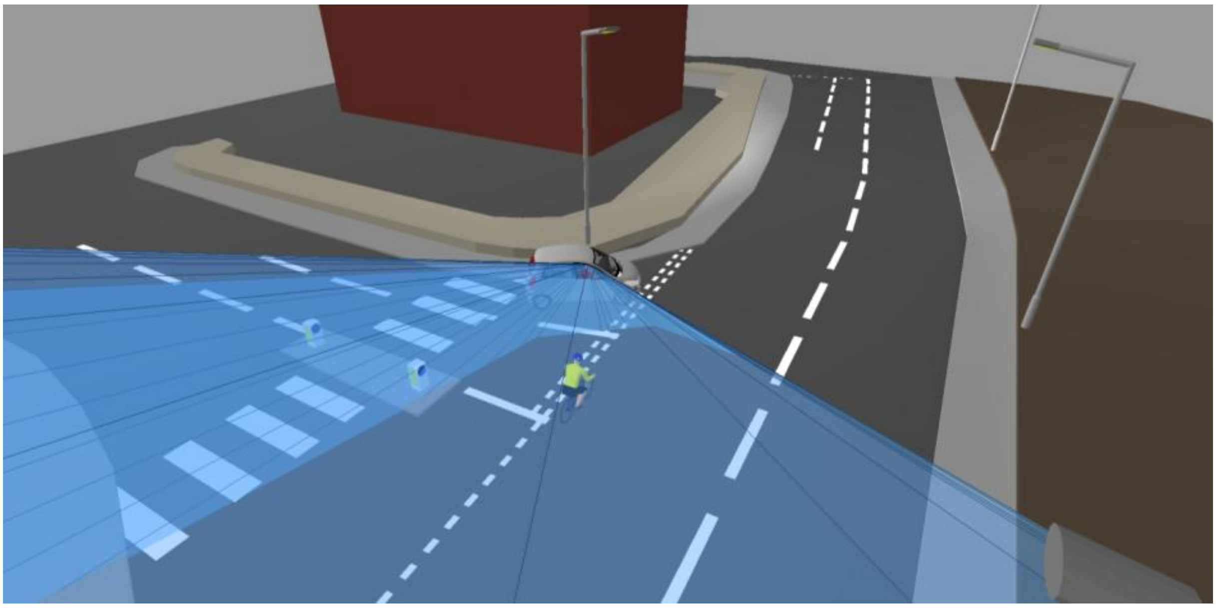

Figure 346. The cyclist located within the field of view through the offside (right) front window

As with the other M_1 vehicles it appears that the A-pillar is very unlikely to be the reason for the driver to have failed to see the cyclist (Figure 347).

Figure 347. Evaluating the possibility of A-pillar obscuration for this scenario

3.5.2.2.5 T-Junction summary

For all of the assessed M_1 vehicles there is an effective 'corridor' blind spot caused by the B-pillar. The orientation of this blind spot is only critical for the larger drivers of each vehicle as the eye point is further forward for the smaller driver and the field of view is clear through the front right window. It is possible that whilst the M_1 driver is performing their observations prior to setting off that the cyclist could have travelled the length of this corridor to within 4.5m of the vehicle. If after glancing right and not seeing any oncoming traffic the driver would then focus their attention to the direction of turn to the left and set off causing the collision. This sequence of events would need very particular timing but Figure 348, Figure 349 and Figure 350 below give an indication of how this may come together to cause the accident.

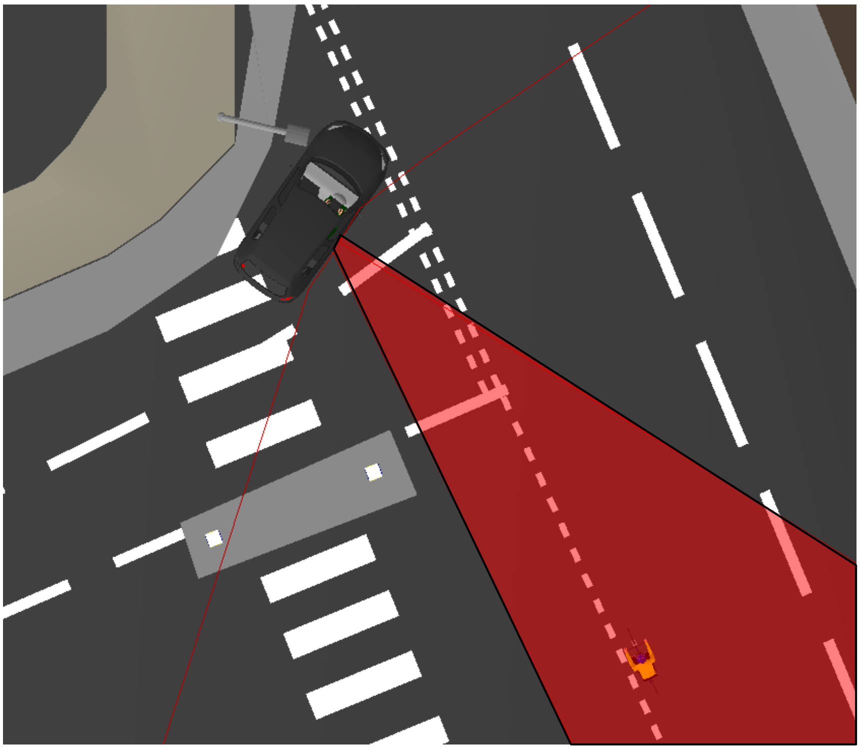

Figure 348. The cyclist travels along the blind spot whilst the M_1 driver performs observations

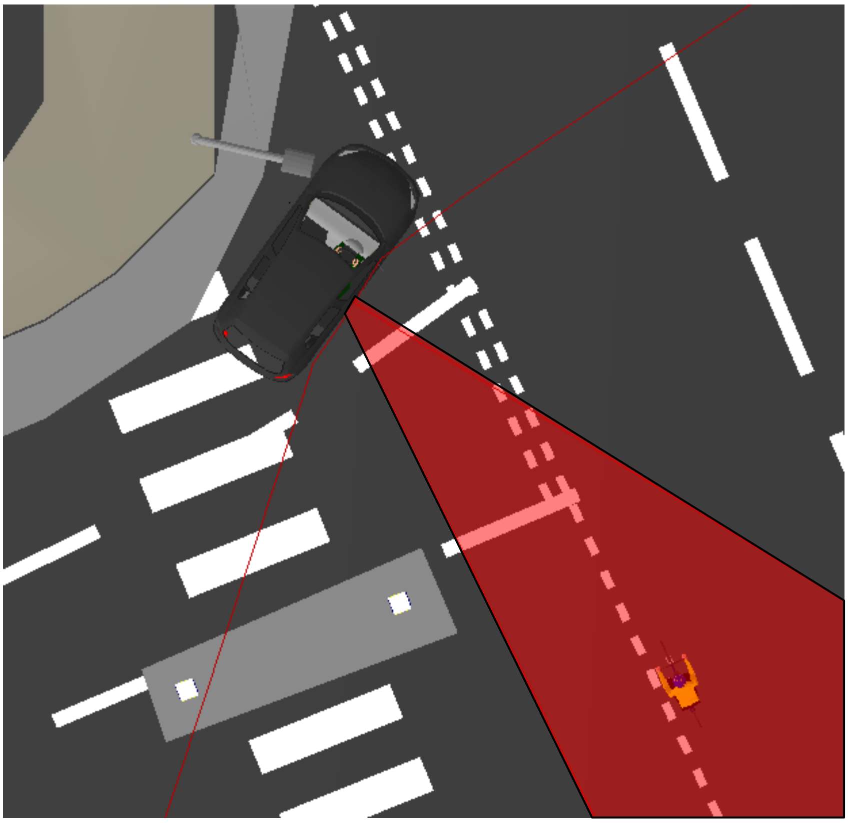

Figure 349. The cyclist travels along the blind spot whilst the M_1 driver performs observations

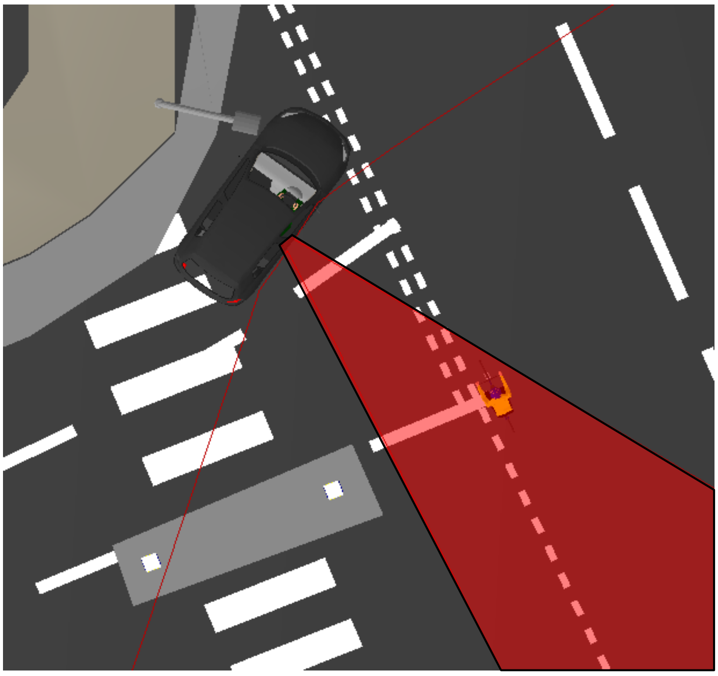

Figure 350. The cyclist travels along the blind spot whilst the M_1 driver performs observations

All three vehicles are potentially capable of being involved in this form of incident with similar sized blind spots for the larger driver (Figure 351). The VW Golf performs slightly better in that its blind spot is more rearwards than the VW Touran or the Hyundai i10 but this benefit is easily negated if the relative positioning of the vehicle is more to the left as shown in the T-Junction scenario. The blind spots are very similar for the Touran and i10. The smaller drivers of all three vehicles are not affected by this blind spot. As such the proximity to the pillar appears to be the largest factor.

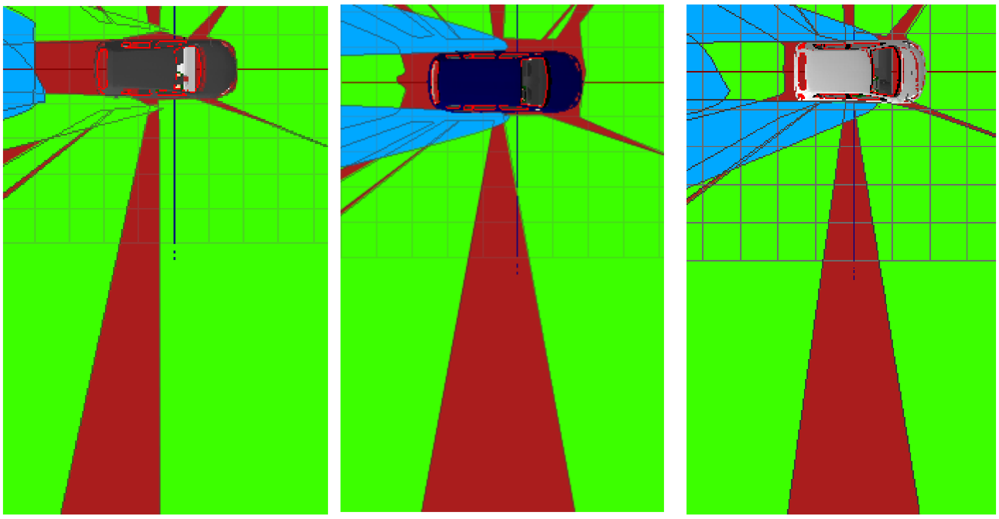

Figure 351. The similarity of the Hyundai i10 and Volkswagen Touran offside B-pillar obscuration

3.5.2.3 Crossroads OTS case

The following scenario examines the visibility from category M_1 vehicles in a situation where the vehicle (P1V1) is proceeding straight on at a give way controlled crossroads, crossing the main carriageway. In the OTS case, the driver of the M_1 category vehicle has pulled out of the junction and collided with a pedal cycle (P2V1) already on the main carriageway.

3.5.2.3.1 Scenario setup

The scenario was modelled using the map data provided in the OTS case report (Figure 352). The angle of the junction from the car park to the main road has the potential to cause difficulty for the category M_1 driver in terms of positioning for optimum visibility to the left of the vehicle to observe vehicles already on the main road travelling from left to right. The vehicle CAD model that represents P2V1 (a Pinarello Angliru pedal cycle) is positioned travelling along the main road from left to right across the path of the M_1 vehicle. P1V1 is positioned to travel across the crossroads bearing slightly left as the junction is offset.

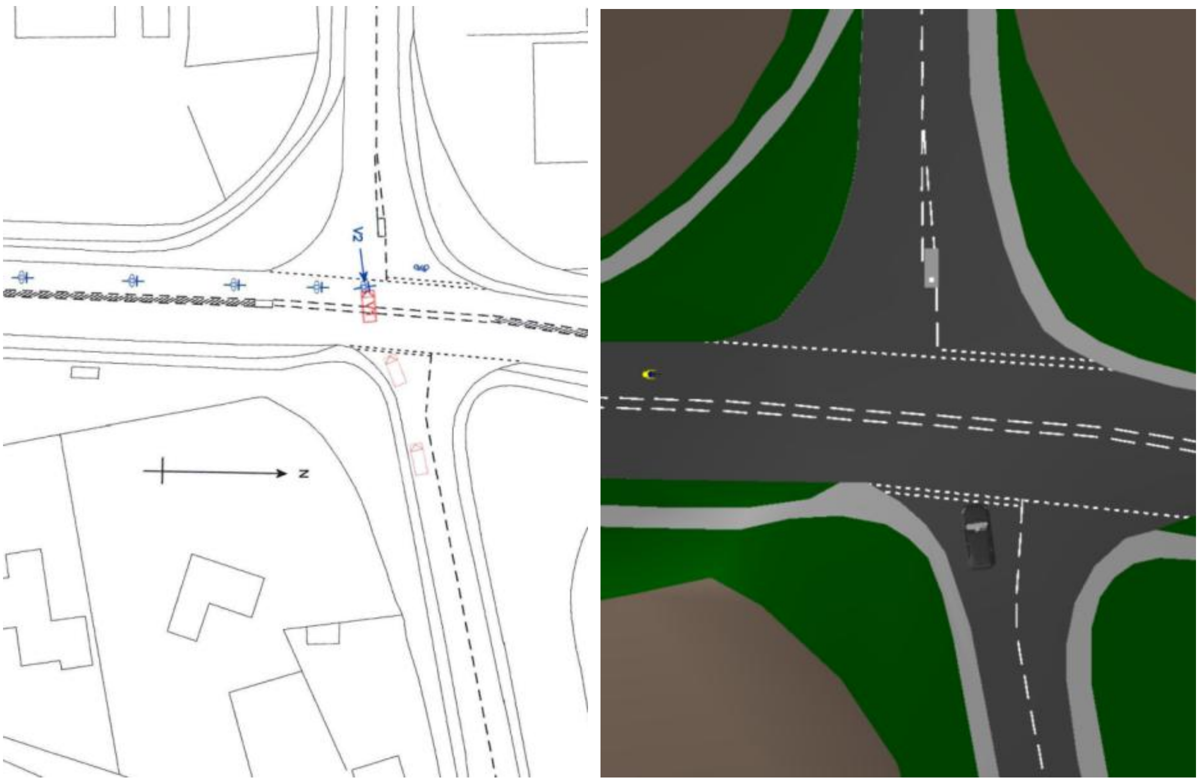

Figure 352. The road layout recreated from the OTS case report

3.5.2.3.2 M_1 – Volkswagen Golf

3.5.2.3.2.1 99th %ile Dutch male

The relative positioning of the vehicles is shown in Figure 353 and Figure 354 below.

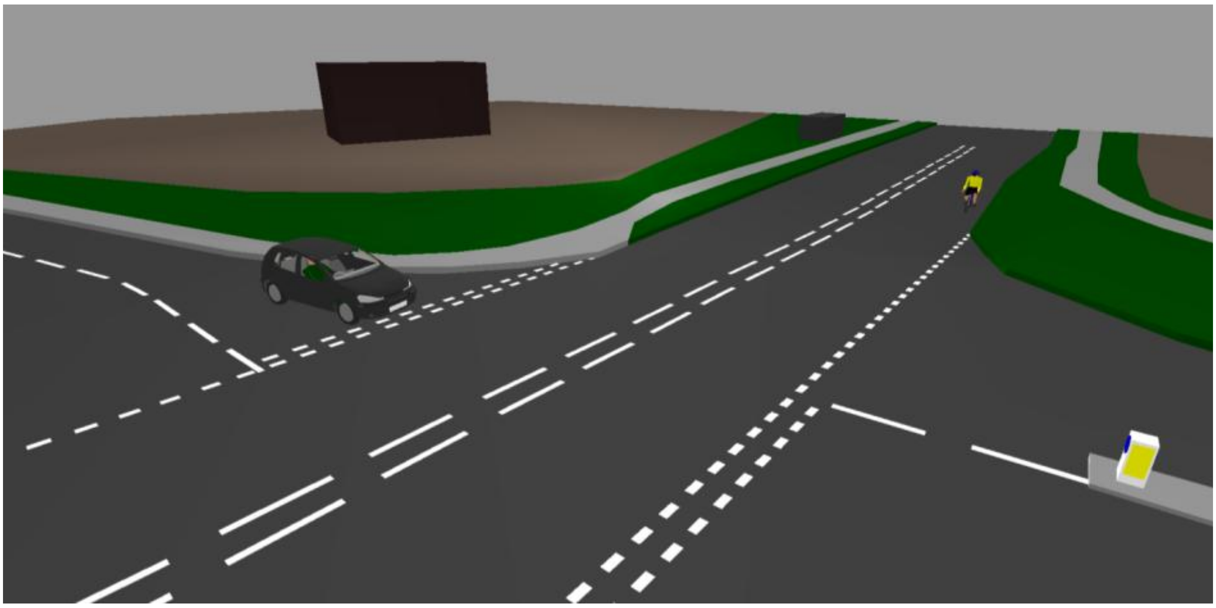

Figure 353. The crossroads layout showing the VW Golf and 99%ile Dutch Male driver

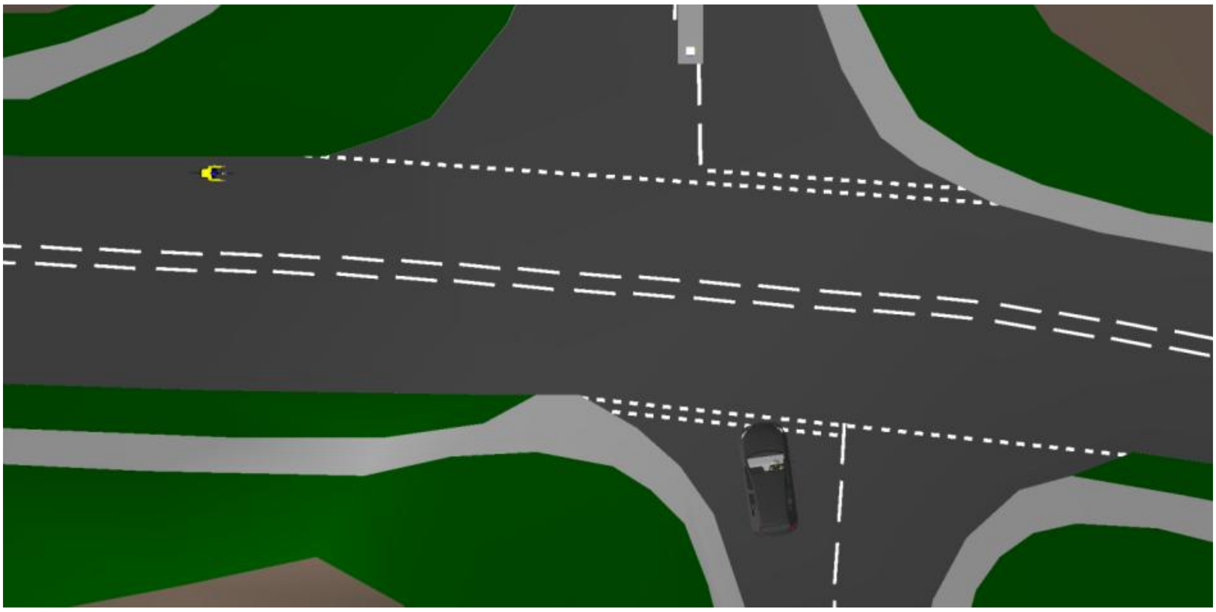

Figure 354. The vehicle positioning at the junction

Figure 355 shows that in this position the cyclist is completely obscured by the nearside (left) A-pillar of the M_1 vehicle. The driver is looking to the right and left to check the road is clear prior to pulling off.

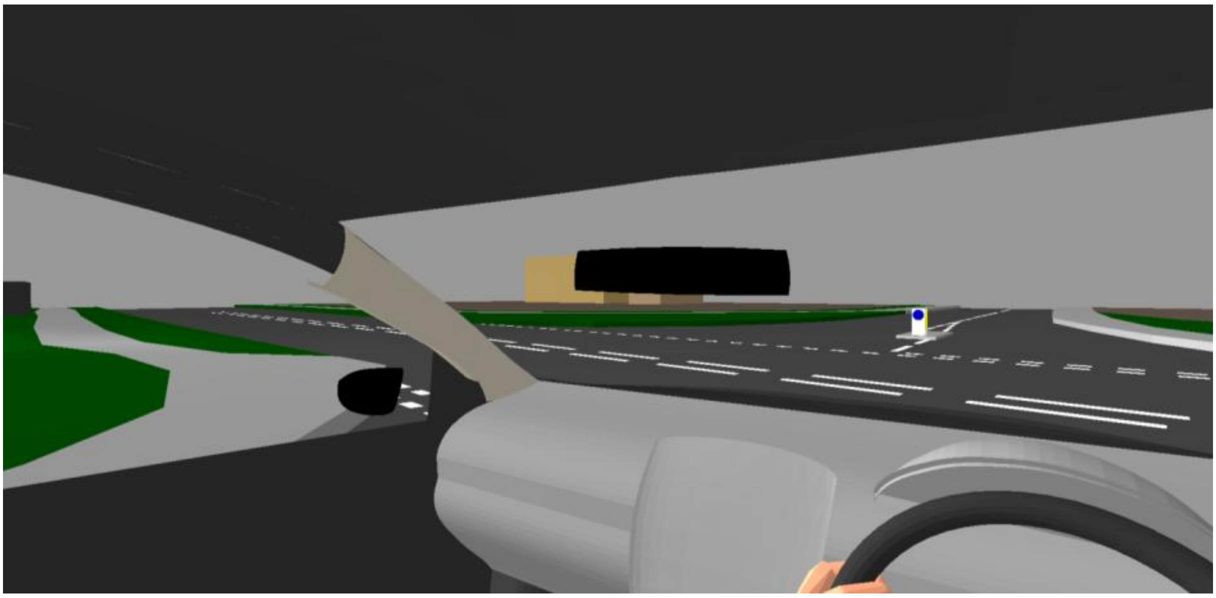

Figure 355. The view of the Dutch male driver

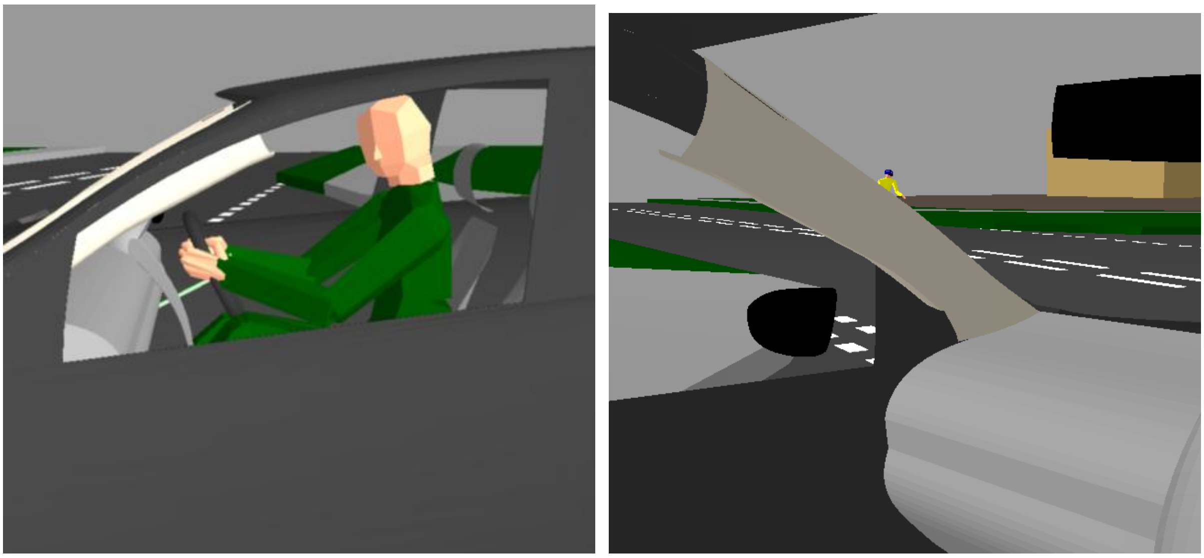

Figure 356. The cyclist can be seen if the driver leans forward

Figure 356 above shows that whilst the A-pillar obscuration does mask the cyclist, it is possible for the driver to 'look around' the obscuration if the driver is aware of the blind spot. Of the three scenarios this one requires the most deliberate of all actions by the driver to lean their torso forward to get a view of anything potentially obscured.

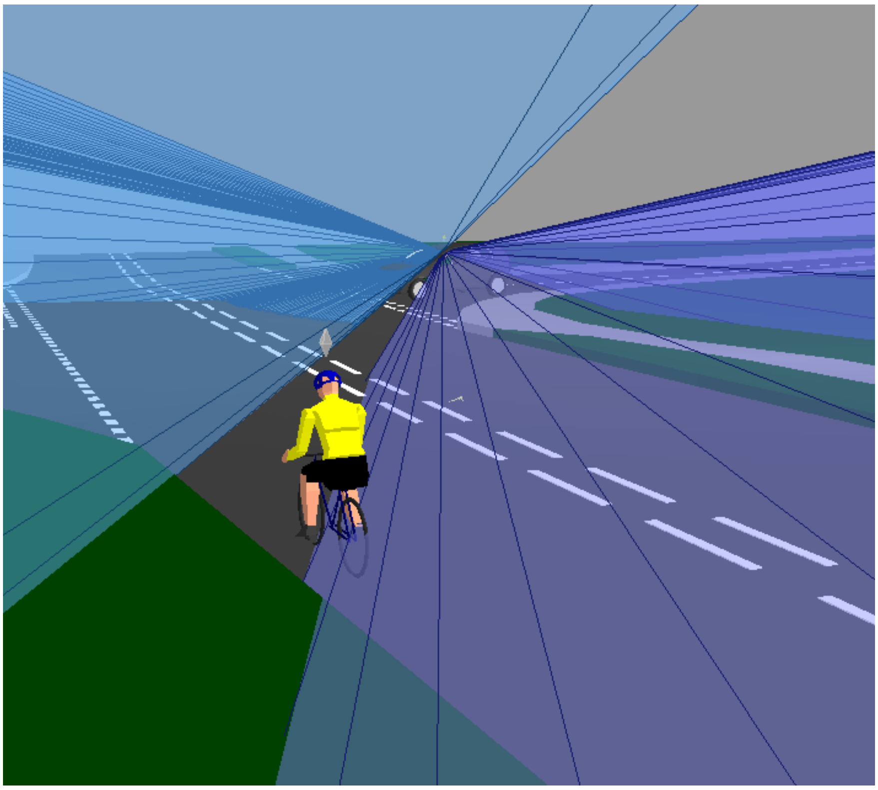

Figure 357. The cyclist located within the blind spot caused by the A-pillar

As observed with the other scenarios the A-pillar forms a clear 'corridor' of obscured field of view (Figure 357). In this instance the corridor is narrow and across the direction the oncoming traffic is moving. Thus it is not possible for the cyclist to travel down the obscured field of view, only through it.

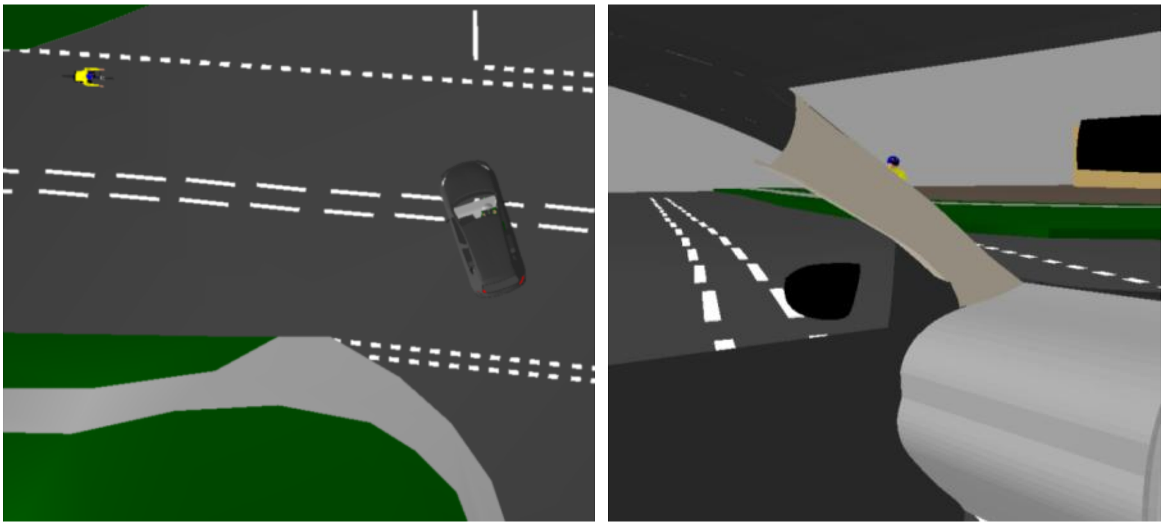

Figure 358. The cyclist needs to be a relatively long way to the left of the M_1 vehicle to stay hidden behind the A-pillar

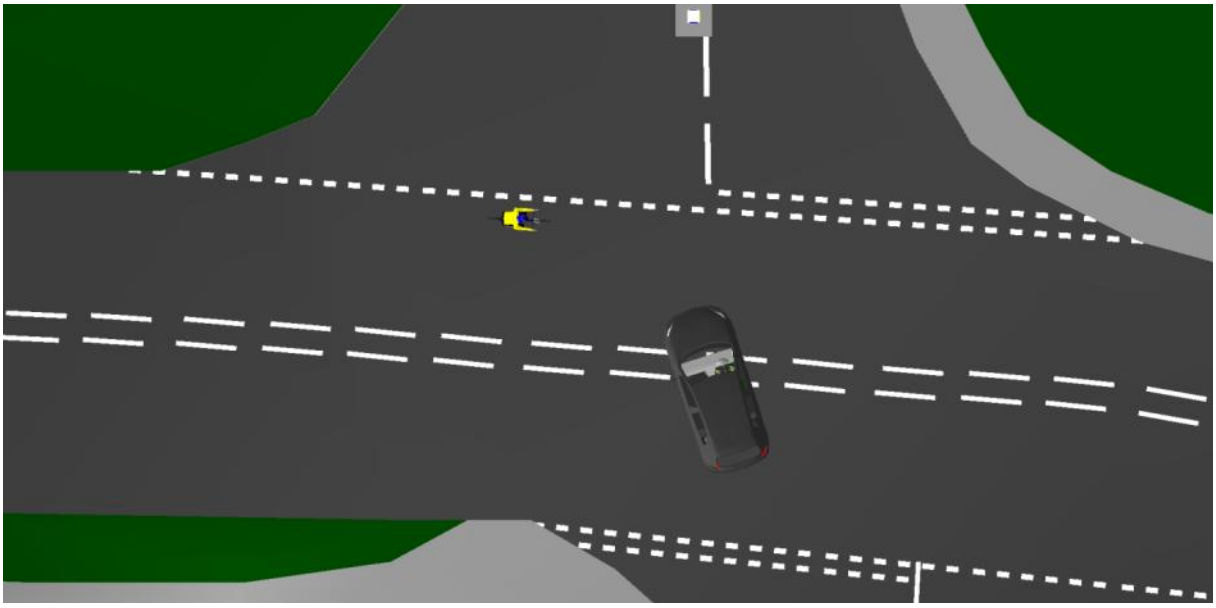

Figure 359. The advanced vehicle positioning at the junction

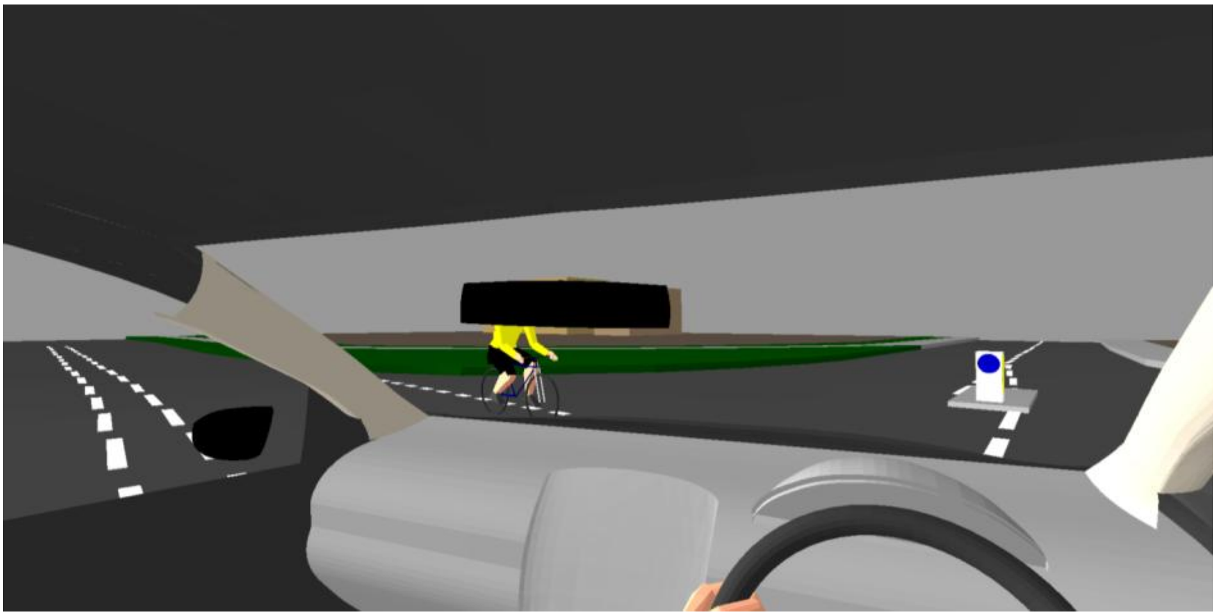

Figure 360. The view of the Dutch male driver as they proceed across the junction

Figure 358, Figure 359 and Figure 360 show the unfolding of the scenario. As the blind spot is a relatively long way to the left of the M_1 vehicle the driver would be able to look and not see the cyclist, potentially look again to the right to check for traffic on the nearest carriageway, and then set off. However, in this time the cyclist will have moved forward down the carriageway and into the field of view of the M_1 driver. In addition, the cyclist will be able to see the M_1 vehicle set off and potentially be able to take avoiding action. If the M_1 vehicle set off at the point in which the cyclist was obscured by the blind spot the collision could occur if the cyclist could not stop in time.

For example, the VW Golf 2.0 TDi has a 0-60 time of approximately 9s. The junction length to completely clear the main carriageway is 13m (to green car outline in Figure 361) and 9.5m to just get to a point of impact (red car outline in Figure 361). The distance to point of impact for the cyclist is 15m (blue cyclist outline in Figure 361).

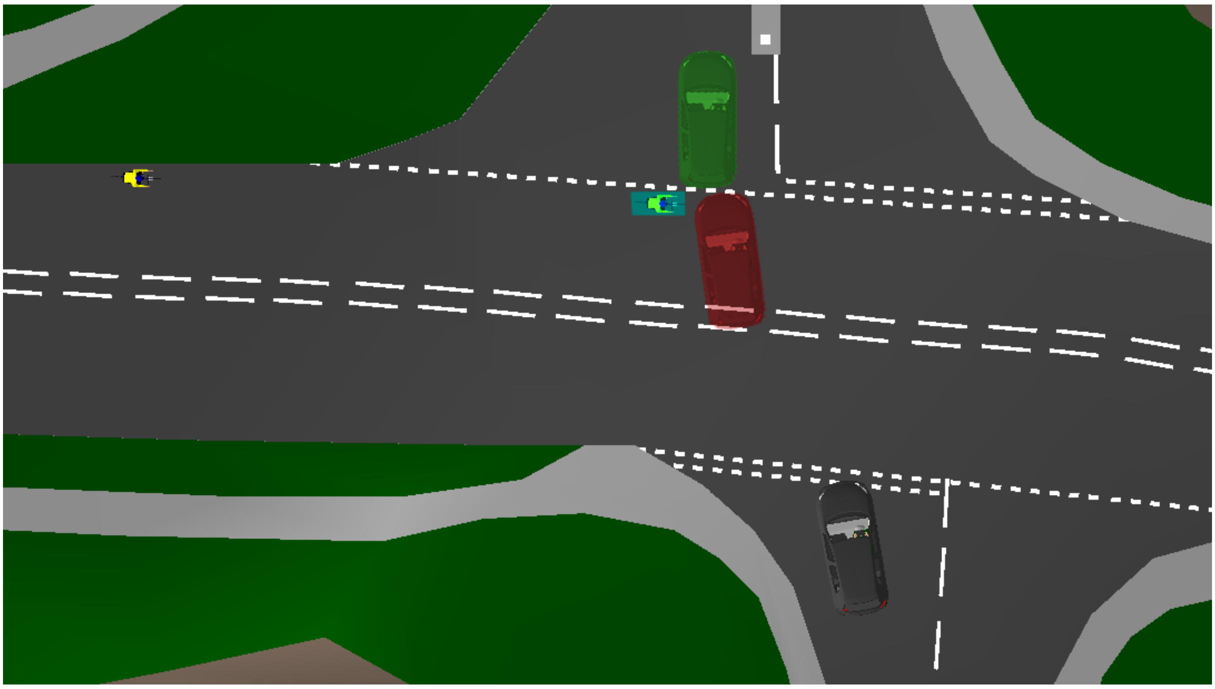

Figure 361. The junction with the theoretical positions of the M_1 vehicle and the cyclist. The red M_1 vehicle and blue cyclist are the positions at the point of impact, the green M_1 is the position to clear the junction

If the car was accelerating at its optimum it would take 9s to get to 60mph (~96kmh or 26.8mps). We can then calculate the likelihood of the vehicles being in the same place at the same time.

Using acceleration (a) = change in velocity divided by time, then a = 26.8 / 9 = 2.97 m/s^2

Then, if time = square root of 2 times the distance travelled divided by the acceleration, T = sqrt (2*9.5 / 2.97) = 2.52s

If the M_1 vehicle reaches the impact point in 2.52 seconds the cyclist would need to be travelling at approximately 13mph to cover the 15m.

From these evaluations it is possible that the collision could occur but unlikely that A-pillar obscuration could be the only factor in this accident.

3.5.2.3.2.2 5^h %ile UK female

The relative positioning of the vehicles is shown in Figure 362 and Figure 363 below.

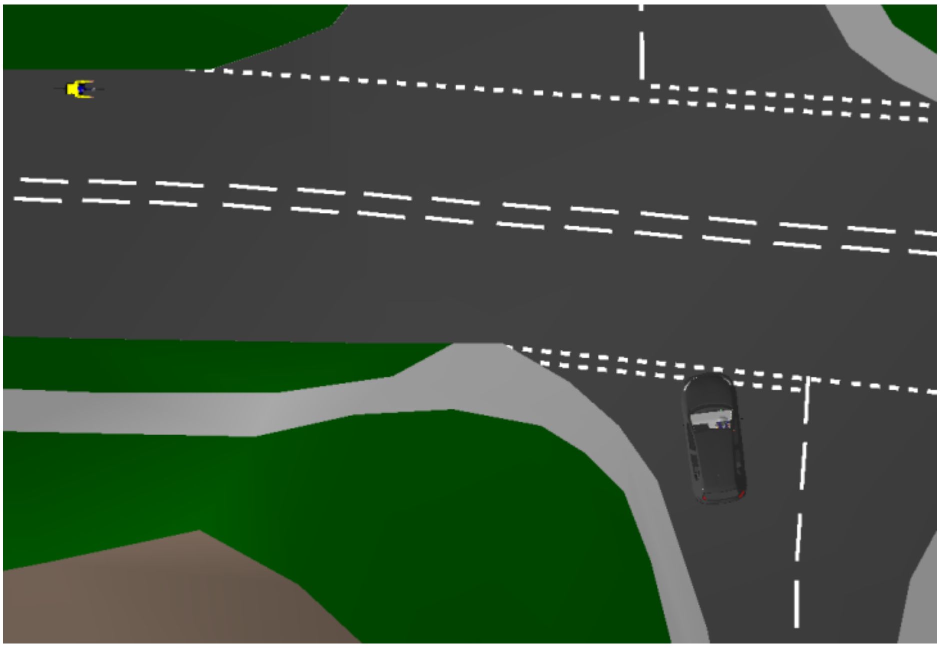

Figure 362. The vehicle positioning at the junction

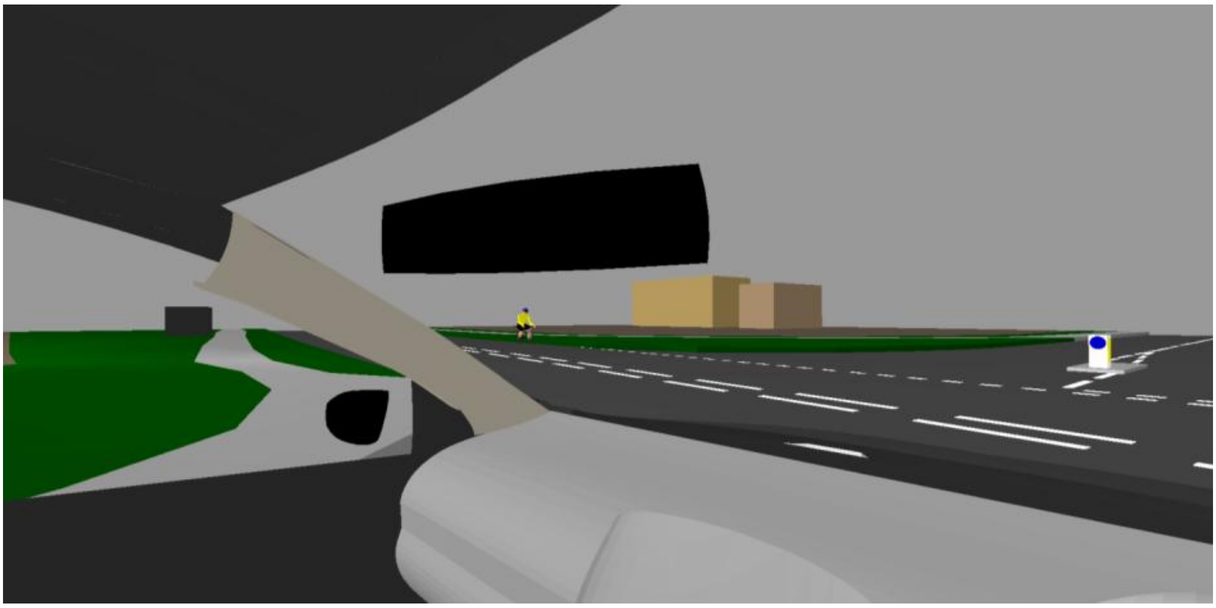

Figure 363. The view of the UK female driver

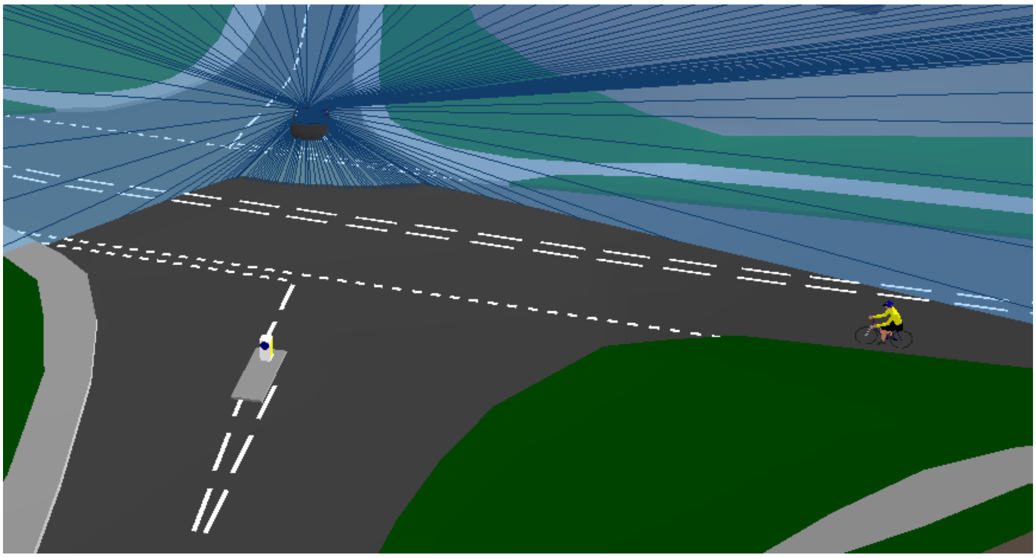

Figure 364. The cyclist located within the field of view through the windscreen

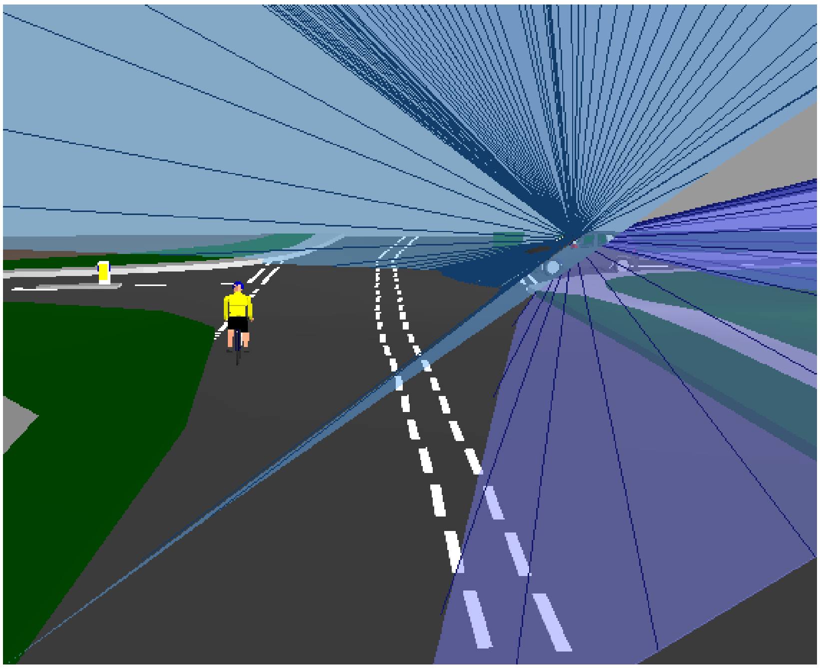

Figure 365. The cyclist located within the field of view through the windscreen (alternative view)

As observed with the other scenarios the A-pillar forms a clear 'corridor' of obscured field of view. In this instance the corridor is relatively narrow and across the direction the oncoming traffic is moving (Figure 364 and Figure 365). For the smaller driver the obscured field of view is also much further down the carriageway such that the cyclist would need to more than twice the distance from the point of impact, an additional 17m, than that observed for the larger driver (Figure 366 and Figure 367).

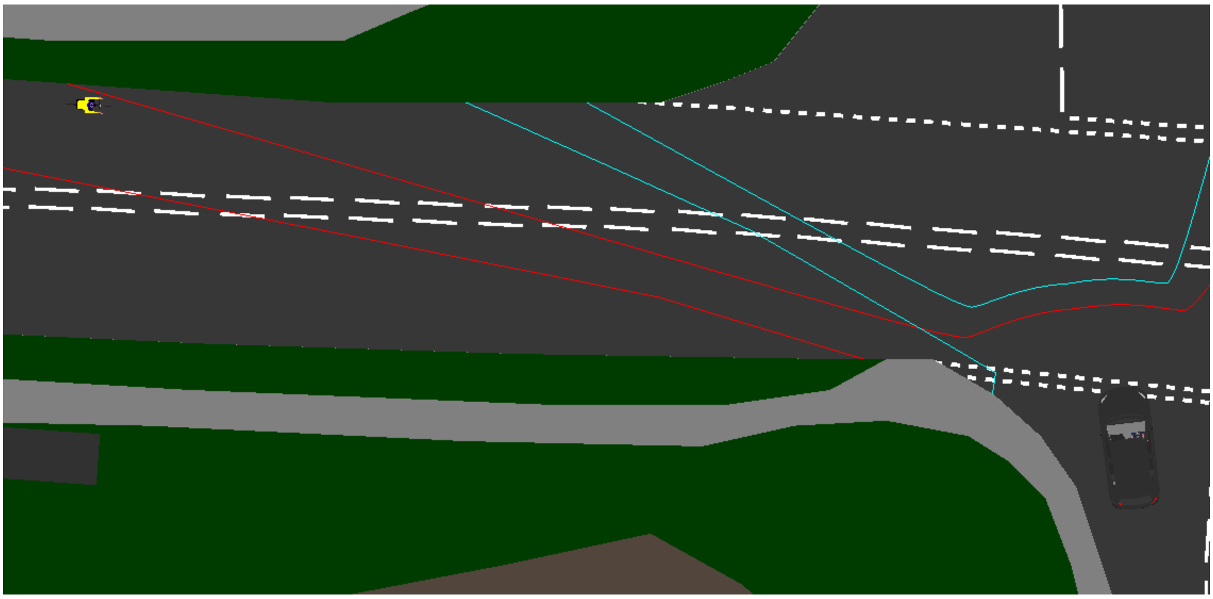

Figure 366. The difference between the blind spot for the 5th%ile UK female (red) and the 99%ile Dutch male (blue)

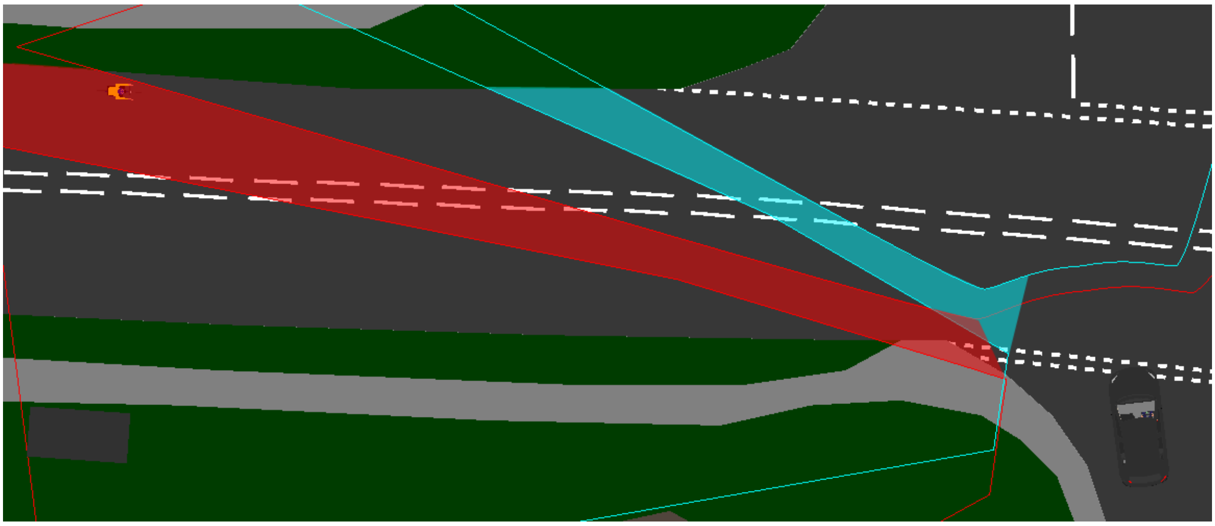

Figure 367. The difference between the blind spot for the 5th%ile UK female (red) and the 99%ile Dutch male (blue) - shaded

3.5.2.3.3 M_1 – Volkswagen Touran

3.5.2.3.3.1 99th %ile Dutch male

The relative positioning of the vehicles is shown in Figure 368 and Figure 369 below.

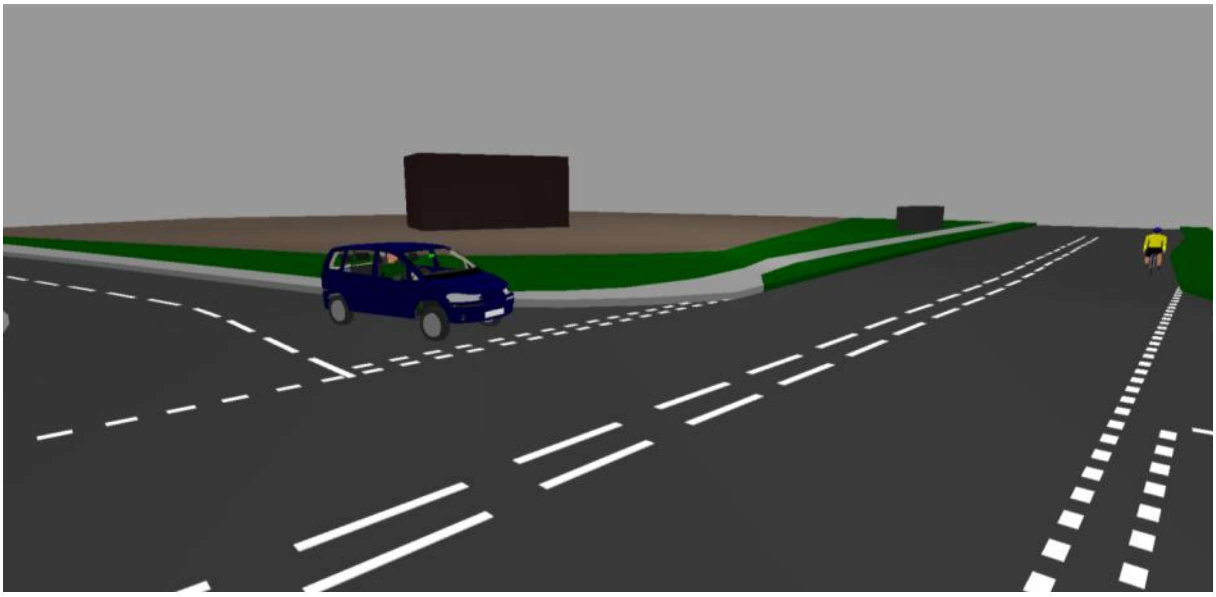

Figure 368. The crossroads layout showing the VW Touran and 99%ile Dutch male driver

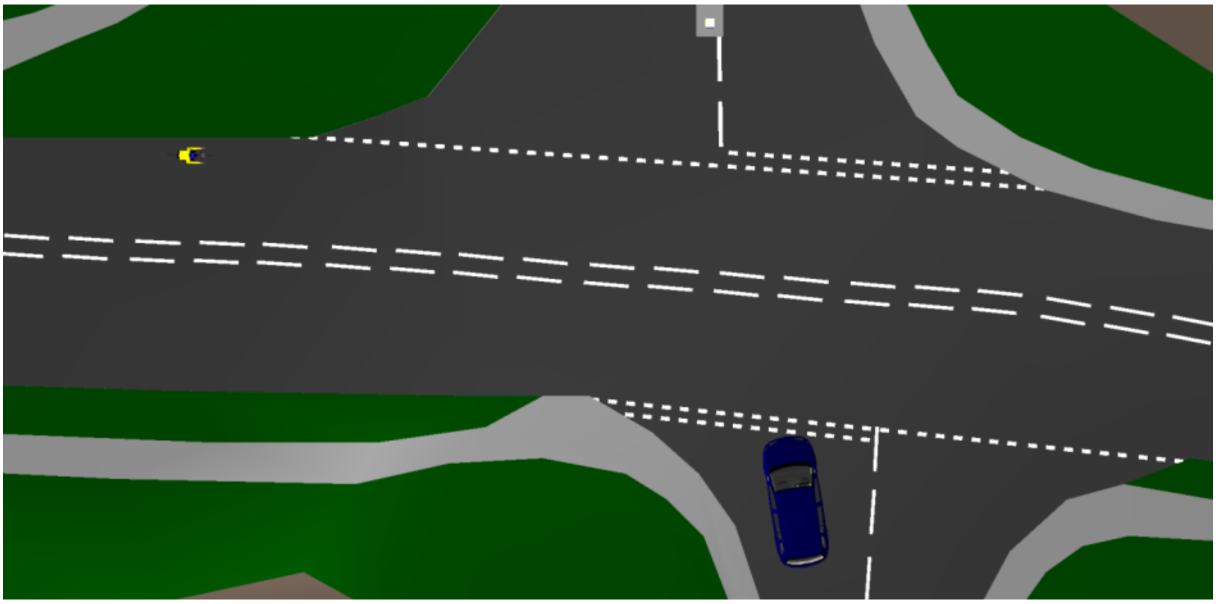

Figure 369. The vehicle positioning at the junction

Figure 370 shows that in this position the cyclist is completely obscured by the nearside (left) A-pillar of the M_1 vehicle and that it is possible to look around the obscuration with a deliberate lean forwards (Figure 371).

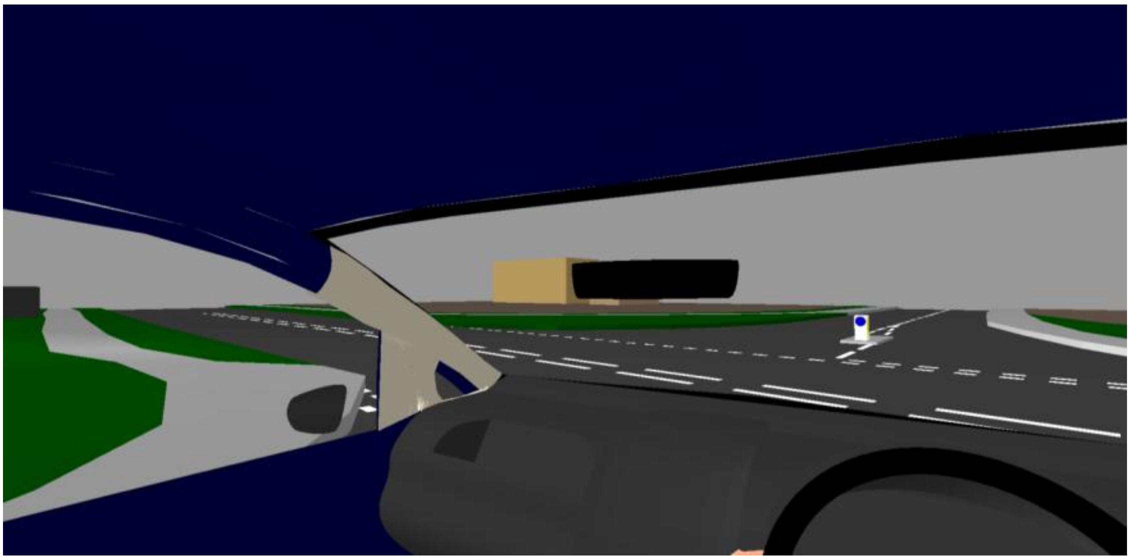

Figure 370. The view of the Dutch male driver

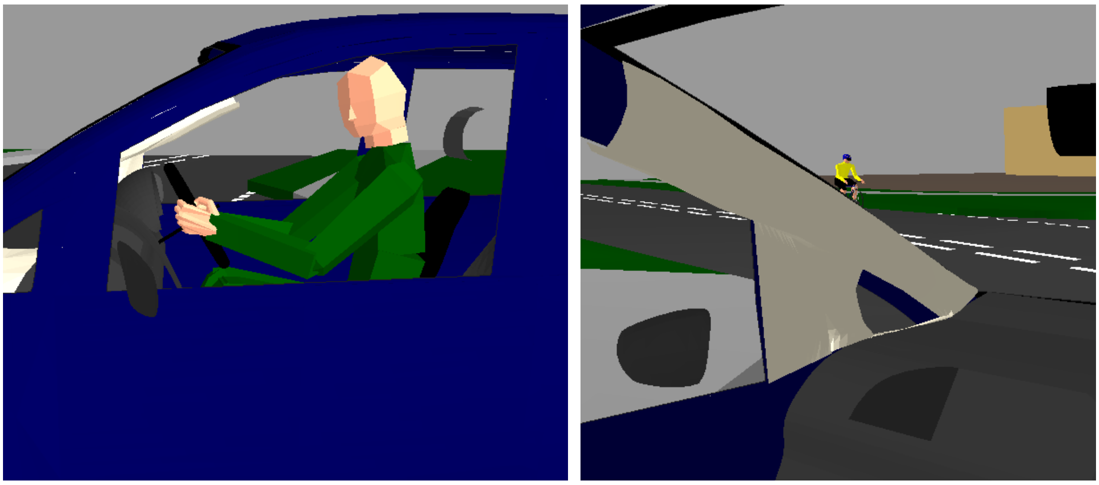

Figure 371. The cyclist can be seen if the driver leans their head forward

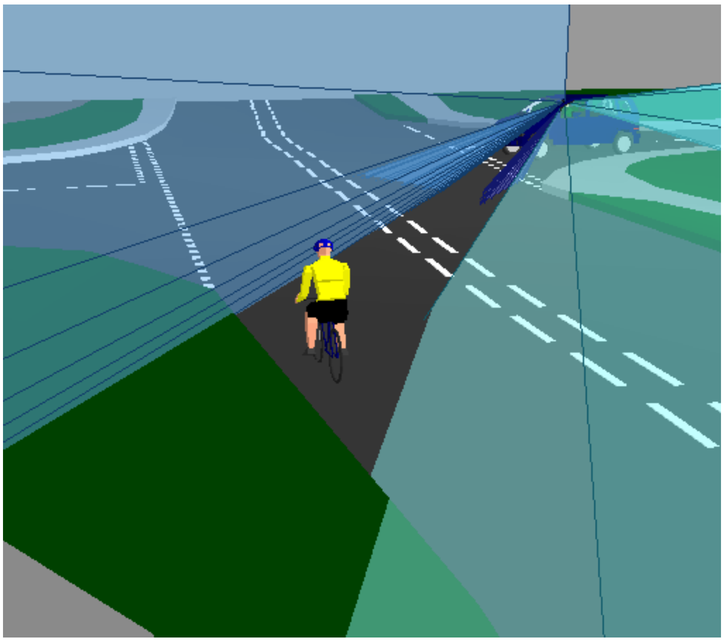

Figure 372. The cyclist located within the blind spot caused by the A-pillar

As with the Golf, the A-pillar forms a clear 'corridor' of obscured field of view. Again the corridor is narrow (but larger than for the Golf) and across the direction the oncoming traffic is moving (Figure 372). Thus it is not possible for the cyclist to travel down the obscured field of view, only through it.

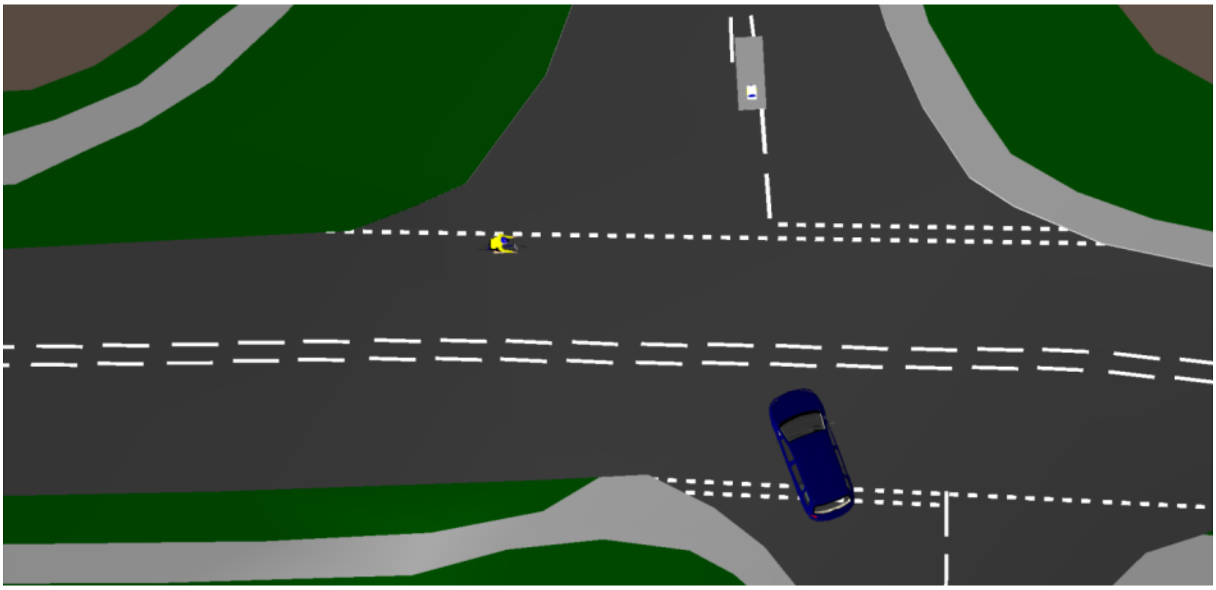

Figure 373. The advanced vehicle positioning at the junction

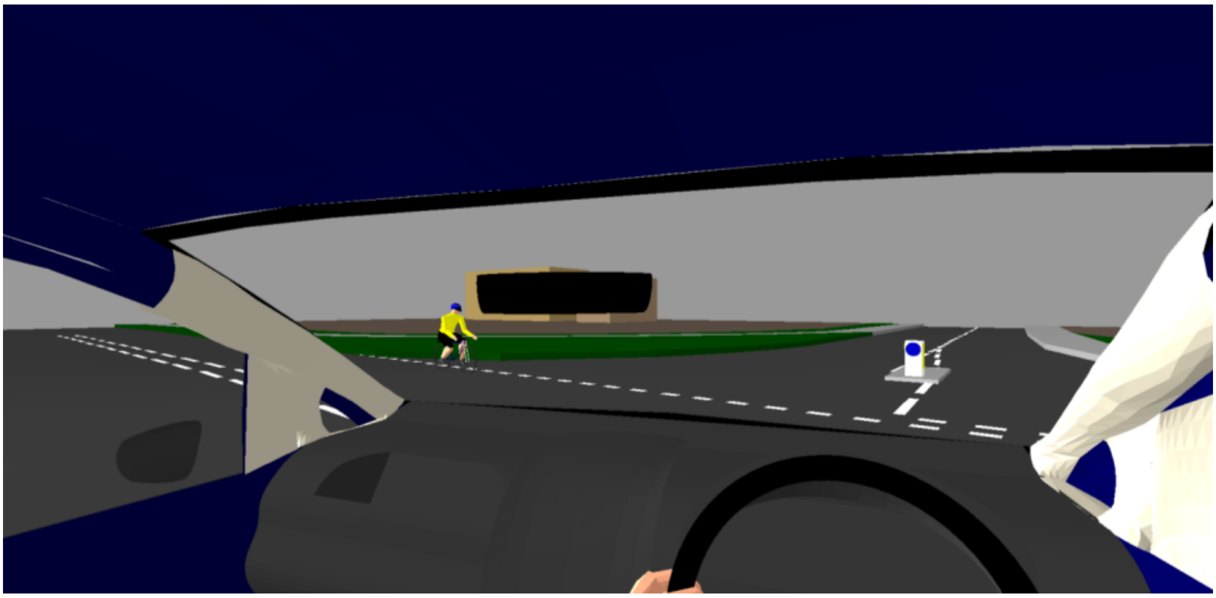

Figure 374. The cyclist needs to be a relatively long way to the left of the M_1 vehicle to stay hidden behind the A-pillar

The distances, positioning and relative fields of view are very similar to those observed for the Golf (Figure 373 and Figure 374). Thus from these evaluations it is possible that the collision could occur but unlikely that A-pillar obscuration could be the only factor in this accident.

3.5.2.3.3.2 35th %ile UK female

The relative positioning of the vehicles is shown in Figure 375 and Figure 376 below.

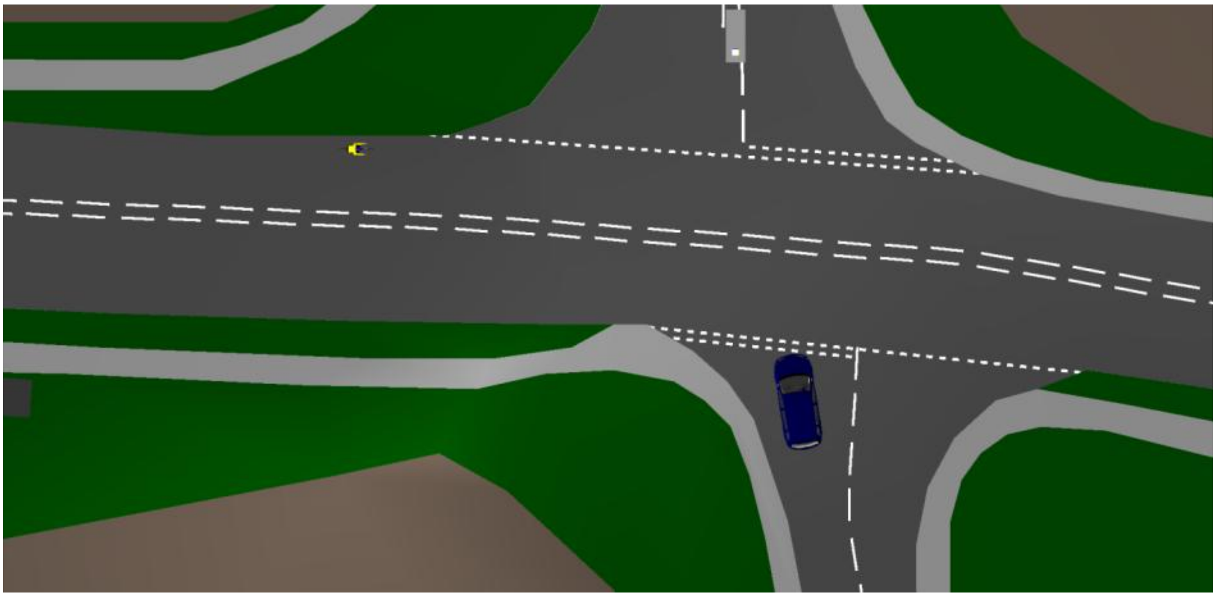

Figure 375. The vehicle positioning at the junction

Figure 376. The view of the UK female driver

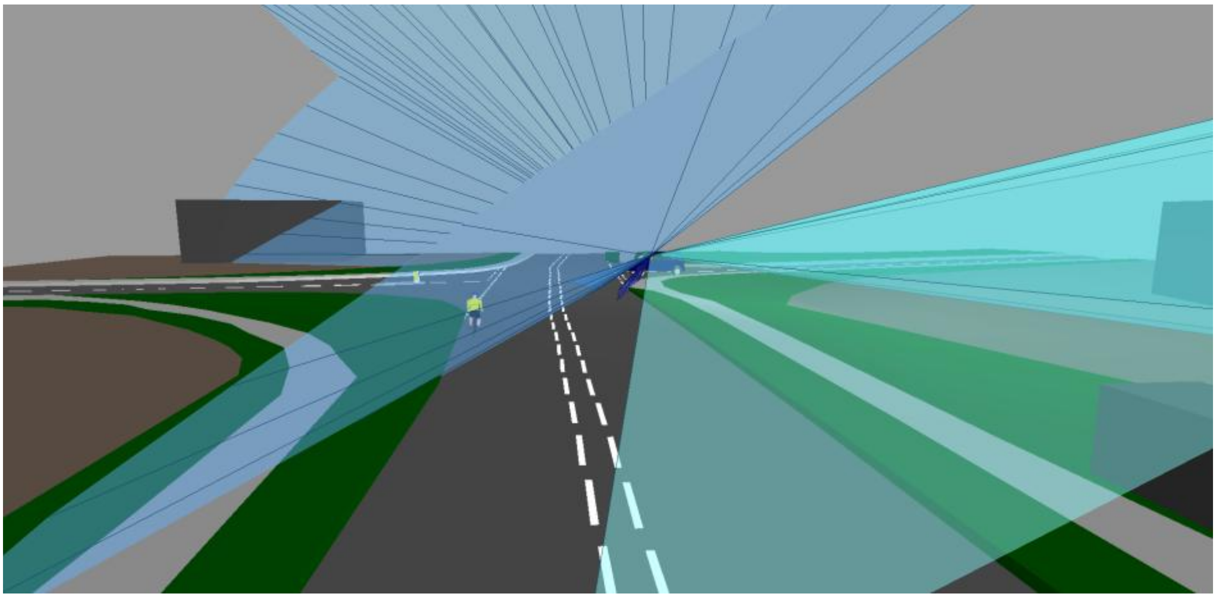

Figure 377. The cyclist located within the field of view through the windscreen

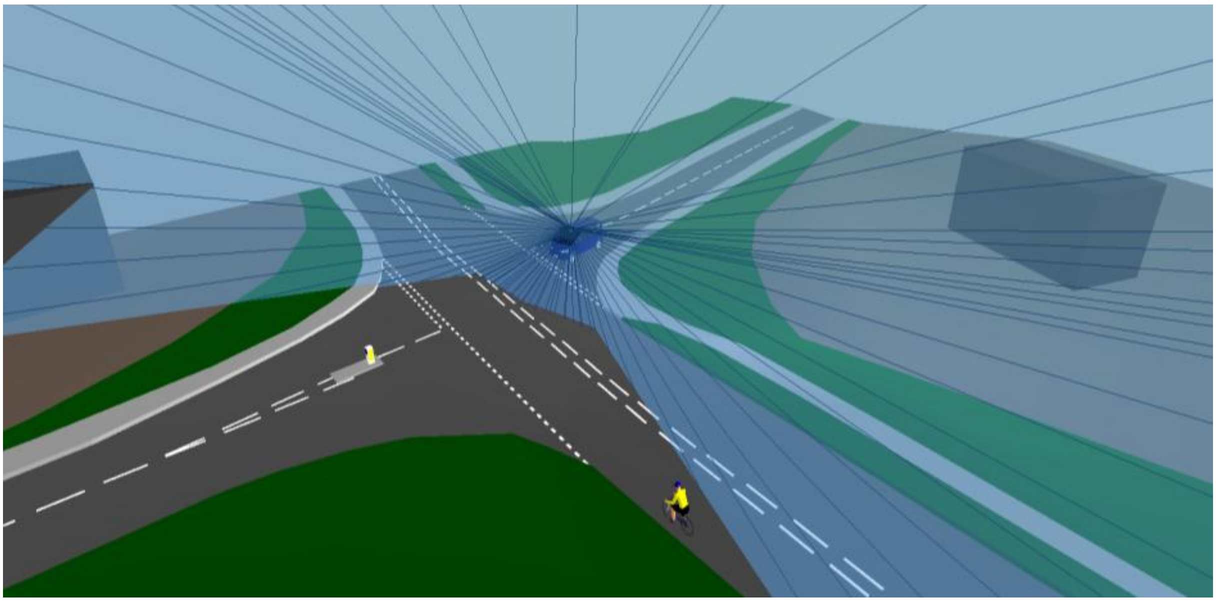

Figure 378. The cyclist located within the field of view through the windscreen (alternative view)

As observed with the other scenarios the A-pillar forms a clear 'corridor' of obscured field of view. In this instance the corridor is easily capable of obscuring the cyclist and like that for the larger driver is aligned relatively across carriageway (Figure 377 and Figure 378). For the smaller driver the obscured field of view is further down the carriageway but significantly different to that observed in the Golf. For the Touran the two blind spots sit adjacent to one another and are wider. However, the cyclist would still be at least 8m further away from the point of impact than that observed for the larger driver. It is interesting to note that the split A-pillar aperture window is ineffective in this scenario (Figure 379 and Figure 380).

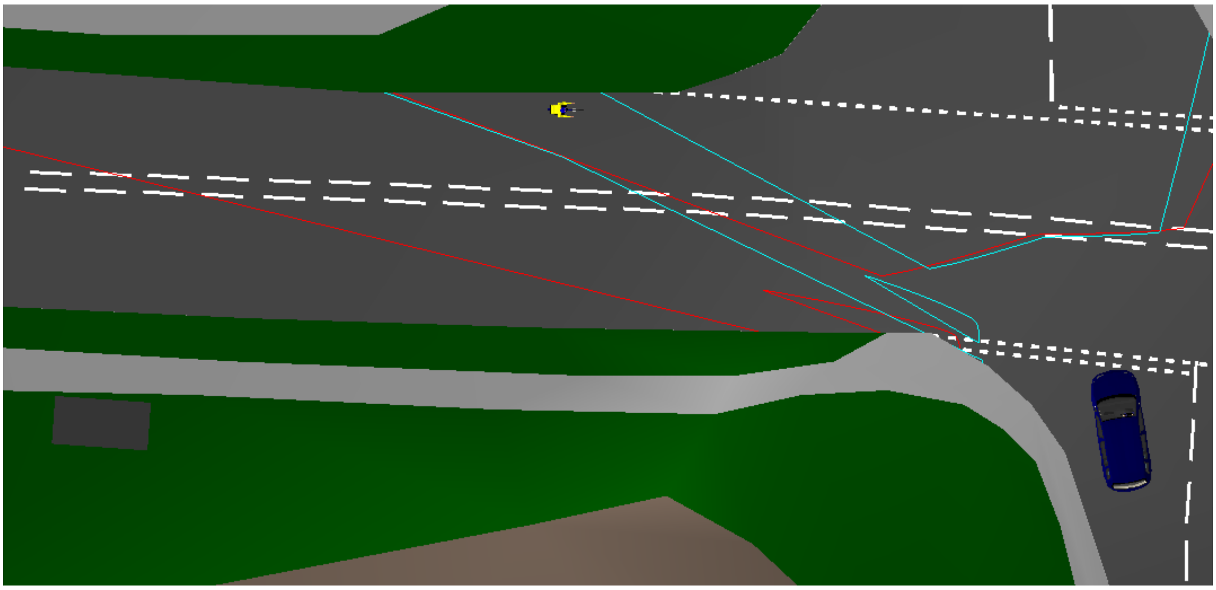

Figure 379. The difference between the blind spot for the 5th%ile UK female (red) and the 99%ile Dutch male (blue).

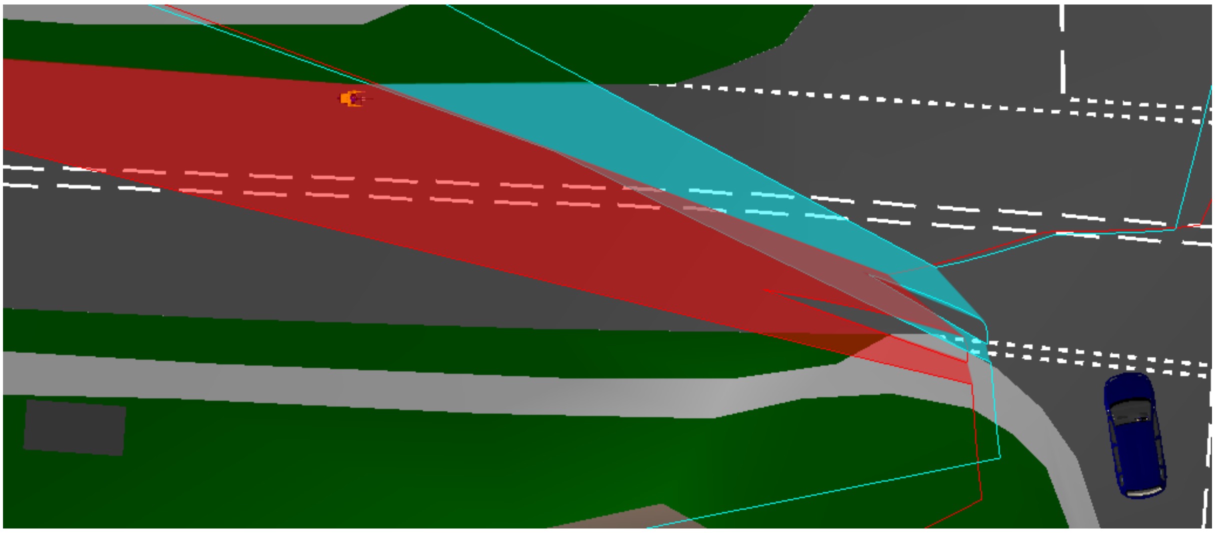

Figure 380. The difference between the blind spot for the 5th%ile UK female (red) and the 99%ile Dutch male (blue). The small triangular cutouts in the shaded areas outline the field of view through the split A-pillar glazed aperture

3.5.2.3.4 M_1 – Hyundai i10

3.5.2.3.4.1 99th %ile Dutch male

The relative positioning of the vehicles is shown in Figure 381 and Figure 382 below.

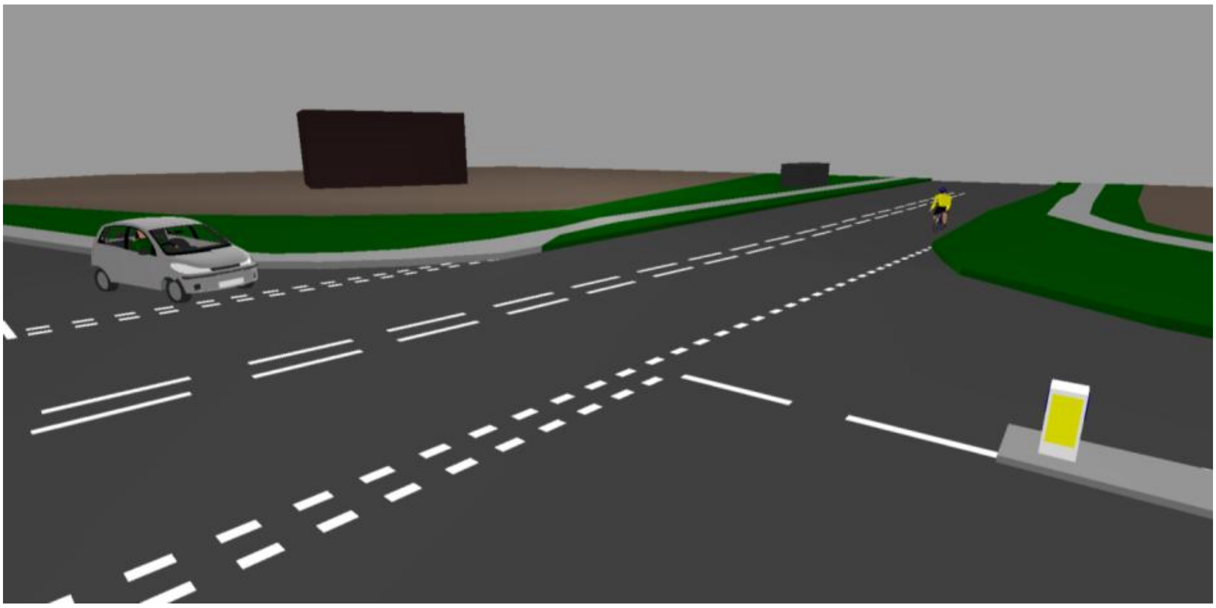

Figure 381. The crossroads layout showing the Hyundai i10 and 99%ile Dutch male driver

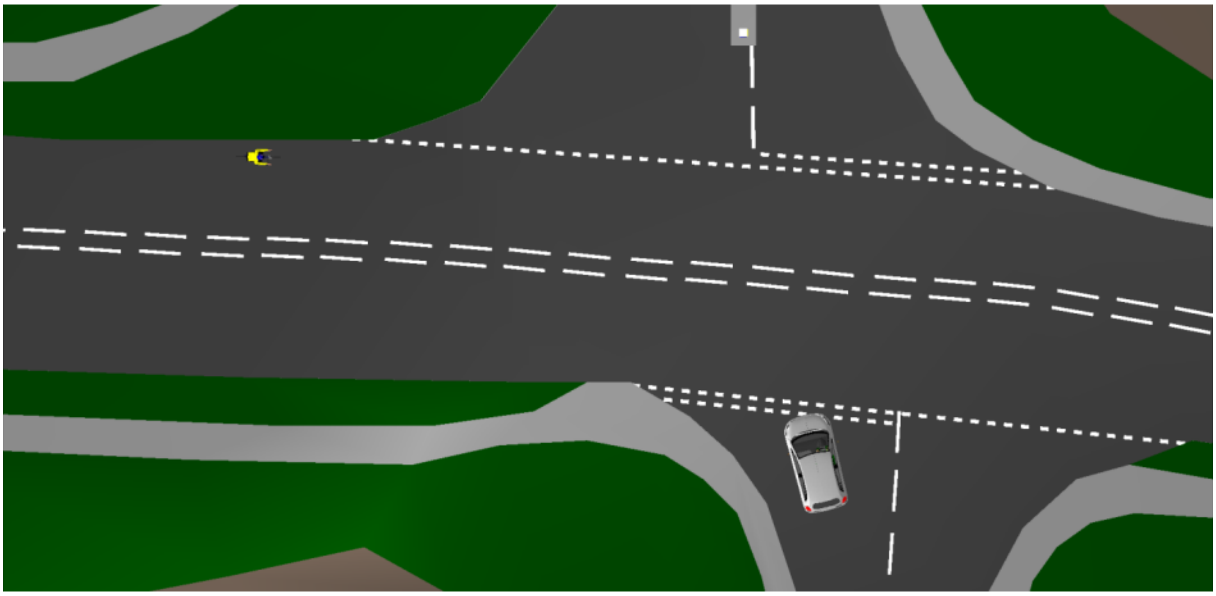

Figure 382. The vehicle positioning at the junction

Figure 383 shows that in this position the cyclist is completely obscured by the nearside (left) A-pillar of the M_1 vehicle.

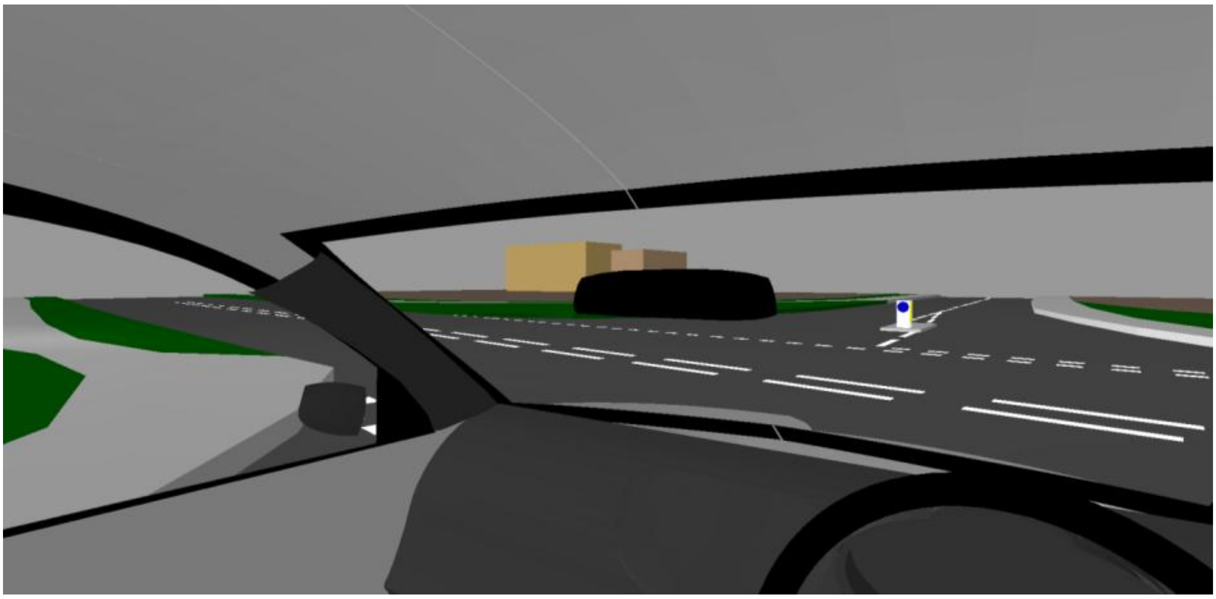

Figure 383. The view of the Dutch male driver

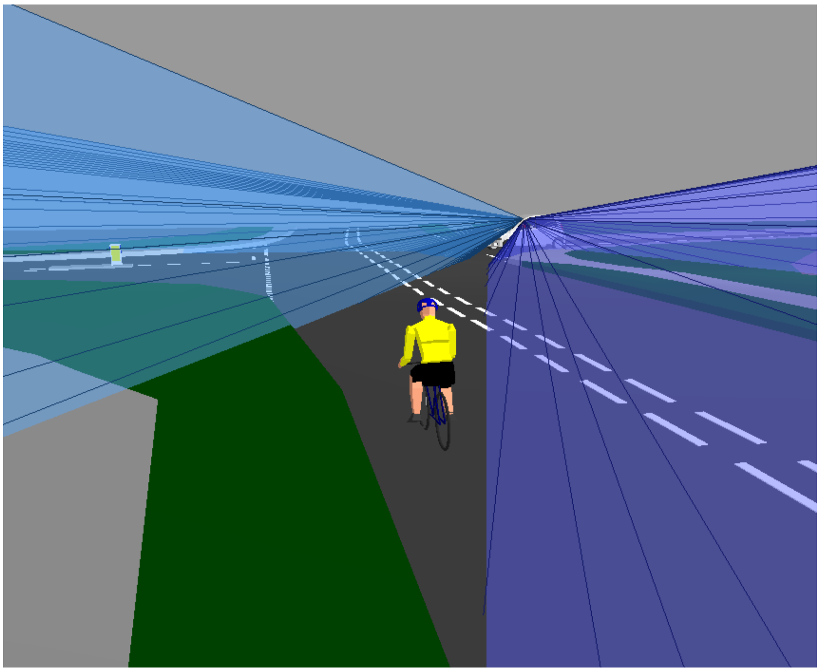

Figure 384. The cyclist located within the blind spot caused by the A-pillar

As with the Golf and Touran the A-pillar forms a clear 'corridor' of obscured field of view. The size of the obscuration appears to be somewhere between the Golf and Touran and relatively across the direction the oncoming traffic is moving (Figure 384). Thus it is not possible for the cyclist to travel down the obscured field of view, only through it. The distances, positioning and relative fields of view are very similar to those observed for the other M_1 vehicles. Thus from these evaluations it is possible that the collision could occur but unlikely that A-pillar obscuration could be the only factor in this accident.

3.5.2.3.4.2 5h %ile UK female

The relative positioning of the vehicles is shown in Figure 385 and Figure 386 below.

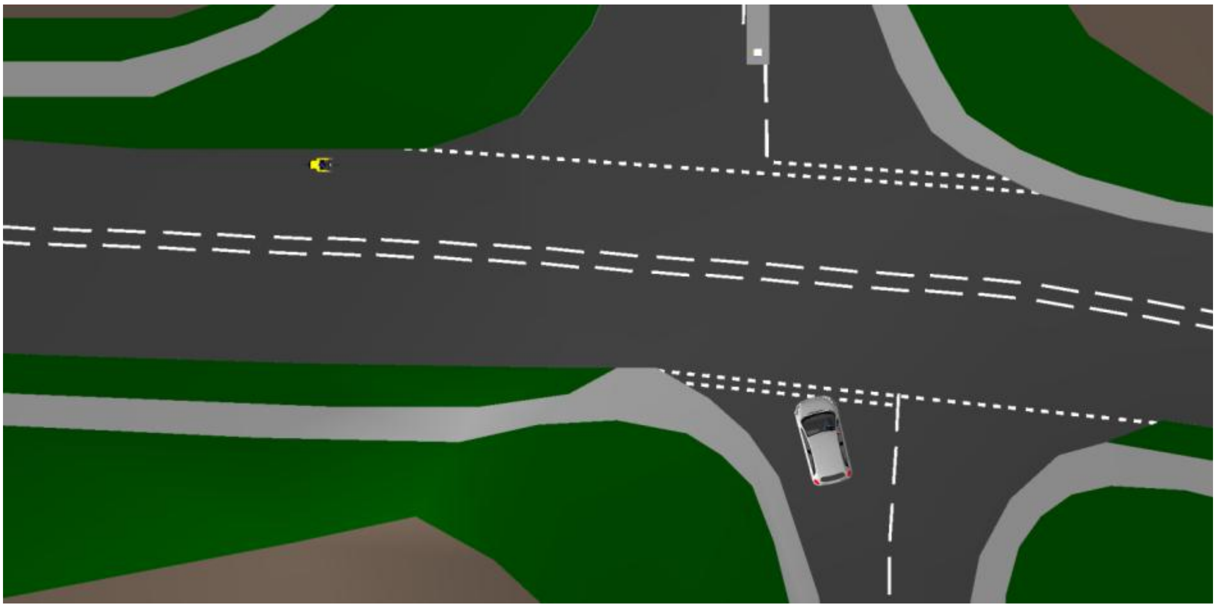

Figure 385. The vehicle positioning at the junction

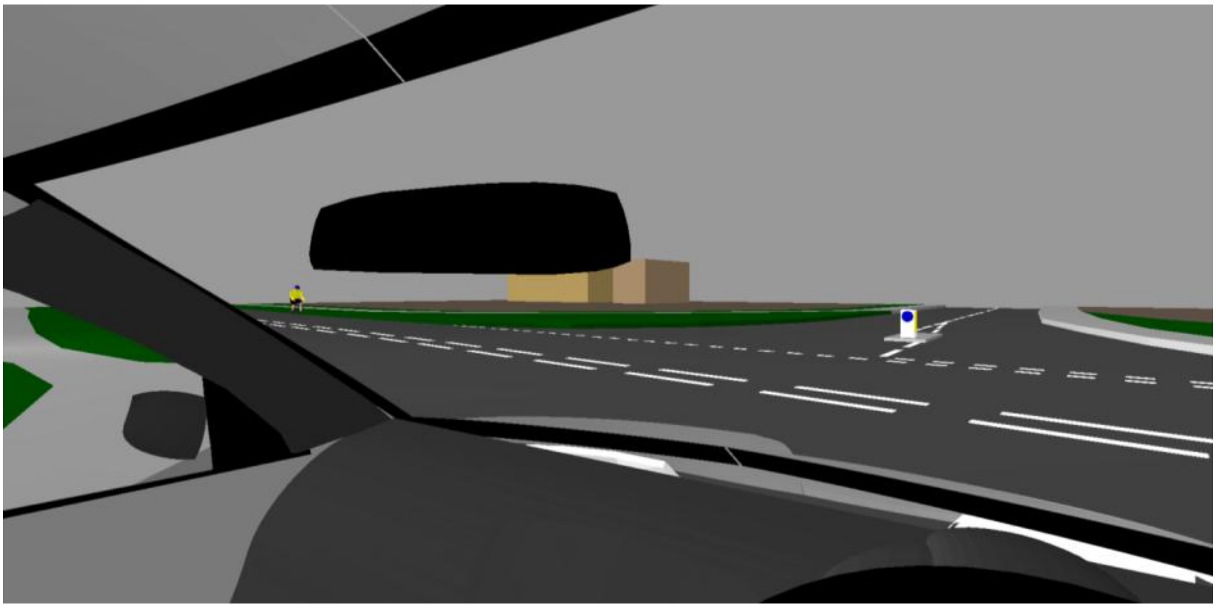

Figure 386. The view of the UK female driver

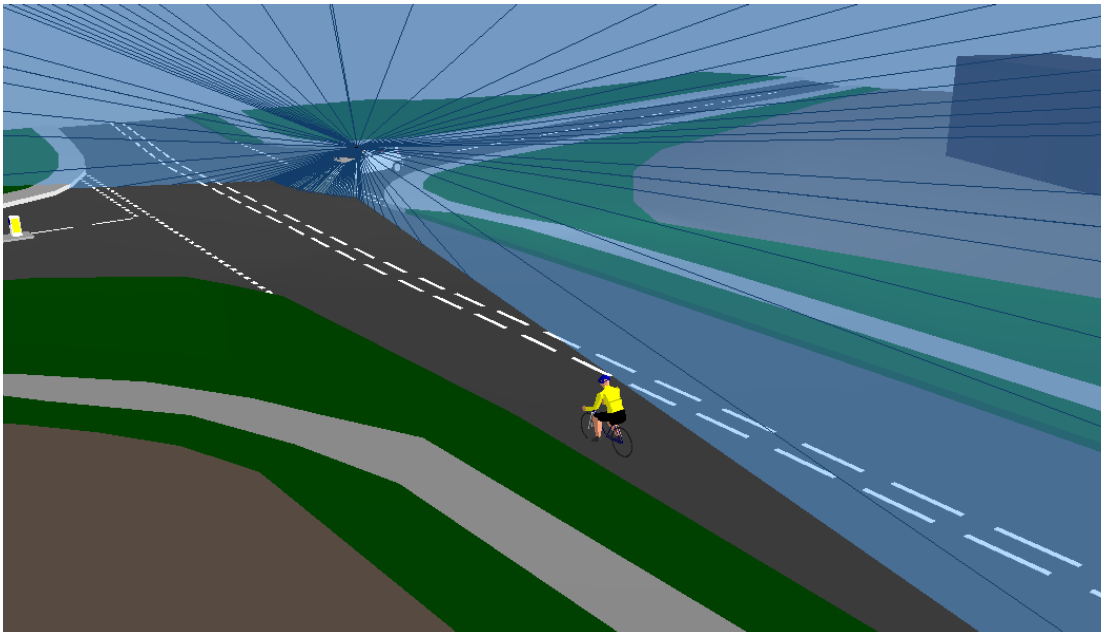

Figure 387. The cyclist located within the field of view through the windscreen

As observed with the other scenarios the A-pillar forms a clear 'corridor' of obscured field of view. In this instance the corridor is easily capable of obscuring the cyclist (Figure 387). In comparison to the corridor for the larger driver that is aligned across the carriageway, the corridor for the smaller driver is largely aligned along the carriageway in the direction of the oncoming traffic. For the i10 the two blind spots sit almost adjacent to one another (Figure 388 and Figure 389). For the smaller driver the cyclist would be at least 20m further away from the point of impact than that observed for the larger driver.

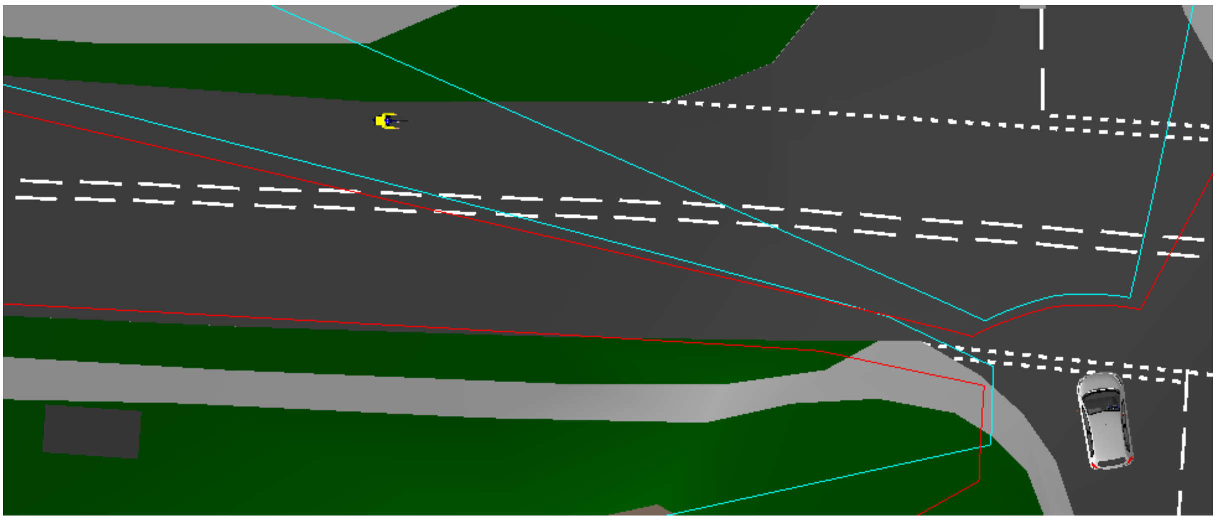

Figure 388. The difference between the blind spot for the 5th%ile UK female (red) and the 99%ile Dutch male (blue)

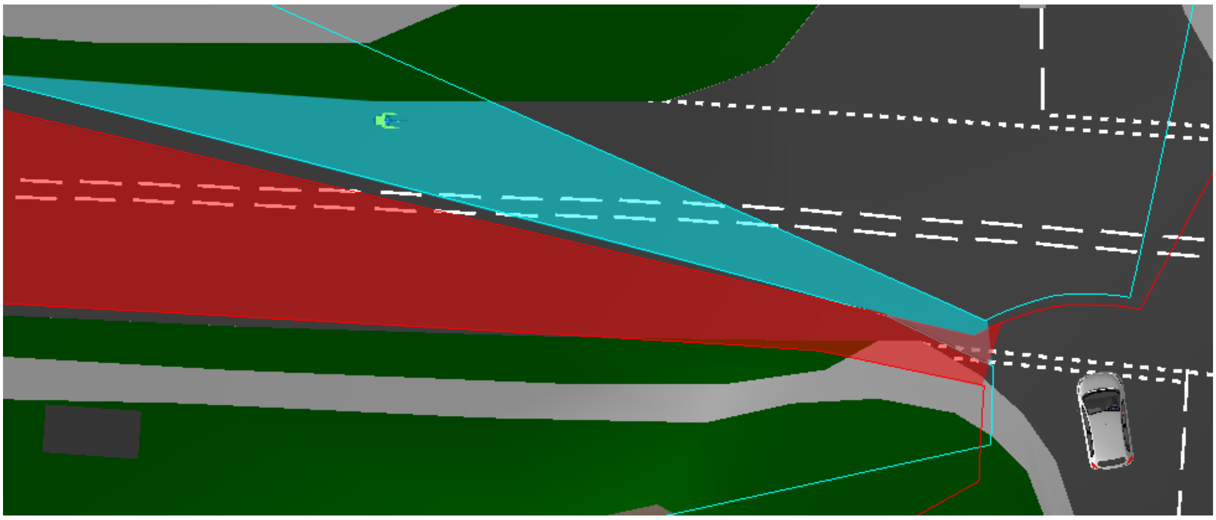

Figure 389. The difference between the blind spot for the 5th%ile UK female (red) and the 99%ile Dutch male (blue) - shaded

3.5.2.3.5 Crossroads summary

For all of the assessed M_1 vehicles there is an effective 'corridor' blind spot caused by the A-pillar. This blind spot's location changes significantly between the two driver size extremes. For the larger drivers of each vehicle the blind spot allows the cyclist to get nearer to the junction and still be obscured. For the smaller driver the blind spot is much further to the left and so the cyclist is visible much sooner. Whilst the M_1 vehicle could pull out in front of the cyclist, in either case there is a good chance that the cyclist would see the M_1 vehicle pulling out in front of them and be able to slow and take avoiding action if necessary. The closest the cyclist can get and still be obscured, is approximately 15m from the junction. Travelling at 20mph the cycle would take 1.677s to cover that distance and the cyclist would be able to clearly see the M_1 vehicle pulling out from the junction.

An alternative scenario for an accident at this junction is for the M_1 vehicle to be turning right. Here the vehicle would be positioned perpendicular to the main carriageway to make the right turn as easy as possible (Figure 390). This would effectively move the blind spot to the right relative to the scenario described above. As such the driver of the M_1 vehicle could look to the right, look to the left and not see a vehicle obscured by the A-pillar and then proceed to pull out with their attention directed to the right. If the second vehicle was motorised, a car or motorbike, the relative speeds would make a collision more likely where the driver of the second vehicle would see the M_1 vehicle pulling out but is unlikely to have time to react.

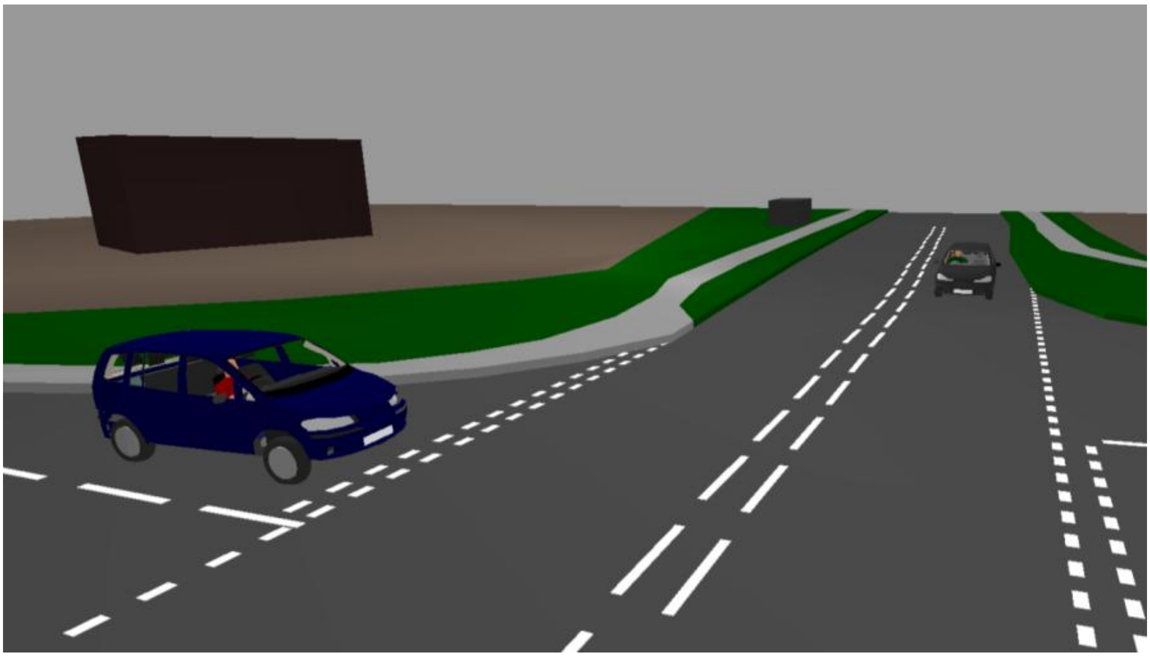

Figure 390. The crossroads layout showing the VW Touran and 5%ile UK female driver

Figure 391, Figure 392 and Figure 393 below show that the A-pillar is capable of hiding an M_1 vehicle approaching from the left.

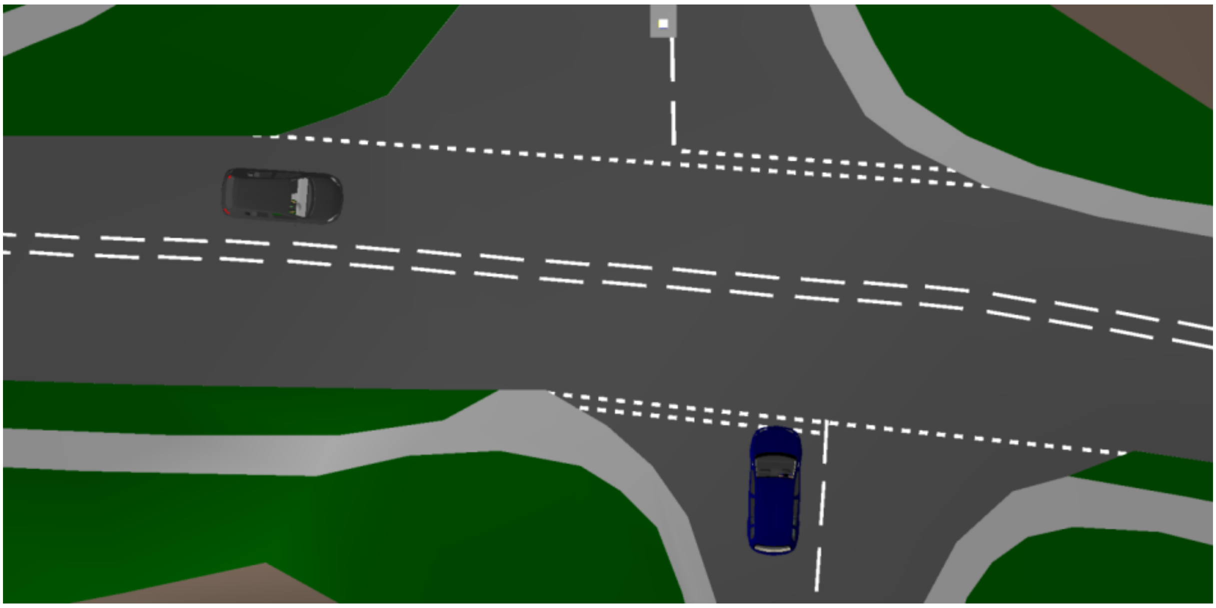

Figure 391. The crossroads with a vehicle approaching from the left and the M_1 vehicle turning right

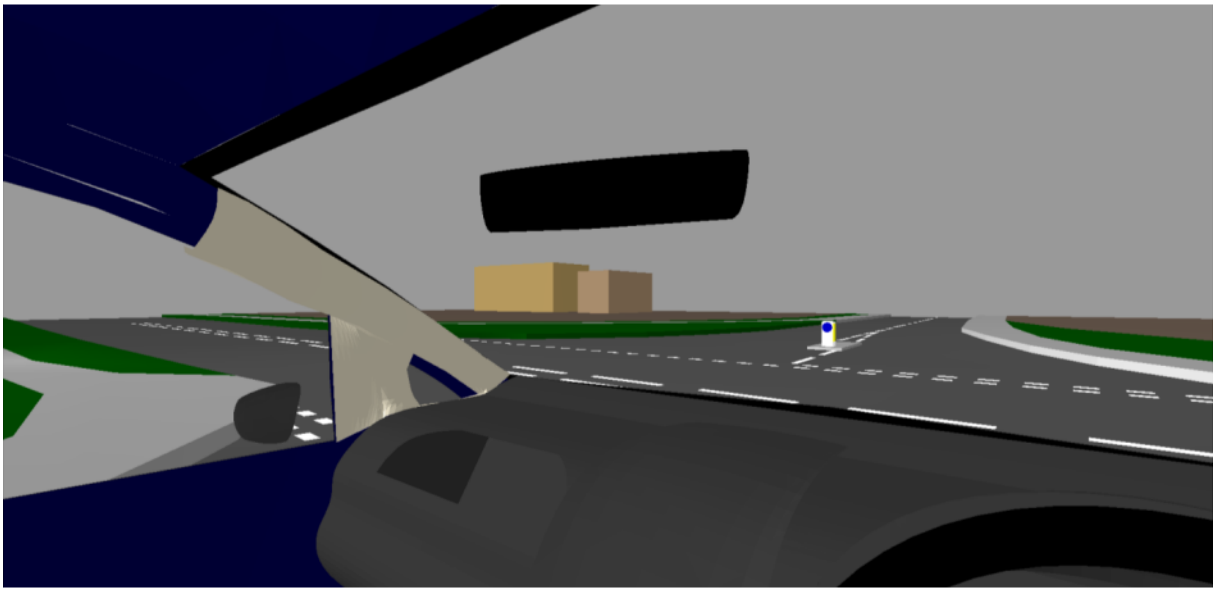

Figure 392. The view of the UK female driver

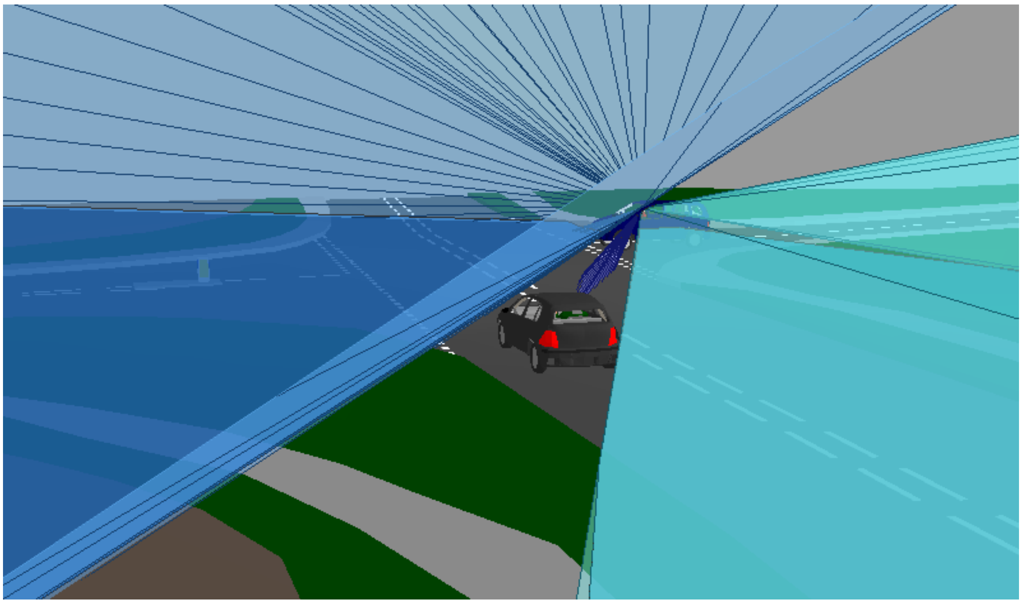

Figure 393. The car located in the blind spot

As this scenario is a right turn for the driver of the M_1 vehicle their focus of attention is to the right. Thus, as they determine that the coast is clear and they pull away they are no longer observing to the left. Figure 394 and Figure 395 below show how the driver's field of view does not show the oncoming M_1 vehicle on the main carriageway.

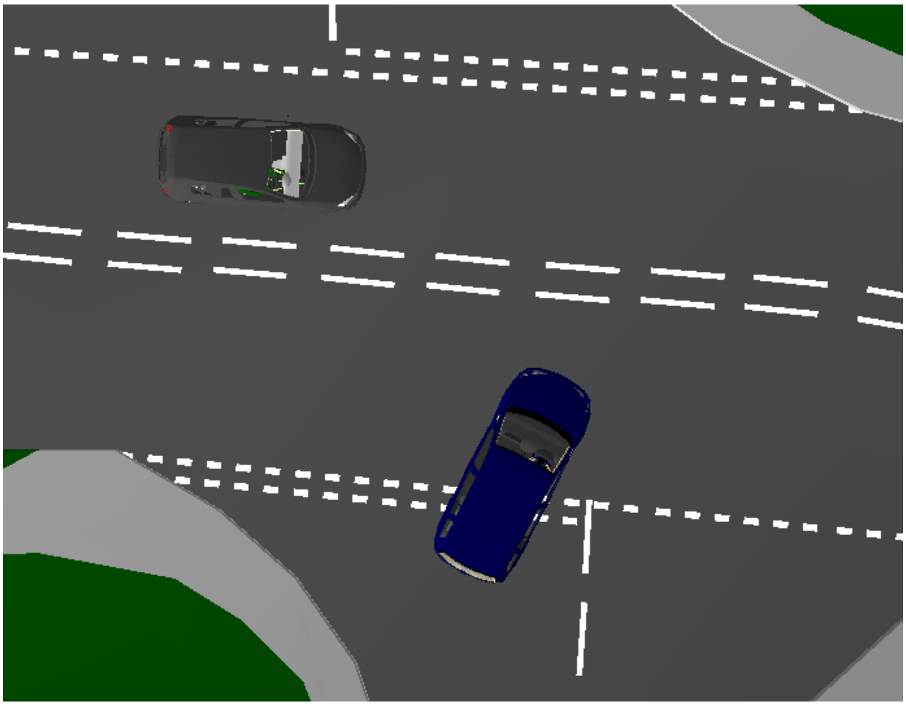

Figure 394. The M_1 vehicle proceeds to pull out in front of the second vehicle

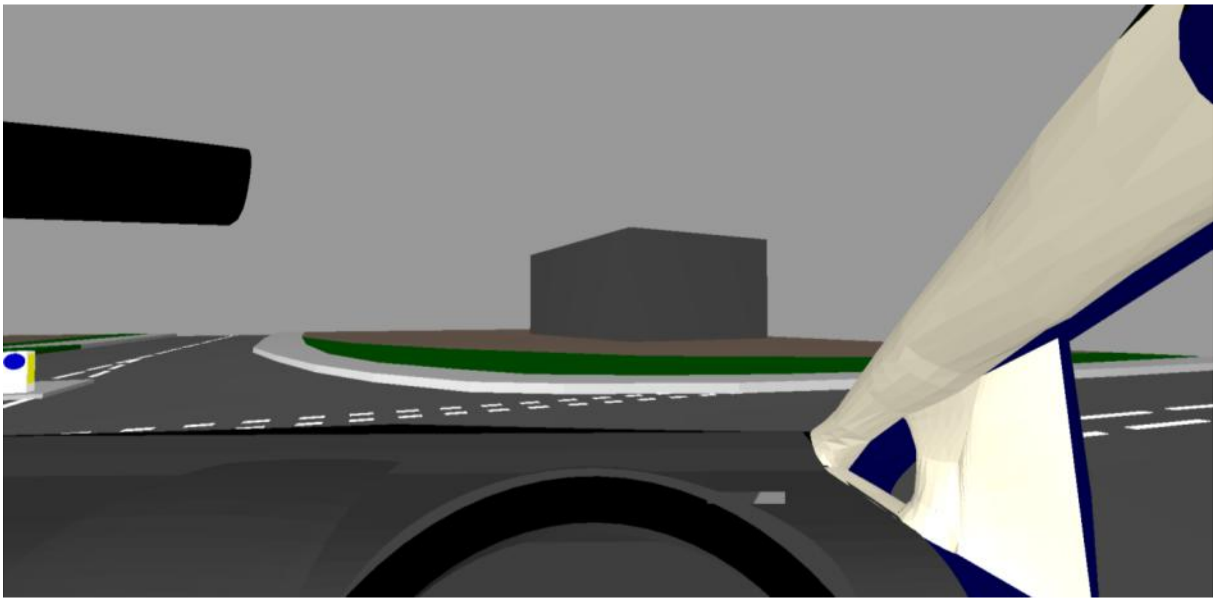

Figure 395. The M_1 driver's field of view is focused ahead and to the right and is not aware of the approaching vehicle

The driver of the second M_1 vehicle would be able to see the first M_1 vehicle pull out but at national speed limits would find it difficult to stop in time to avoid the accident (Figure 396). The blind spot obscures the second M_1 vehicle from the first M_1 at a distance of 15m from the potential point of impact at 30mph this would be covered in 1.11s, at 40 in 0.83s, and at 60 in 0.55s, leaving very little reaction time for the driver.

Figure 396. The field of view of the driver of the second vehicle clearly shows the M_1 vehicle pulling out but at speed they might have insufficient time to react and avoid an accident

3.5.3 Binocular vision.

All of the evaluations shown in this Work Package thus far have used a mean eye point and monocular vision. This provides a consistent generic approach to the view that would be apparent to a real person. However, it does not take into account the binocular view afforded to a person exposed to the real world observations simulated in this work. This evaluation shows the effect of binocular vision over and above the evaluations illustrated here.

Figure 397 shows the evaluative setup of a 99th %ile Dutch male driver in the Volkswagen Golf M_1 vehicle positioned relative to a cyclist approaching from the opposite direction. At this point the cyclist is completely obscured from the driver when using monocular vision from the 'mean' eye point (Figure 398 and Figure 399).

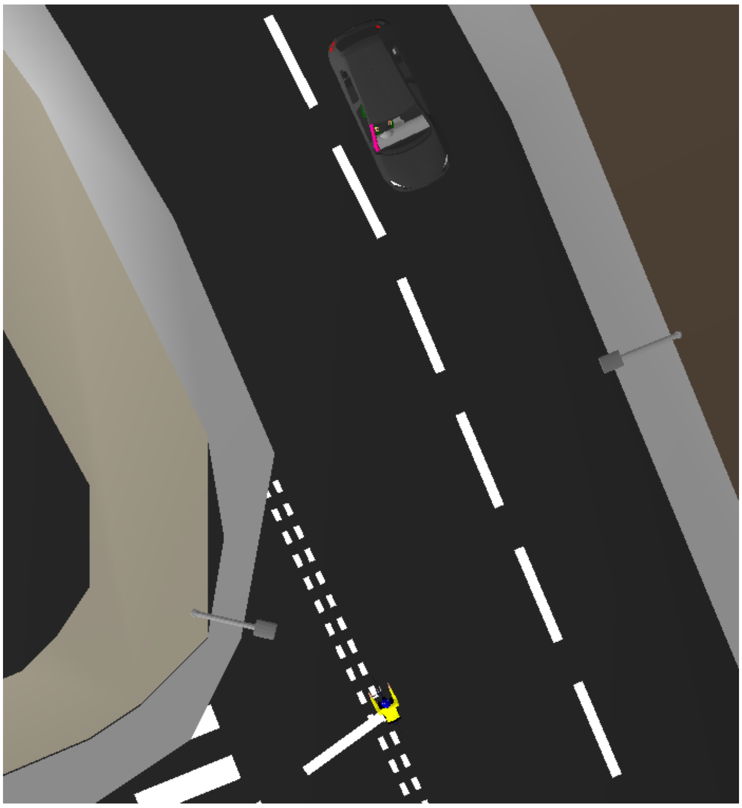

Figure 397. The evaluative setup.

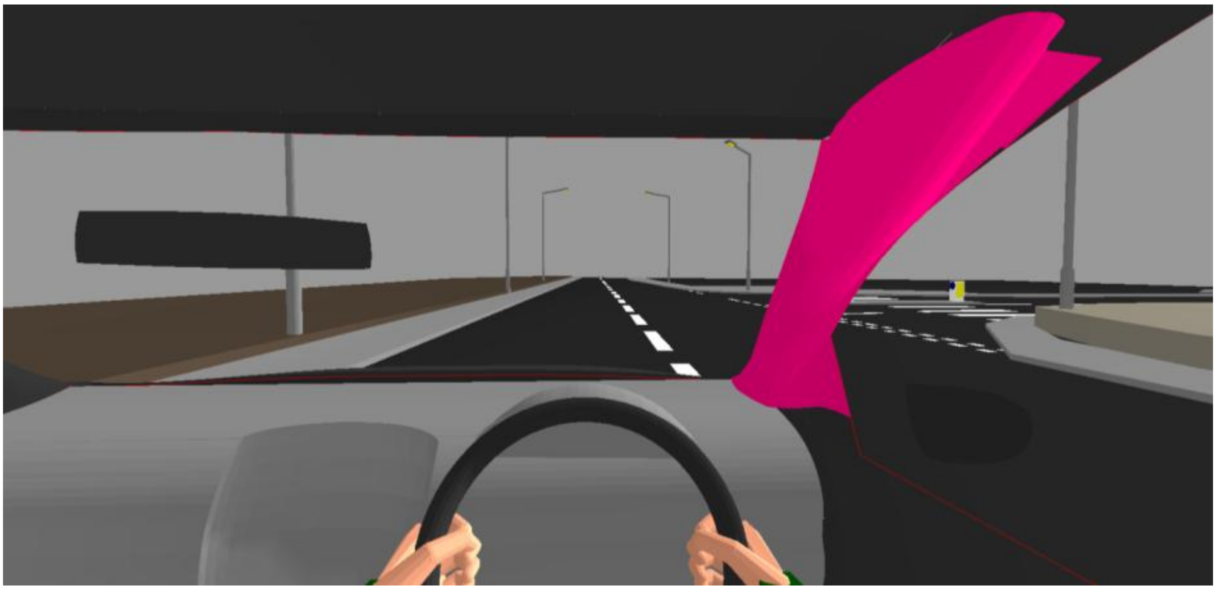

Figure 398. The monocular view of the Dutch Male driver

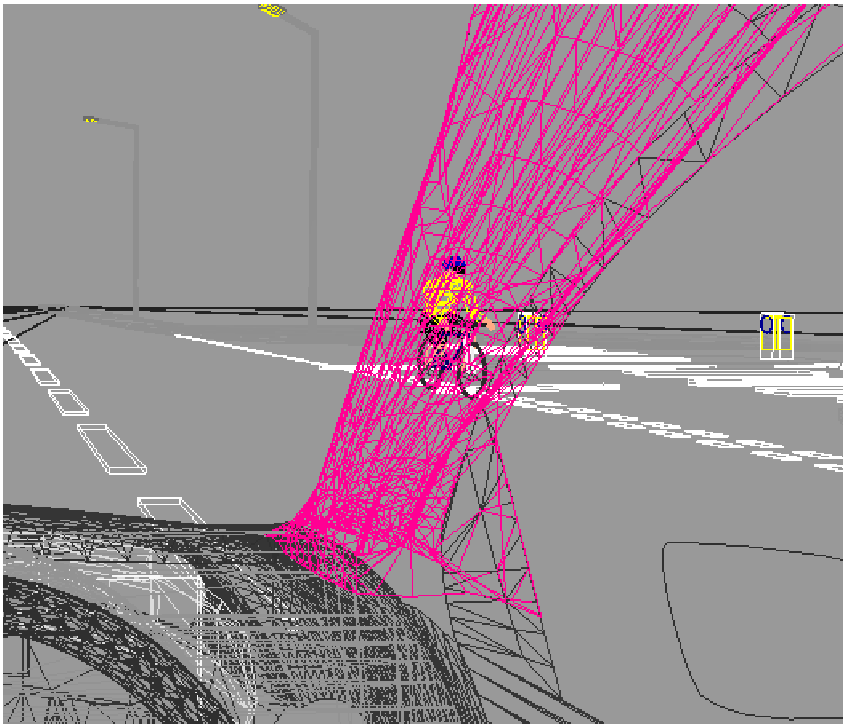

Figure 399. A cyclist hidden in the A-pillar blind spot

Figure 400. Left and Right eye views respectively

Figure 401. Left and Right eye views respectively

The monocular vision from the left and right eyes respectively (Figure 400 and Figure 401) can then be combined to form the binocular image shown in Figure 402 and Figure 403. The images show that the cyclist, completely obscured in monocular vision for the Dutch male driver, becomes slightly visible in binocular vision, with the effective width of the A-pillar reduced substantially.

Figure 402. The binocular view of the Dutch Male driver

Figure 403. The binocular view showing a reduction in obscuration

If the cycle is replaced with a larger target, in this case a second M_1 vehicle, shown in the scenario below (Figure 404, Figure 405 and Figure 406). It can be seen that the significant obscuration is reduced but binocular vision is insufficient to completely reveal the vehicle.

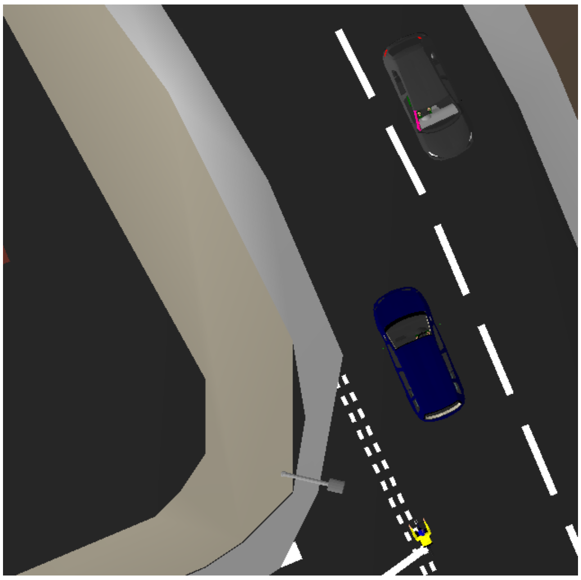

Figure 404. The evaluative setup.

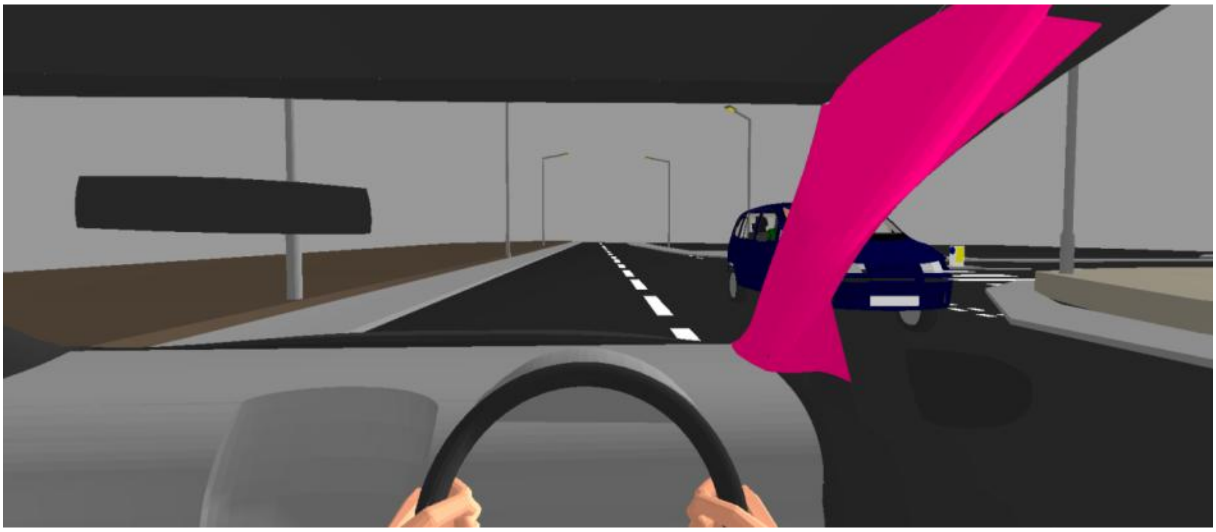

Figure 405. The monocular view of the Dutch Male driver

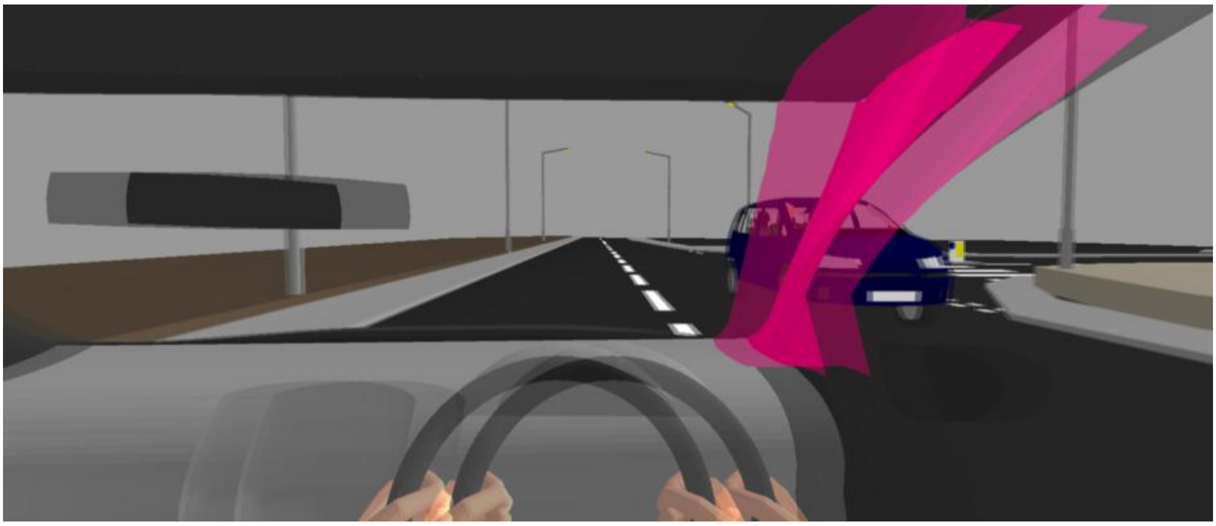

Figure 406. The binocular view of the Dutch Male driver

Repeating the exercise with the UK female driver the effect is still evident but much reduced. Figure 407 and Figure 409 below show how the effective pillar size is reduced and the obscured cyclist becomes very slightly visible.

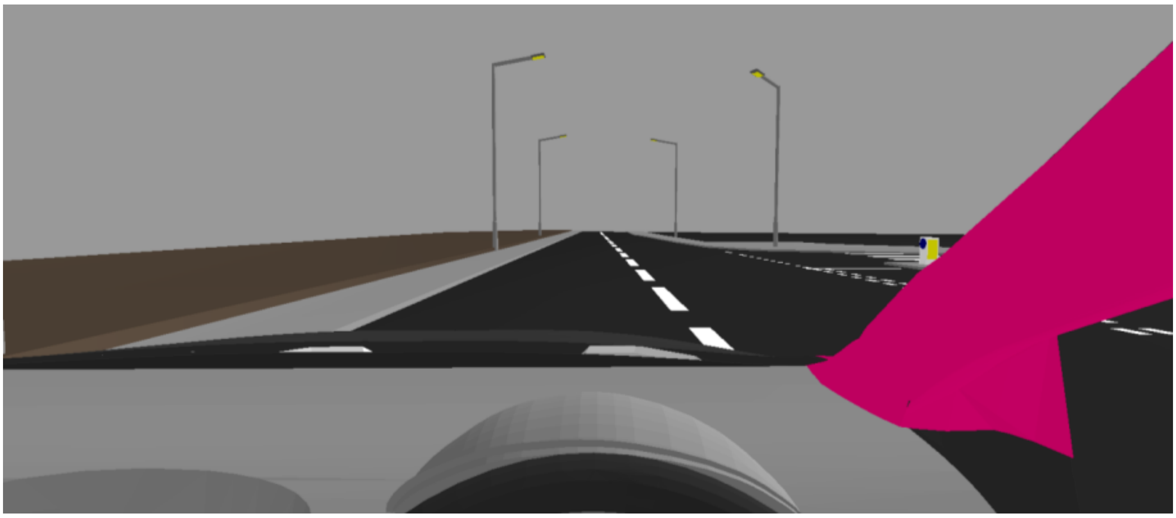

Figure 407. The monocular view of the UK female driver

Figure 408. The binocular view of the UK female driver

Figure 409. The binocular view of the UK female driver

Figure 397 to Figure 409, above show that a small visual target completely obscured by the A-pillar in monocular vision becomes partially visible with binocular vision. A larger target partially obscured becomes significantly less obscured with binocular vision. However, the pillar never fully disappears and the effect is markedly greater for eye points further from the A-pillar such as that for the 99%ile Dutch male. For smaller drivers, the A-pillar is a greater obscuration to vision and the effect of binocular vision is much reduced.

3.5.4 Incremental A-pillar evaluation

A potential outcome from the evaluations detailed earlier is to recommend a reduction in A-pillar size in order to afford greater visibility for the driver and minimise any blind spots. This evaluation attempts to understand the improvement to vision through incremental reductions in A-pillar dimensions. For this evaluation the largest selling and most 'typical' of the assessed M_1 vehicles is used: the Volkswagen Golf (Figure 410).

The images below show the evaluations for the worst case configuration. The smaller driver's proximity to the A-pillar, in this case the 5%ile UK female, results in a much larger obscuration.

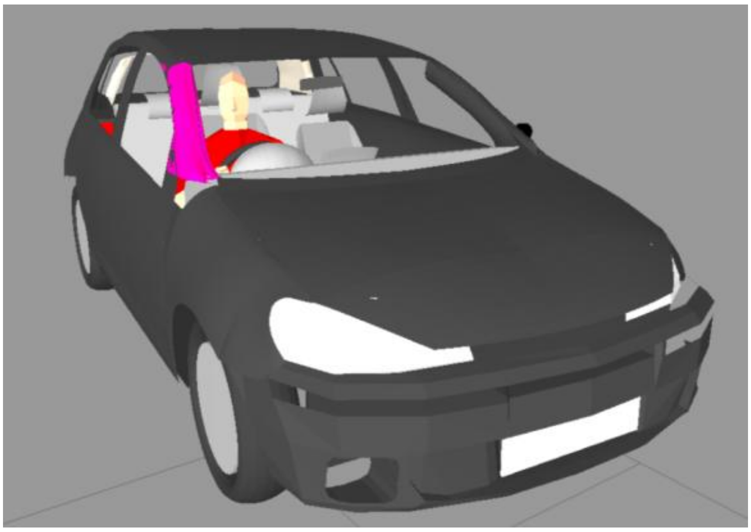

Figure 410. The evaluative setup - the Volkswagen Golf with a highlighted offside A-pillar

Figure 411 below shows the obscuration from the offside A-pillar (Figure 412) in the tapering 'corridor' format that has been identified in earlier evaluations.

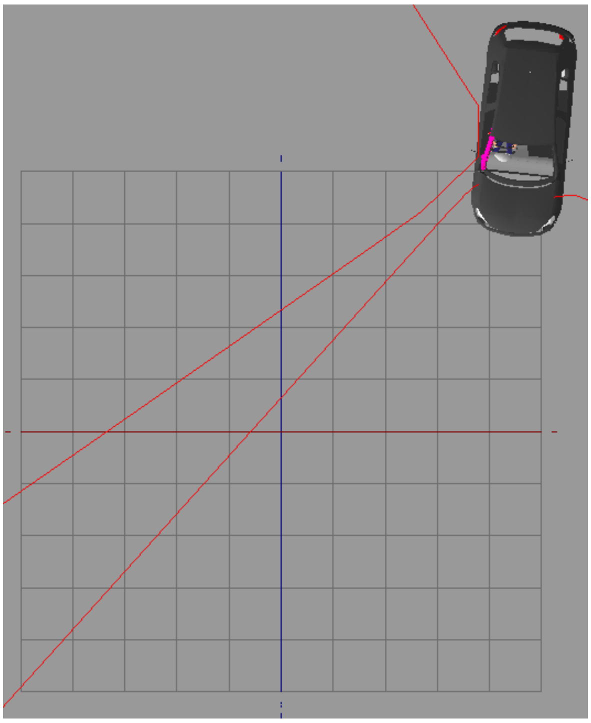

Figure 411.The blind spot generated by the A-pillar obscuration

Figure 412. The Volkswagen Golf with a highlighted offside A-pillar

Reducing the size of the A-pillar by 10mm in both the fore-aft (longitudinal) direction and in the left-right (transverse) directions results in an increase in the visible area, or alternatively a reduction in the effective blind spot. Figure 413 and Figure 414 show the reduction in blind spot plotted level with the eye point. The black lines indicate the default situation, the green lines show the boundaries when the A-pillar size is reduced. The increase in viewable area is very slight for quite substantial changes in A-pillar size. For a 10mm change the limit of the field of view through the windscreen alters the angle subtended by approximately 1 degree, and through the side window by 0.5 degree.

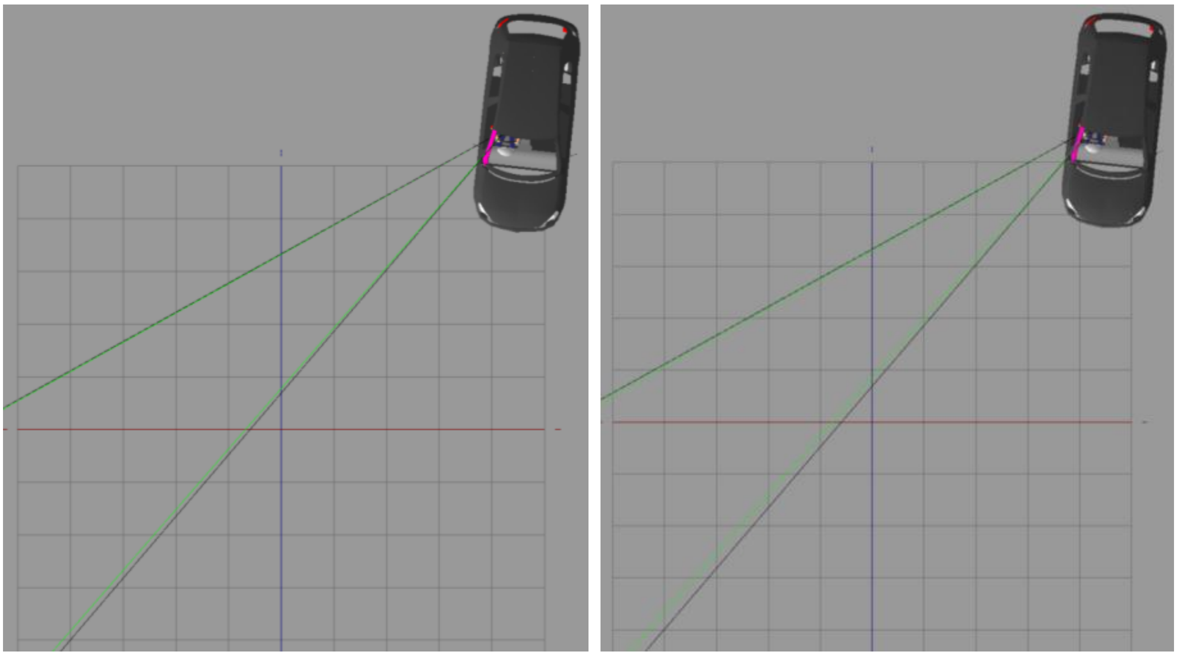

Figure 413. The reduction in blind spot through a reduction in A-pillar size. The image on the left is a 10mm reduction, the image on the right a 20mm reduction.

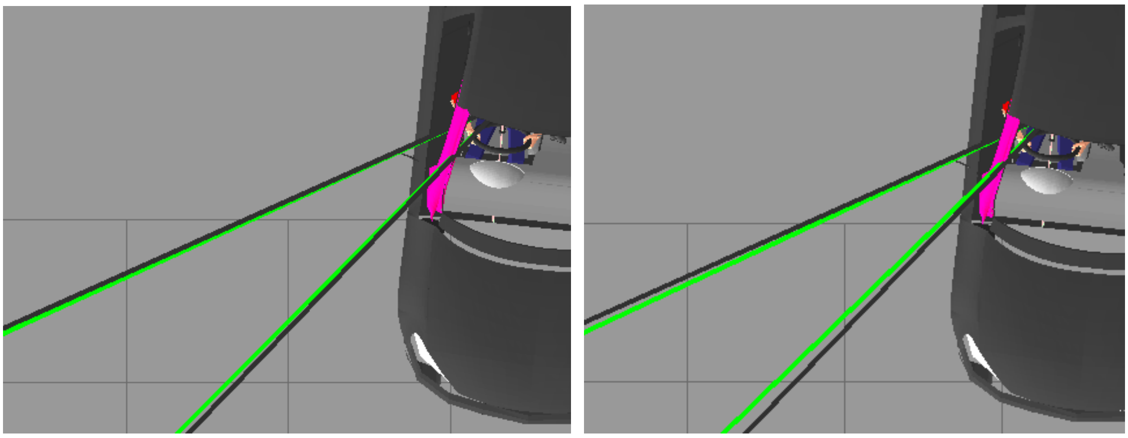

Figure 414. The reduction in blind spot through a reduction in A-pillar size. The image on the left is a 10mm reduction, the image on the right a 20mm reduction (close up view)

Figure 415. The view from the Golf with its original A-pillar size

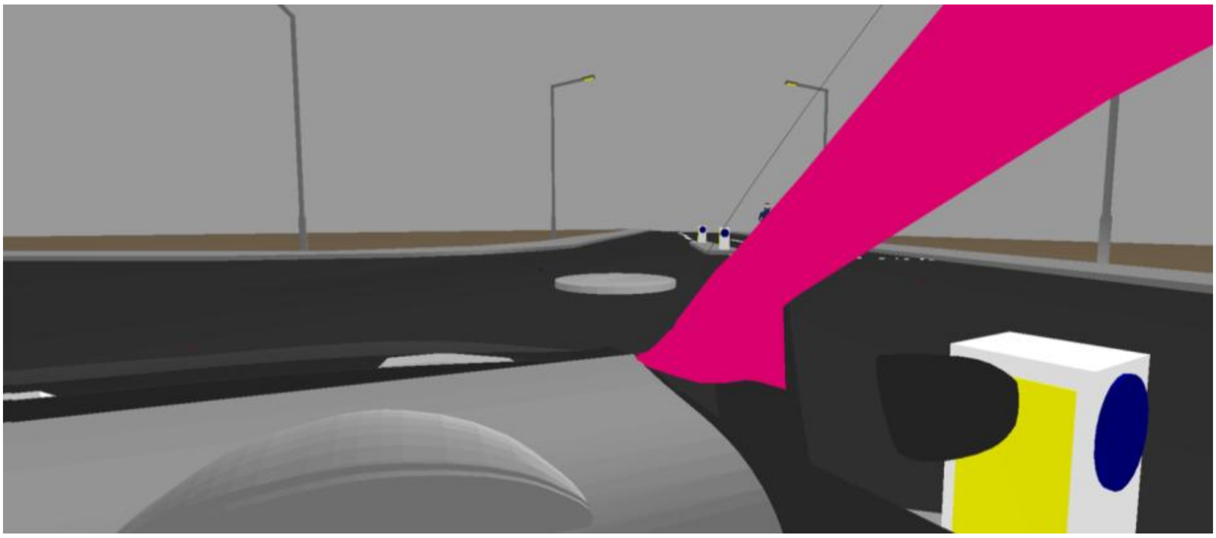

Figure 416. The view from the Golf with its A-pillar reduced in size by 50mm front to back and side to side

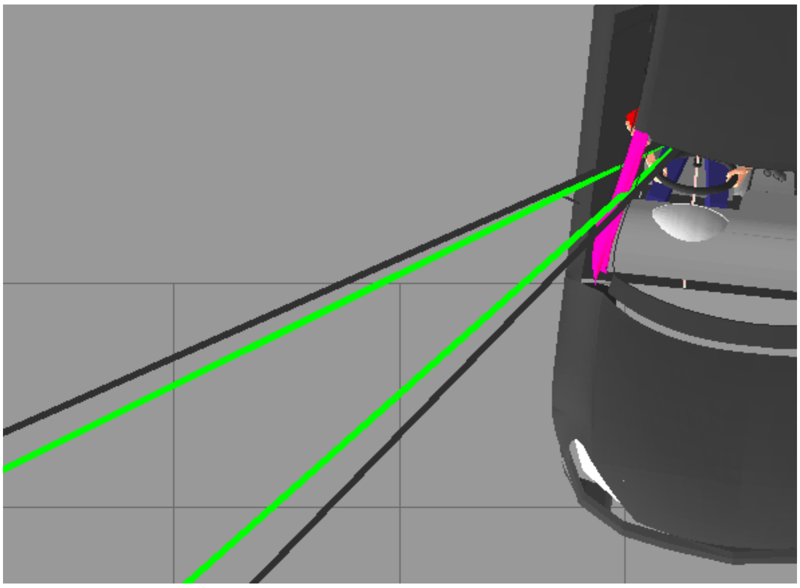

Figure 417. The reduction in blind spot through a reduction in A-pillar size by 50mm (2.5 degrees through the side window, 4 degrees through the front window)

Figure 415, Figure 416 and Figure 417 shown above show a visual comparison of reducing the A-pillar of the Volkswagen Golf from its current configuration to a size reduced in both longitudinal and transverse directions by 50mm. In reality this would be a major structural change to the vehicle and require substantial re-engineering of the crash structure. If it were feasible to achieve this reduction the increase in view is illustrated above. The increase in view is still relatively modest even with this degree of A-pillar reduction. The A-pillar is still a clear obstruction to view. Part of this effect is due to the geometrical alignment of the A-pillar and the relative position of the eye point. As the eye point is inboard of the A-pillar the axes of the A-pillar alignment are not aligned with the direction of view. As such, reductions in size are not the equivalent of reducing the width of the a-pillar horizontally in a plane perpendicular to the direction of view. The impact of this effect is that the size of the A-pillar has to be substantially reduced to have a noticeable effect on A-pillar size in the direction of view, as shown in the images. A further consequence of this effect is that it would be possible to increase the depth, parallel to the direction of view, of the A-pillar structure without increasing the observed a-pillar size. Theoretically this would allow the A-pillar to maintain a critical size for structural reasons but be reduced to improve visibility. The limitation to this approach is that there is no consistent eye point for the driving population, such that the direction of view is different between the largest and smallest drivers. Furthermore increasing the dimension of the A-pillar in the direction of view increases its profile from the front of the vehicle and this would affect aerodynamic performance and fuel economy.

As shown in the binocular vision evaluation in Section 3.5.3, stereoscopic vision provides a perceived reduction in A-pillar size. Thus, it is theoretically possible to reduce the A-pillar size to an extent to which it would effectively disappear from view. This is caused by two views, one from each eye, separated by the inter-ocular distance (the distance between the centres of rotation of the eyeballs of an individual) overlapping beyond the A-pillar such that the combined view removes the obscuration. Figure 418 and Figure 419 show the A-pillar reduced in size until the stereoscopic nature of vision removes the obscuration.

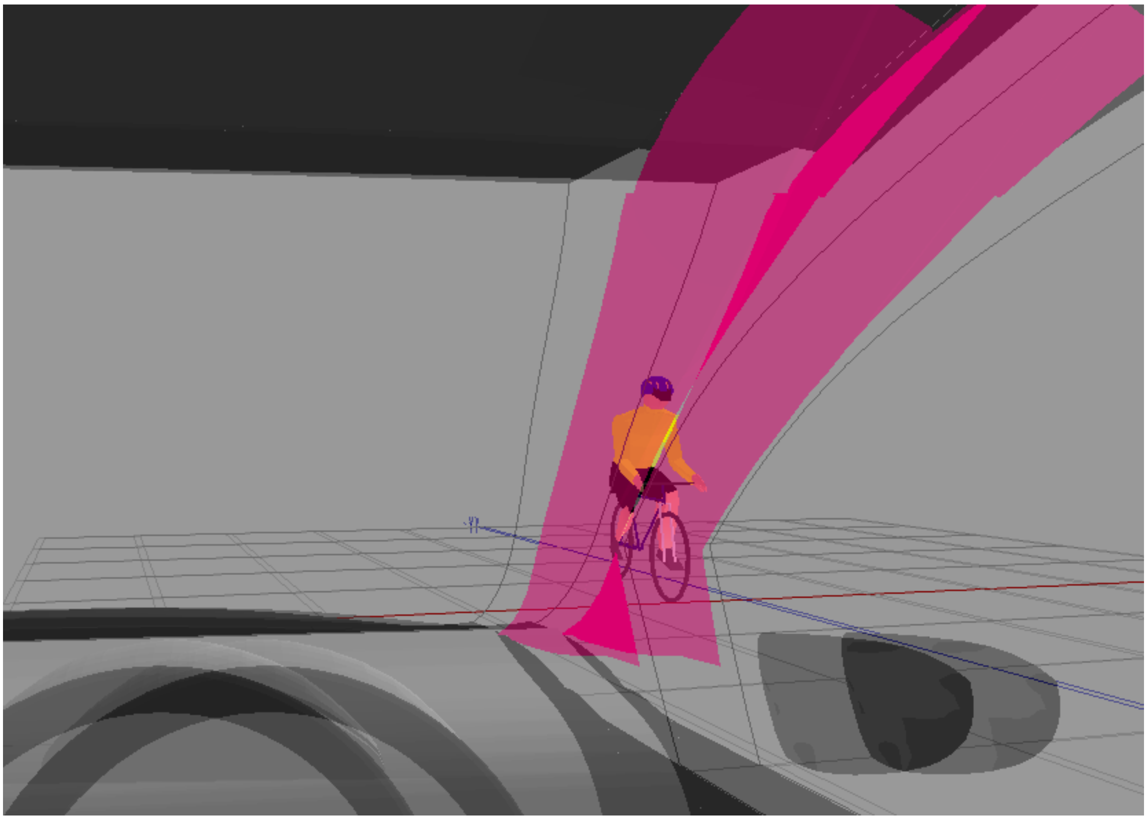

Figure 418. The 99%ile Dutch male view with the A-pillar obscuration removed due to stereoscopic vision (original size reduced by 60mm)

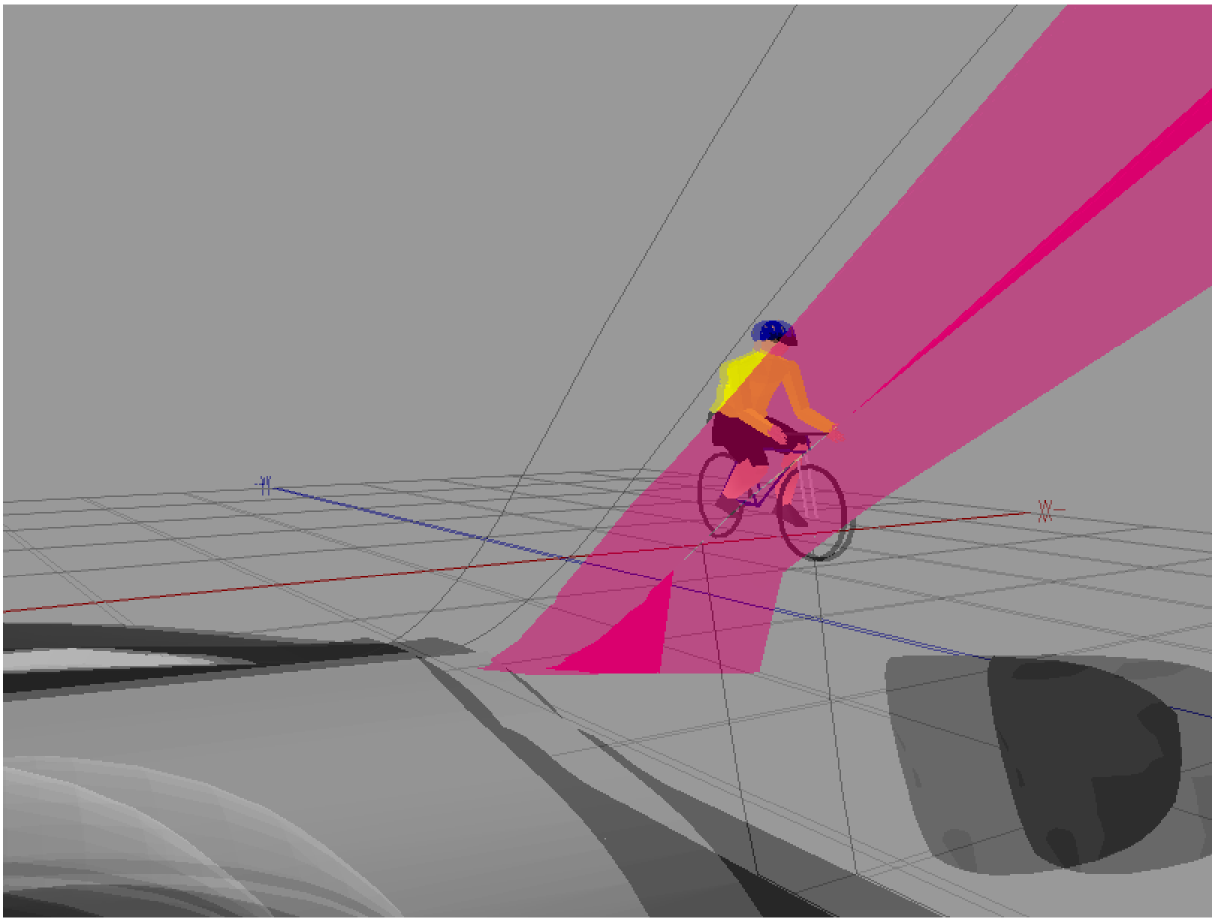

Figure 419. The 5%ile UK female view with the A-pillar obscuration removed due to stereoscopic vision (original size reduced by 120mm)

With all efforts to change the A-pillar to accommodate a particular eye point any solution is always going to be dedicated to a single eye point. To accommodate an inter-ocular distance for the smaller driver the pillar has to be very slim (Figure 420). Thus it is not feasible to produce a generic inter-ocular A-pillar solution that would be able to accommodate all drivers.

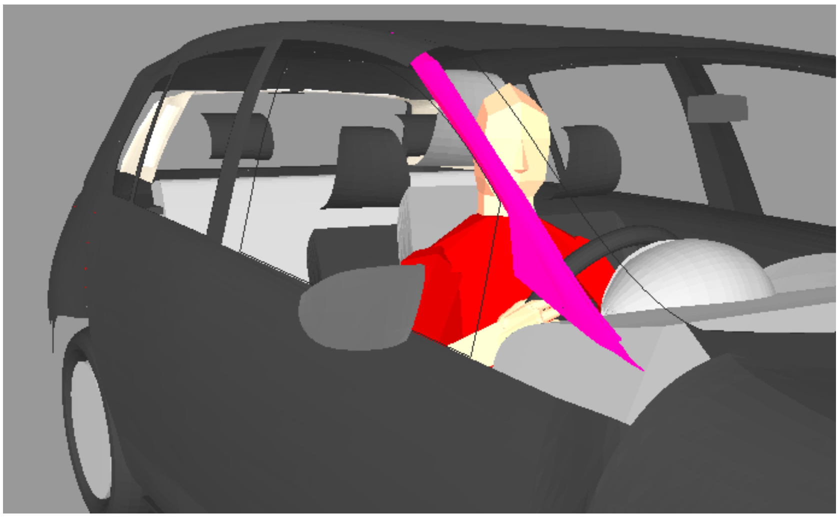

Figure 420. The size of A-pillar required to accommodate the 5%ile UK female in an inter-ocular solution

3.6 Solutions

The evaluations in this Work Package have identified that both A and B-pillars can establish a blind spot for the drivers of M_1 vehicles. In addition these blind spots appear to be a contributory factor in the recreation of accident scenarios taken from real accidents recorded in the OTS database.

However, the blind spots are variable in both size and position based on the design of the pillar, the position of the pillar and the eye point of the driver. Thus a smaller pillar combined with the driver being relatively close to the pillar may provide an equivalent blind spot to a larger pillar with the driver being relatively further away. This is the situation observed with the Volkswagen Touran and the Hyundai i10 (Figure 421).

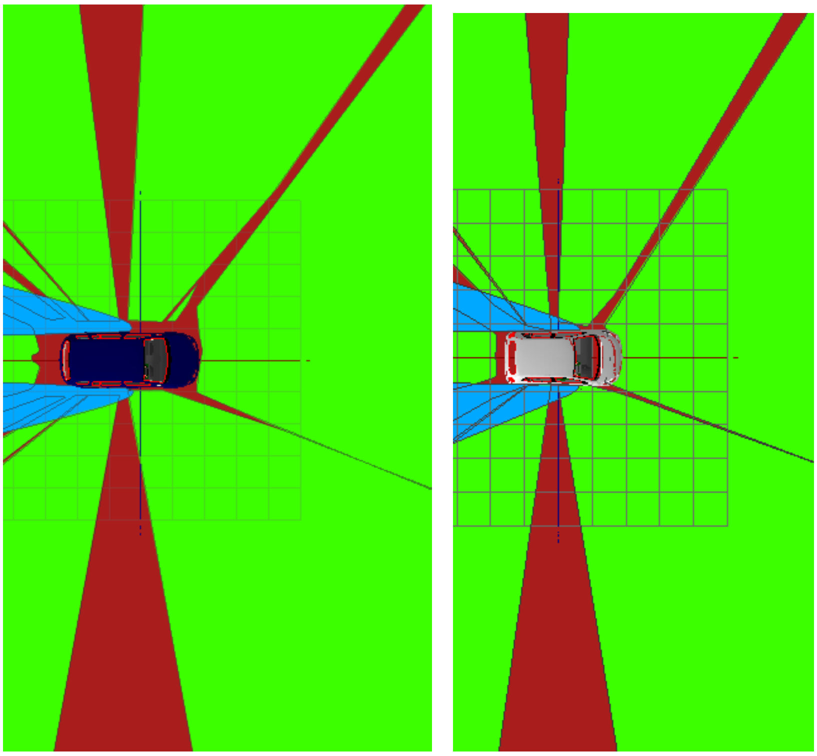

Figure 421. The similarity of the Touran and i10 blind spots

Blind spot awareness is part of driver training and so all drivers should be looking to manage blind spots in a particular vehicle. The evaluations performed showed that all blind spots identified that are attributed to A or B-pillar obscuration could effectively be eliminated by altering the posture and thus eye-point of the driver and essentially 'looking around' the pillar. However, other contributory factors such as tiredness, the driver being in a hurry, busy road conditions with lots of visual demand, other distractions such as passengers, etc. could all lead to the driver failing to check the blind spot. Thus, any solutions that could limit the effective blind spot would be helpful in maximising the driver's field of view and thus minimising the impact of any blind spots.

Solutions are limited to this particular issue. Ideally pillars would be designed to be non-existent, transparent, or as slim as possible such as those proposed in the Volvo Safety Concept Car (Figure 422 and Figure 423).

Figure 422. The webbed A-pillar of the Volvo SCC (courtesy of volvocars.com)

Figure 423. The curved interior B-pillar of the Volvo SCC (courtesy of volvocars.com)

However, crash testing requirements and standards for occupant safety place significant structural demands on the pillar structure and alternative configurations whilst showcased in concept vehicles have yet to appear in mainstream designs.

Whilst it is not possible or practical to recommend a target size of pillar, manufacturers should be made aware of the importance of this area to primary as well as secondary safety. They should be encouraged to seek solutions in engineering and materials design with a view to reducing pillar size and should ensure that treatments in this area such as darkened screen edges do not exacerbate the problem of A-pillar obscuration.

An alternative solution that is available for aftermarket fitment is the Serravista A Pillar System[12]. This adhesive lens is placed on the windscreen adjacent to the A-pillar and works to decrease the obscuration caused by it by bending light using microscopic prisms. Its usability and suitability across a range of drivers was not assessed within this project and so comment regarding its performance cannot be made. Further investigation via validated usability testing is required.

[12] http://www.bendinglight.co.uk/serraview_APS.asp

4 WORK PACKAGE 3: M_1 & M_2 REAR FIELD OF VIEW – VISIBILITY OF REAR OBSTACLE

4.1 Aim

The aim of this Work Package is to investigate and understand the rearward field of view obscuration issues for category M_1 and M_2 vehicles. The DHM analysis will consider both direct and indirect vision and investigate the latter with reference to the relevant legislative requirements.

4.2 Rationale

There is a perception that the current standard for rearwards visibility for category M_1 and M_2 vehicles may allow for a vehicle design to comply with the standard but not actually provide an adequate field of view in close proximity to the rear of the vehicle. It is therefore important to evaluate the driver's view of the rear of these categories of vehicle with reference to a specified minimum height of object which is required to be visible to the driver.

4.3 Task 1: Digital human modelling

Following a similar approach to the previous Work Package, DHM was performed using the SAMMIE system for a specific evaluation of the direct and indirect field of view to the rear of category M_1 and M_2 vehicles. These evaluations use a combination of targets including a 1.1m high target as required by ISO/TR 12155 which defines the requirements for obstacle detection for commercial vehicles.

The DHM evaluation includes the following:

1. Two appropriate vehicles identified (including one M_1 and one M_2).
2. The capture of 3d data from these vehicles.
3. CAD Modelling of the vehicles and the building of mirrors.
4. The CAD models were then analysed to determine the rearward visibility from the vehicle including the height of the lowest visible target (e.g. a child's head). This evaluation was performed using a suitable range of size of human model to represent the variability of the European driving population (smallest female

capable of driving the vehicle to 99^{th}%ile Dutch male i.e. tallest European population).

4.3.1 Evaluation vehicles

The vehicles selected for the DHM evaluations included:

- M_1: a current (2010 on) model Volkswagen Touran – this MPV style vehicle is based upon the current Golf VI platform, shown in Figure 424 A-C.
- M_2: a current (2006 on) model Ford Transit in long wheelbase mini-bus configuration, shown in Figure 425 A-C.

Figure 424A. Volkswagen Touran MPV

Figure 424B. Volkswagen Touran MPV

Figure 424C. Volkswagen Touran MPV

Figure 425A. Ford Transit Minibus

Figure 425B. Ford Transit Minibus

Figure 425C. Ford Transit Minibus

4.3.2 Methodology

The Transit was scanned, and imported in the SAMMIE system using the protocol defined in Section 3.4.1. The Touran (which was reused from Work Package 2) had Class I and III mirrors fitted and the Transit had Class I, II and IV mirrors fitted. (Small Class IV mirrors were integrated into lower portion of the Class II mirror housing). There was no Class V mirror. Both vehicles had front, side and rear windows as shown.

The evaluation methodology consisted of evaluating direct vision through the glazed areas of the vehicle together with indirect vision through the mirrors available on each vehicle. The eye point used for the evaluations was determined using the protocol defined in Section 3.4.2.

The evaluation was completed with two 'driver' human models (see Table 28). The human models used consisted of both the largest and smallest people capable of driving the vehicle as per WP 2. The human models able to 'fit' the vehicles with a realistic driving posture are shown in the table below. The human models used for the Touran were as per WP2.

	Category M_2 and M_1 vehicles	
	Ford Transit	Volkswagen Touran
Largest Driver	99%ile Dutch male	99%ile Dutch Male
Smallest Driver	5%ile UK female	35%ile UK female[13]

Table 28. Human models used in the evaluations of WP 3

The initial evaluative setup assesses the direct visibility of two configurations:

- A: 4 raised target markers 1100mm high and spaced 400mm inboard of either outside edge of the vehicle, in two rows, 600mm and 1600mm rearwards of the vehicle according to ISO/TR 12155
- B: 1 wall-like target directly behind the vehicle as a tool to identify the height of a visible target that may represent a small child, or other fixed obstacle. The target is 5m wide and is centred to be equidistant either side of the mid plane. Its initial height is 1000mm and will be increased to determine minimum requirements.

For both of the configurations above, visibility is assessed both ideally and in a real world sense that takes into account obscurations from passengers, interior fittings etc. In addition visibility metrics defined such as the height of an obstacle visible through the obstructed rear window, are provided in both an absolute value e.g. 1.4m and also a relevant target measure for context such as the 5%ile stature of a 14yr old UK male.

[13] See Section 3.4.4 for further information.

The evaluation also includes a number of assessments of indirect visibility for the relevant Classes of mirrors fitted to the vehicles compared of the field of view specified in standards ECE46-01,ECE46-02, 2003/97/EC and FMVSS111. This comprises a plot on the ground plane representing the field of view taken from the eye point of the assessed human through the relevant mirror compared visually to a zone corresponding to that described in the relevant standard.

4.4 Task 2: Analysis and write-up

4.4.1 M_2 – Ford Transit minibus

4.4.1.1 99th %ile Dutch male

4.4.1.1.1 Direct vision – human's view

The posture adopted to gain an appropriate rearward view is shown in Figure 426 below. Figure 427, Figure 428, Figure 429, Figure 430 and Figure 431 show the two evaluative configurations.

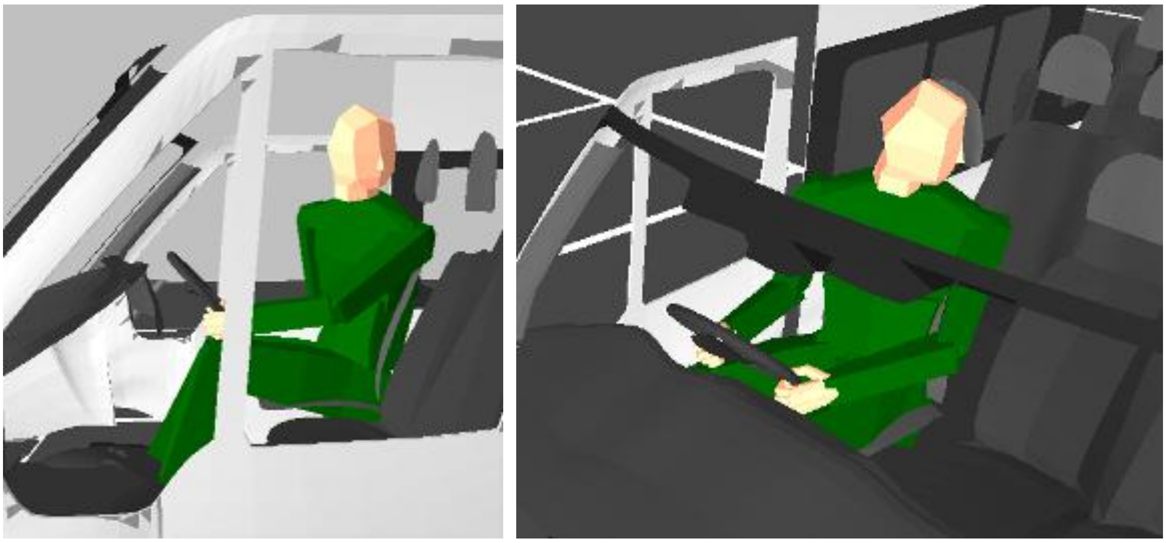

Figure 426. Rearwards view posture (99th%ile Dutch male)

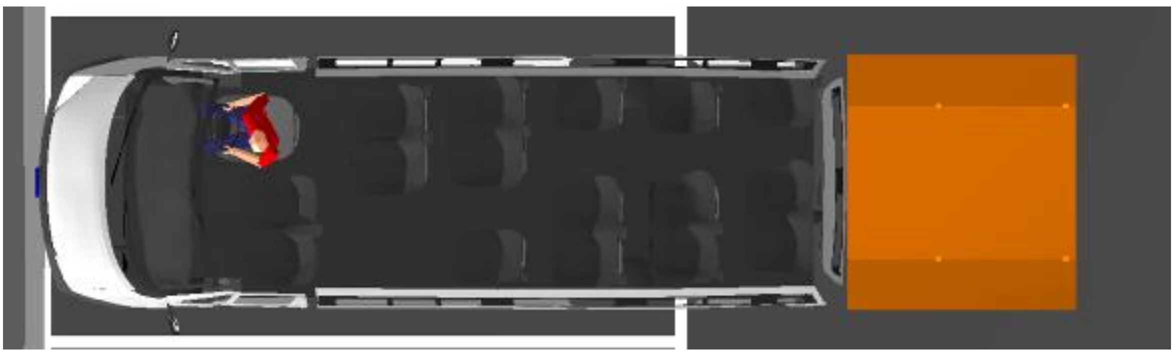

Figure 427. Rearwards visibility test A for 1100mm rearwards target (plan view)

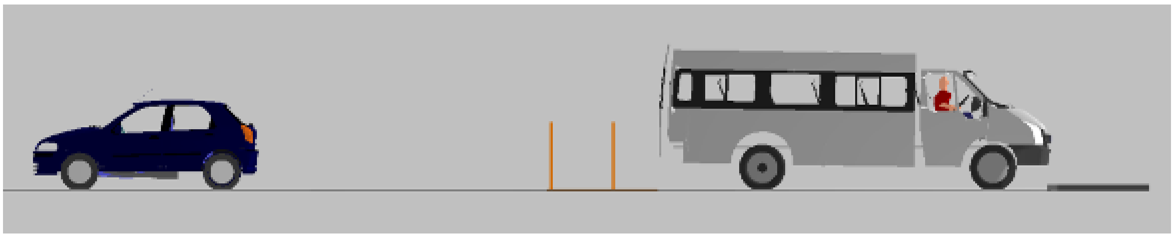

Figure 428. Rearwards visibility test A for 1100mm rearwards target (side view)

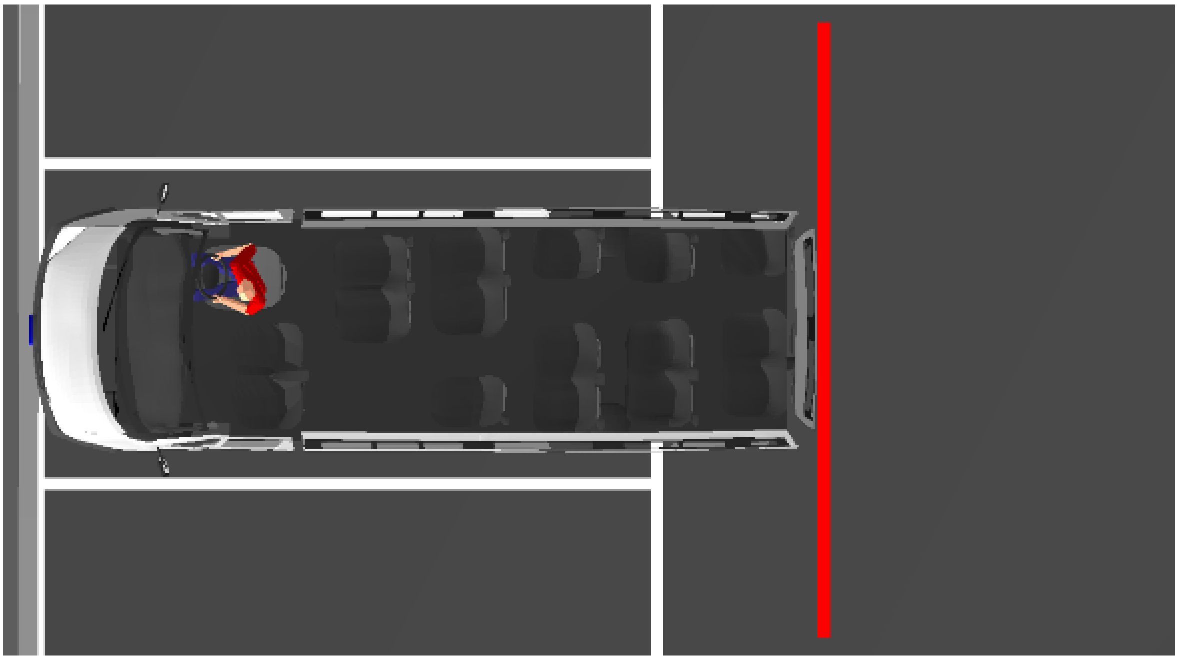

Figure 429. Rearwards visibility test B for 1000mm rearwards target (plan view)

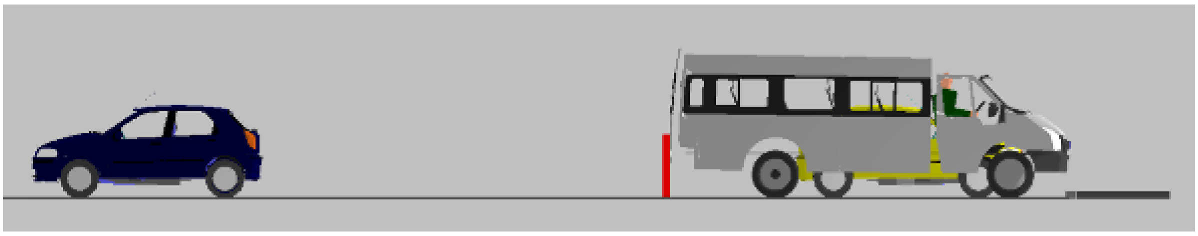

Figure 430. Rearwards visibility test B for 1000mm rearwards target (side view)

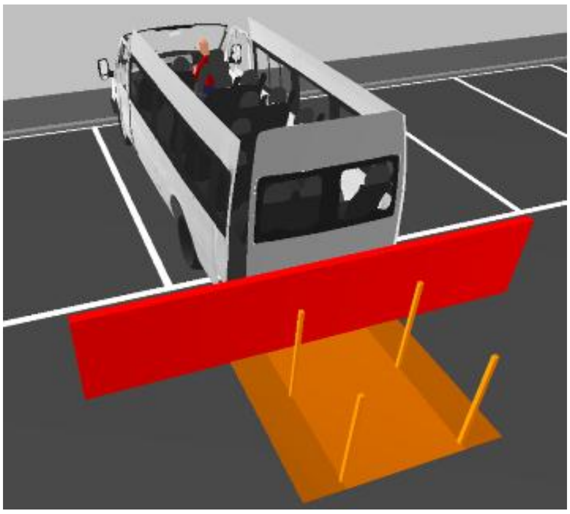

Figure 431. Rearwards visibility tests A and B located behind the vehicle.

Figure 432. 1m Rearwards visibility with occupants (head restraints at highest setting)

Figure 432 shows the direct rearwards view, for an occupied vehicle with the head restraints all set to their highest, is almost completely obscured. A small amount of the nearside is visible through the side windows. Target A and B are both fully obscured.

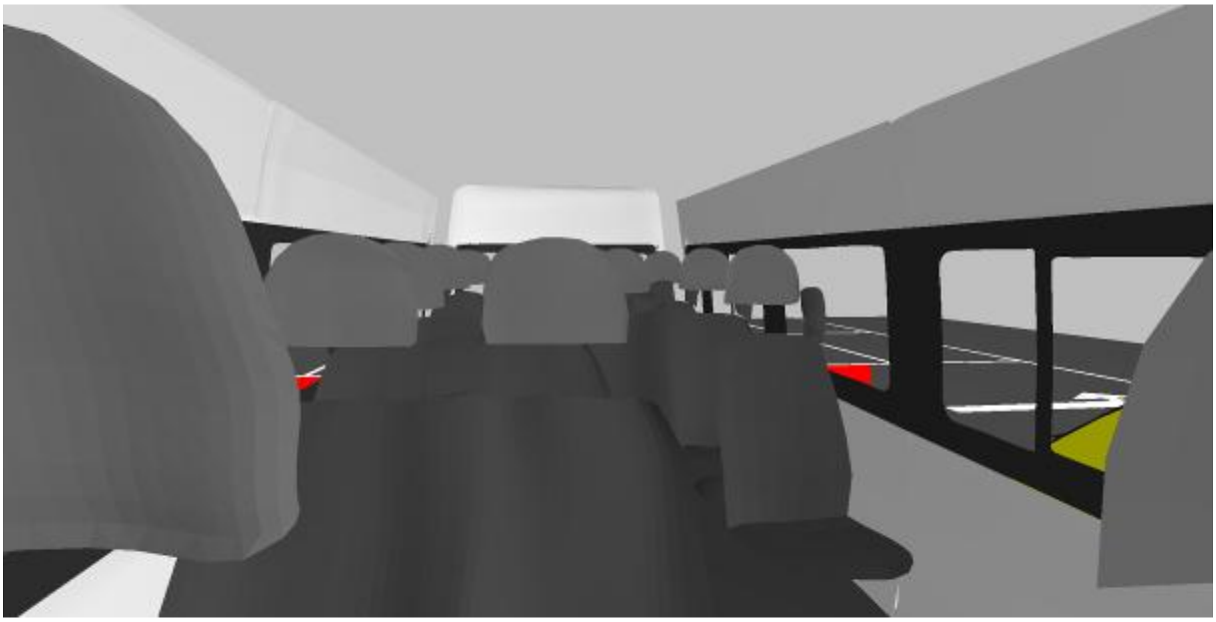

Figure 433. 1m Target Rearwards visibility unoccupied (head restraints at highest setting)

Figure 433 shows the direct rearwards view, for an unoccupied vehicle with the head restraints all set to their highest, is also almost completely obscured. An increased area of the nearside is visible through the side windows. None of target A is visible.

A very small amount of target B is visible at either end. It is likely that seatbelts and other areas of uncaptured geometry would effectively mean that target B is again largely obscured.

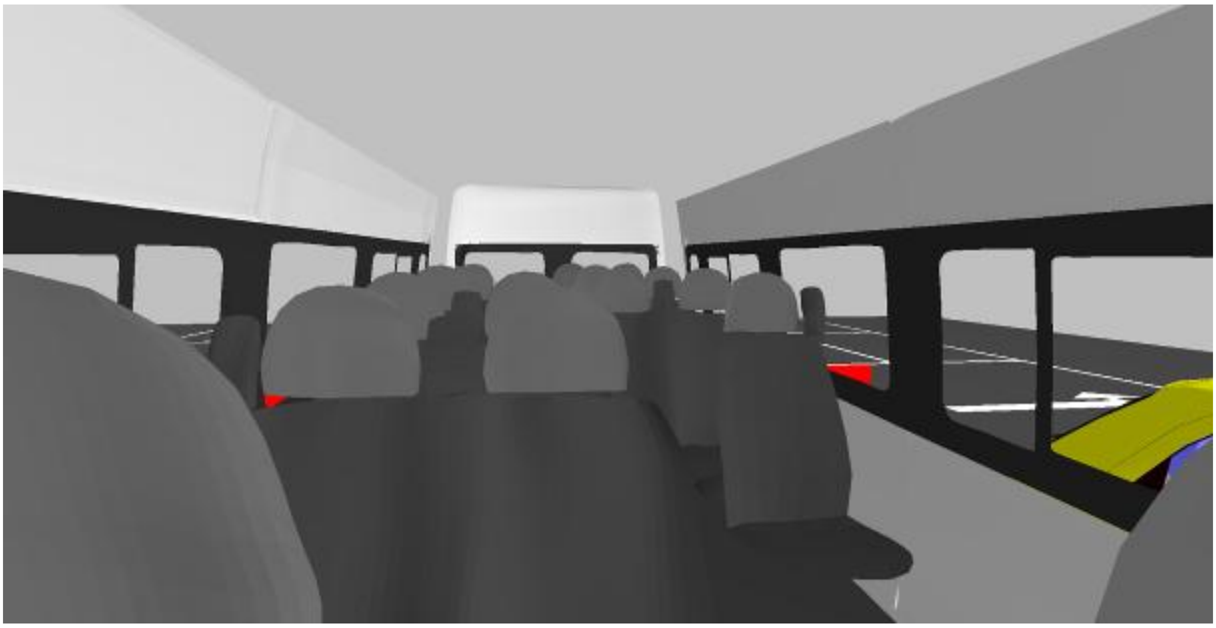

Figure 434. 1m Target Rearwards visibility unoccupied (head restraints at lowest setting)

Lowering the head restraints increases rearwards visibility but only by a relatively small amount. An increased amount of both the nearside and offside is visible in Figure 434. In addition the driver can now see out of the rear windows. This reduction has no appreciable difference on the visibility of either target A or B.

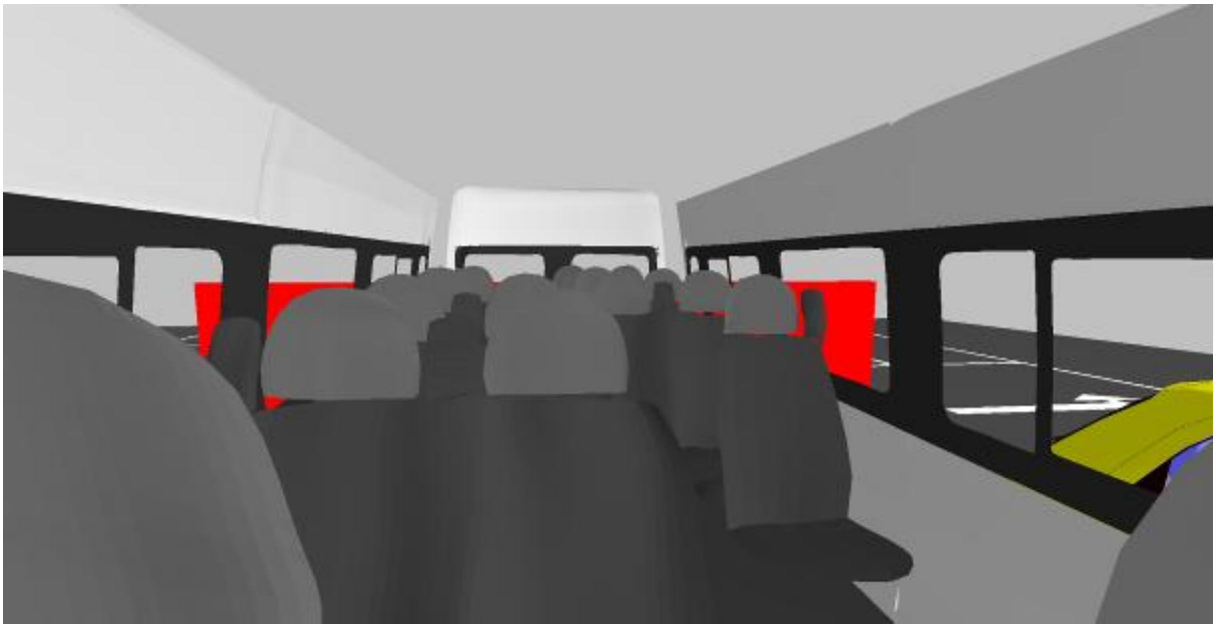

Figure 435. 1.7m Target Rearwards visibility unoccupied (head restraints at lowest setting)

Figure 435 above shows the height of target B required to be viewed directly out of the rear windows. This requires a target of 1700mm in height, equivalent to a 22nd %ile UK male. However, the amount of visible area of the target is negligible and it is unlikely that anything would actually be recognisable from this level of view.

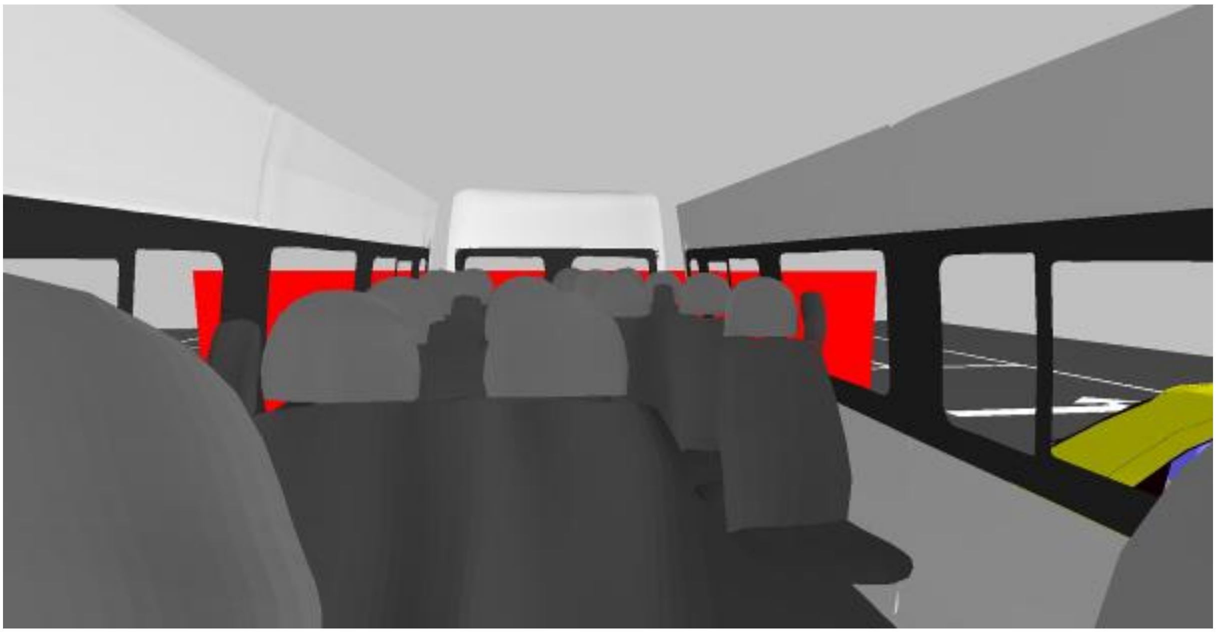

Figure 436. 1.8m Target Rearwards visibility unoccupied (head restraints at lowest setting)

Increasing the target height to 1800mm, equivalent to a 74%ile UK male, begins to provide a view in which a target may be recognisable out of the rear windows. At this level a target to the rear quarters, at least 500mm outside of either side of the vehicle would be visible (Figure 436).

Figure 437. 1.8m Stature person (74%ile UK Male) rearwards of the vehicle

Figure 438. 1.8m Stature person (74%ile UK Male) rearwards of the vehicle

In a practical test, a human with a stature of 1800mm (74%ile UK male) is barely visible out of the rear of the vehicle (Figure 438).

Figure 439. 1.912m Stature person (99%ile UK Male) rearwards of the vehicle

Figure 439 shows a 99%ile UK male (1912mm stature) visible in the rear windows. This gives an indication of maximum visibility possible in this configuration.

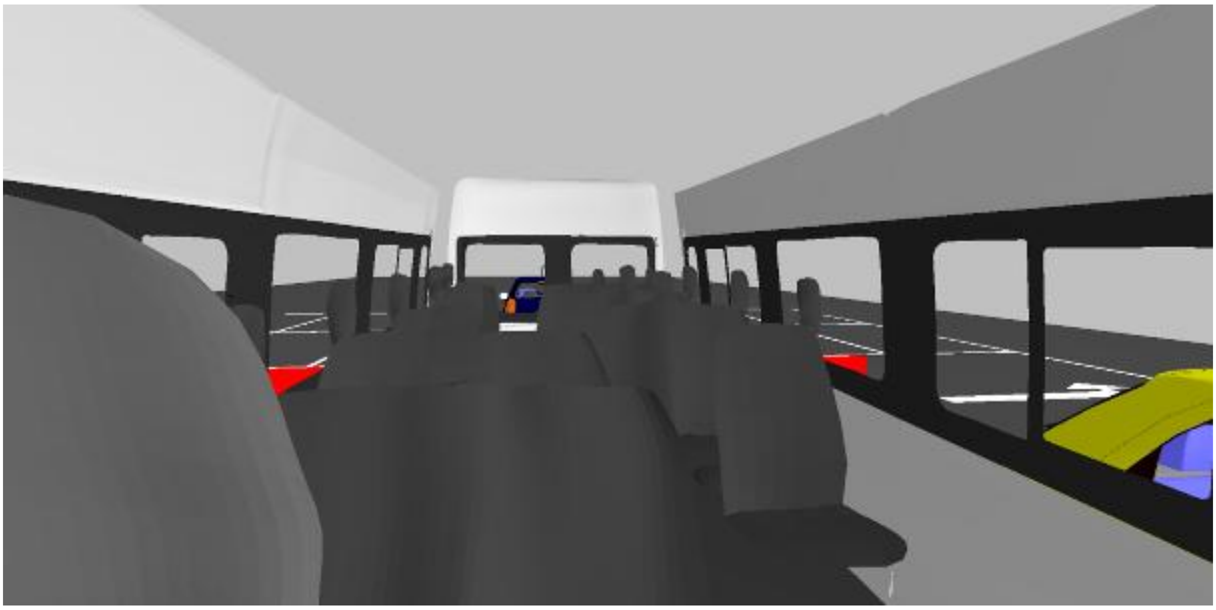

Figure 440. Rearwards view of targets with head restraints removed

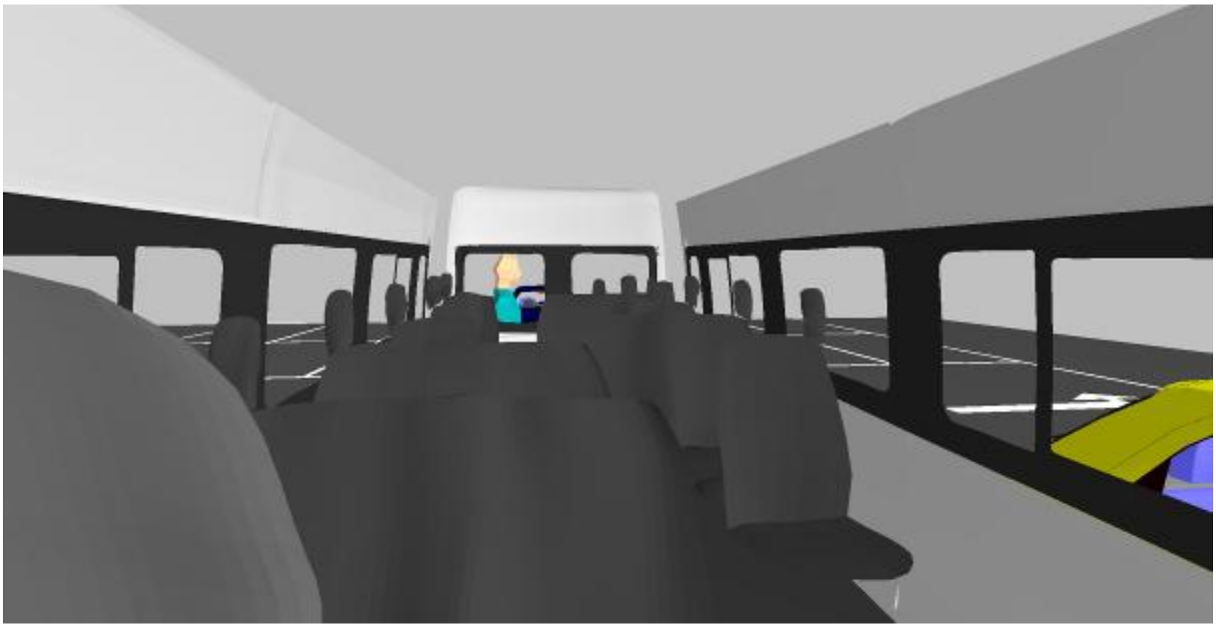

Figure 441. Rearwards view of human with head restraints removed

Whilst the head restraints are an important safety feature it is interesting to evaluate their impact on the rearwards visibility. Removal of the head restraints increases rearwards visibility significantly. However, full visibility from the rear windows is still not possible. In one area on the offside rear window, visibility is possible from 1400mm vertically upwards (Figure 440). Even in this configuration both targets A and B are not visible directly to the rear (Figure 441).

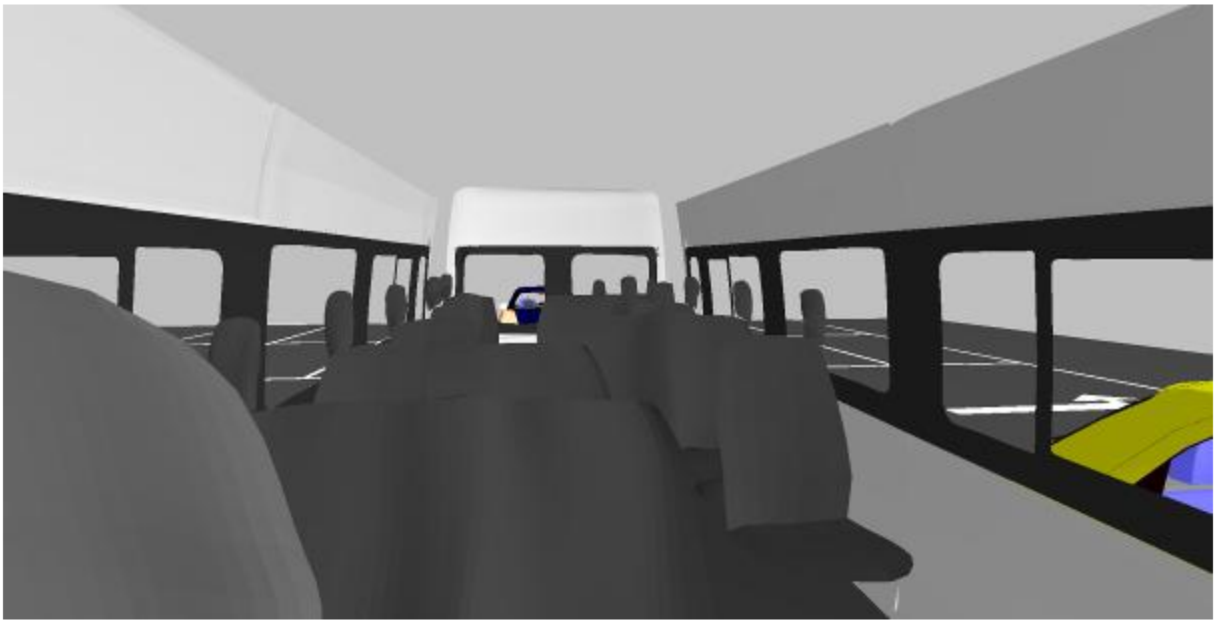

Figure 442. 1.47m Stature person (1%ile UK Female) rearwards of the vehicle (head restraints removed)

Figure 442 shows that it is possible to see a 1%ile UK female from the rear of the vehicle in this configuration. This is also equivalent to a 5%ile 14 year old UK female (1480mm).

4.4.1.1.2 Direct Vision – Volume Projections

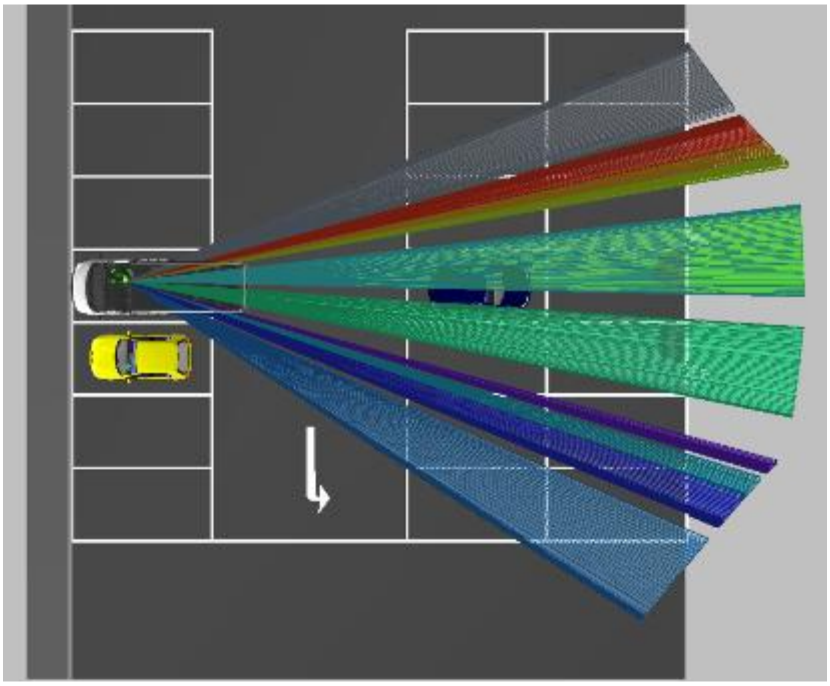

Figure 443. Rearwards view volume projections

The volumetric projection of rearwards visibility in Figure 443 shows a largely symmetrical field of view extending both rearwards and to both near and offside at approximately 30 degrees.

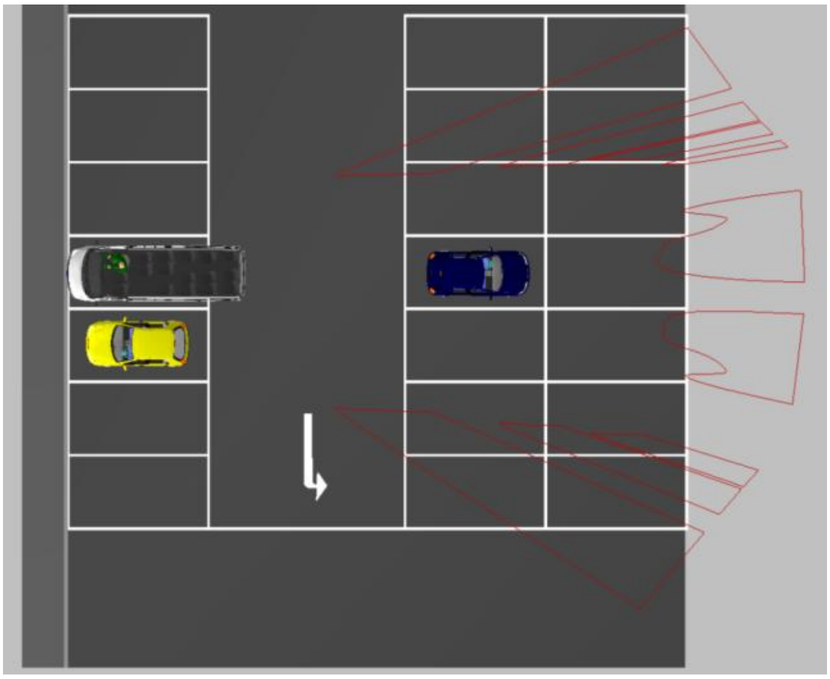

Figure 444. Rearwards view plane projections (ground plane)

Figure 444 shows the theoretically visible areas rearwards of the vehicle on the ground plane. Even in this idealised format, where the impact of any internal obscurations (head restraints, seats, seatbelt mountings etc.) is negated, there is still a significant area (extending approximately 16m rearwards of the back of the vehicle) that is not visible directly to the rear.

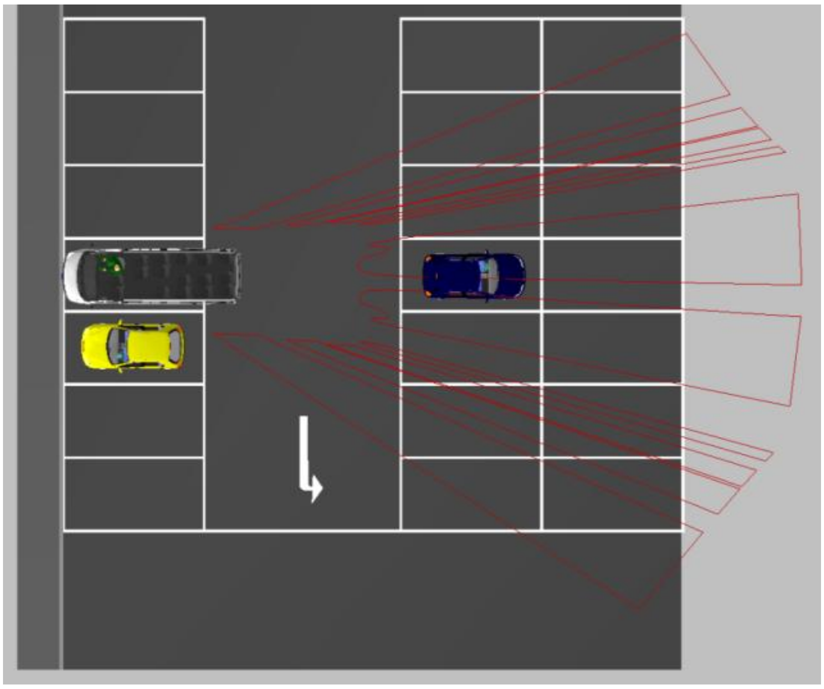

Figure 445. Rearwards view plane projections (ground plane + 1000mm)

Projecting on to a plane parallel to the ground at a height of 1m, provides a much improved area of visibility though there is still an area directly behind the vehicle that is not visible (Figure 445). This area extends approximately 4m rearwards of the back of the vehicle.

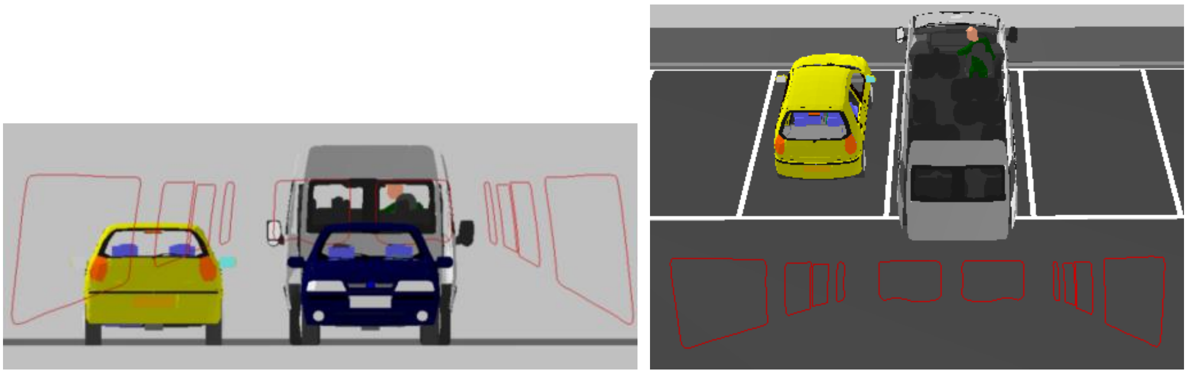

Figure 446. Rearwards view plane projections (vertical plane, rear of vehicle + 2000mm)

Figure 446 shows the projections on a plane parallel to the rear of the vehicle at 2m behind the vehicle. This provides an indication of the idealised 'windows' of visibility extending across the back of the vehicle.

4.4.1.1.3 Indirect vision

The posture adopted to gain an appropriate rearward view is shown in Figure 447 below.

Figure 447. Forwards view posture (99th%ile Dutch male)

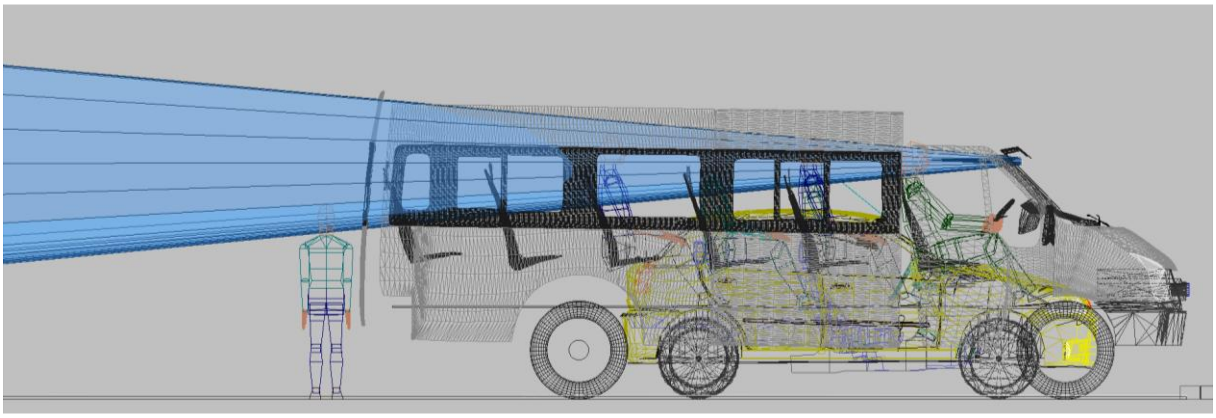

Figure 448. Idealised indirect rearwards view (Class I mirror)

Figure 448 and Figure 449 show the idealised rearwards projection of the indirect field of view from the Class I mirror. However it is also clear that the view would be obscured by internal elements in the same manner as the direct vision analysis shown earlier.

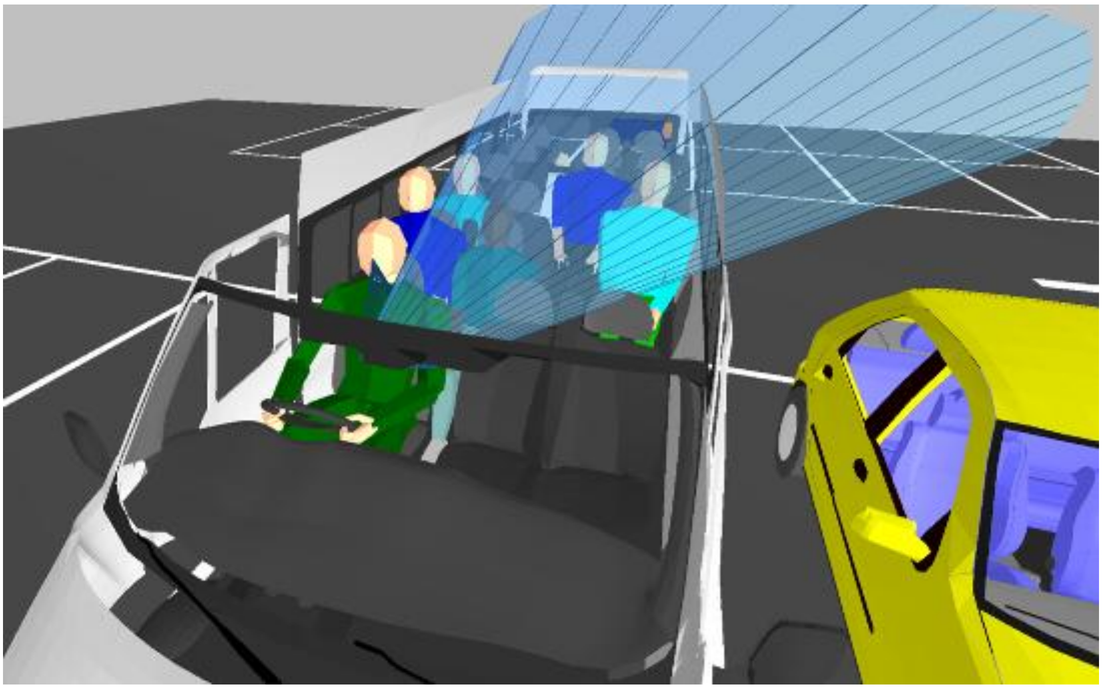

Figure 449. Idealised indirect rearwards view (Class I mirror)

For M_2 vehicles the Class I mirror is not a compulsory fitment. However, the field of view afforded by the Class I mirror in the Transit is compared here to that specified in ECE46-02 and 2003/97/EC for completeness. The idealised rearwards field of view of the Class I mirror meets or exceeds the stated requirements. Figure 450 below shows the relevant specification, with the corresponding requirements for passenger cars in FMVSS111 indicating that the ground must be visible 61m behind the vehicle, but with no overall width specified.

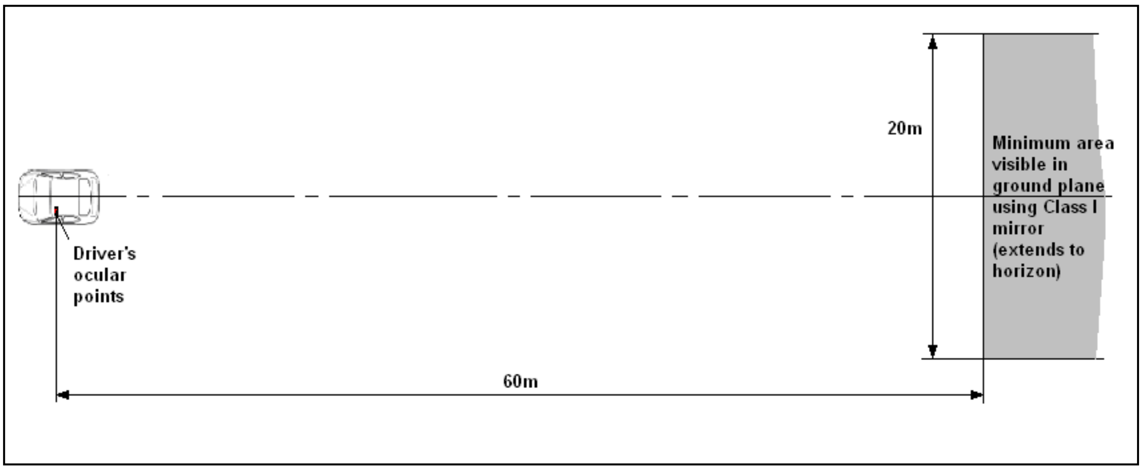

Figure 450. Minimum Field of View Specified in ECE46-02 and 2003/97/EC for Class I (Interior) Mirror

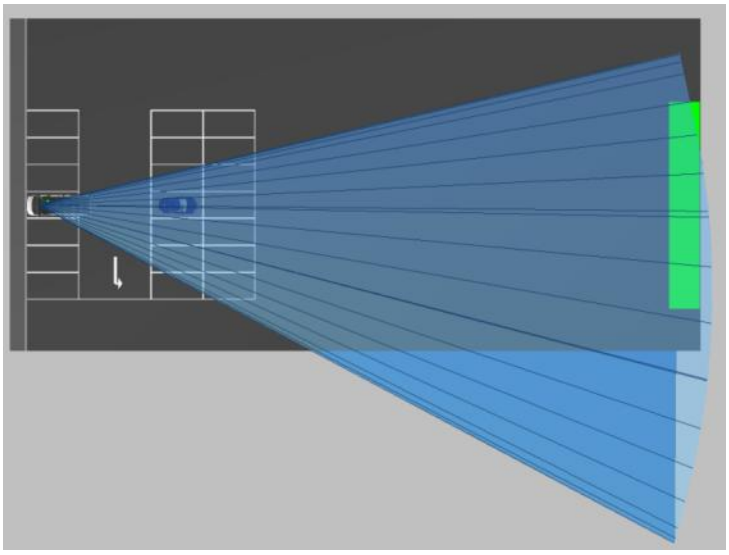

Figure 451. Idealised indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class I mirror)

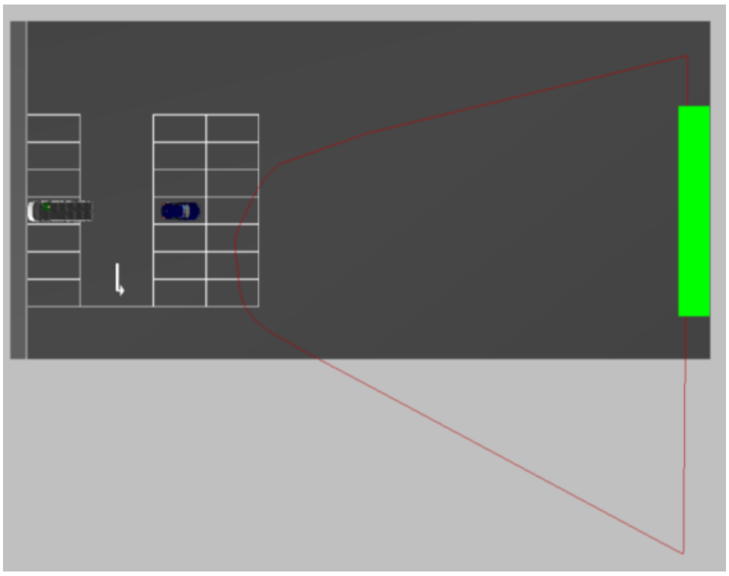

Figure 452. Idealised indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class I mirror)

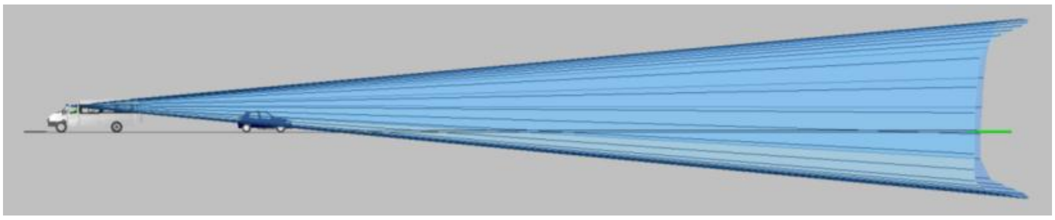

Figure 453. Idealised indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class I mirror)

Figure 451, Figure 452 and Figure 453 above show that the recommended area is clearly within the idealised projection.

In comparison to the field of view specified in ECE46-02 and 2003/97/EC (Figure 454, Figure 455, Figure 456, Figure 457 and Figure 458) the rearwards field of view of the Class II mirrors also meets or exceeds the stated requirements.

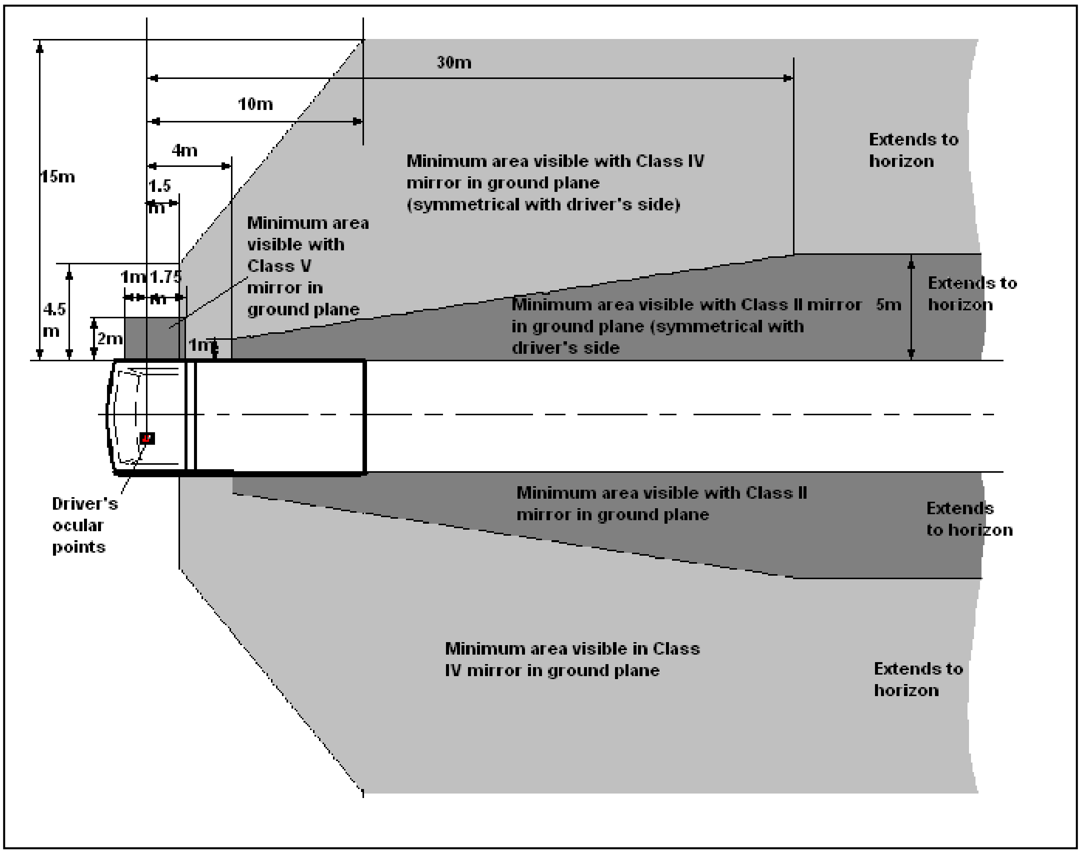

Figure 454. Overlapping Minimum Zones of Field of View for the Different Mirrors (Class II, IV and V) Specified in ECE46-02 and 2003/97/EC.

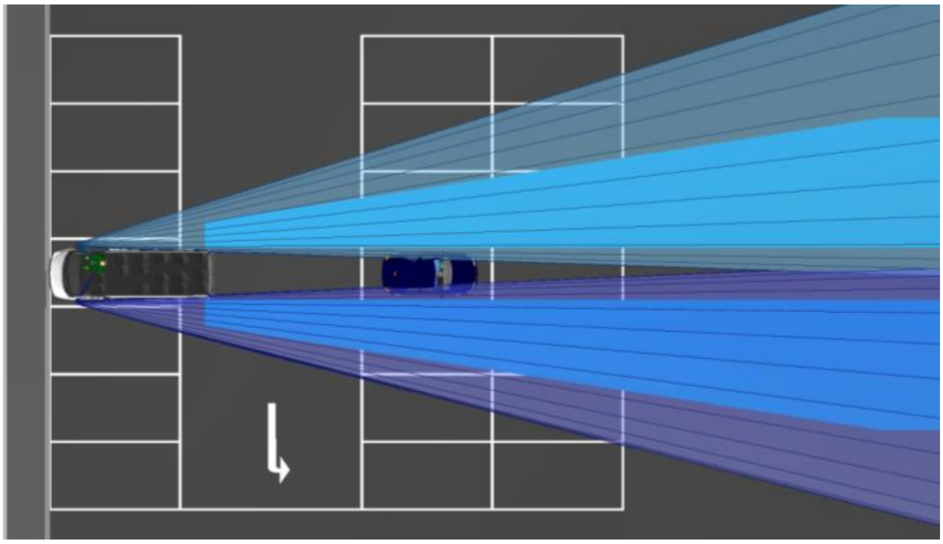

Figure 455. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class II mirrors)

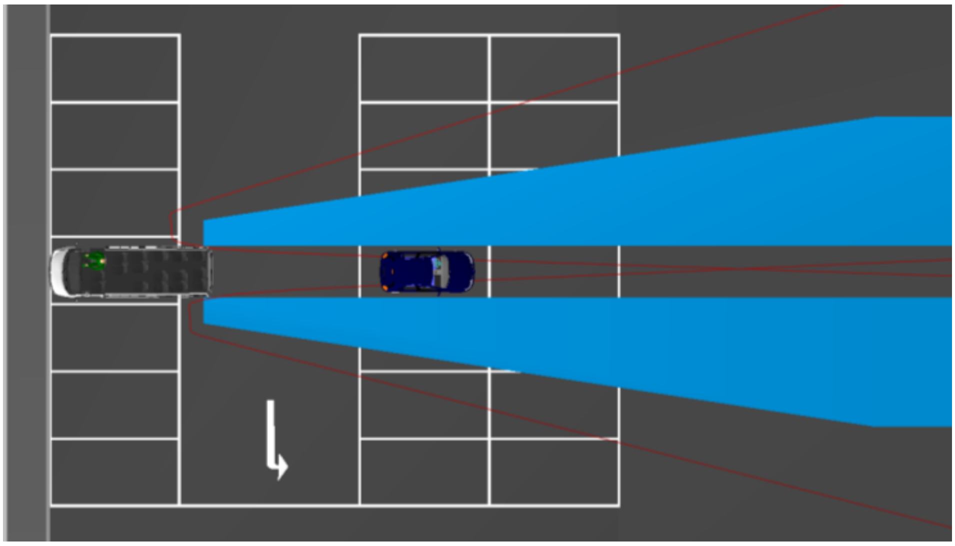

Figure 456. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class II mirrors)

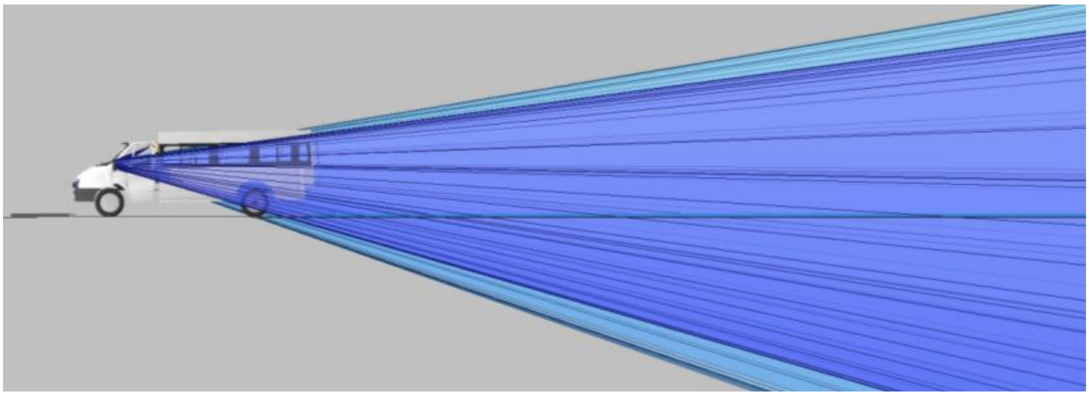

Figure 457. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class II mirrors)

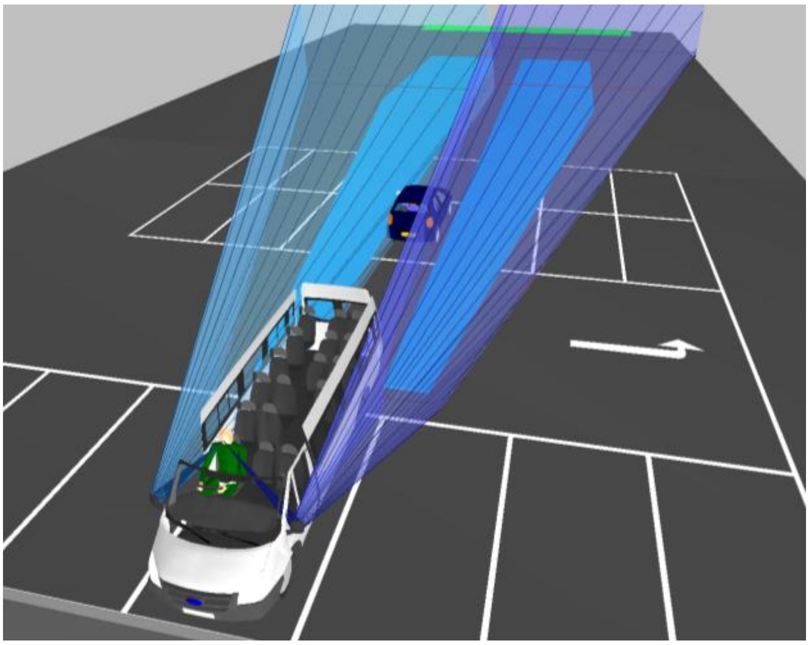

Figure 458. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class II mirrors)

In comparison to the field of view specified in ECE46-02 and 2003/97/EC the rearwards field of view of the Class IV mirrors falls short of the stated requirements (Figure 459, Figure 460 and Figure 461). However, it should be noted that Class IV mirrors are not a compulsory fitment for M_2 vehicles.

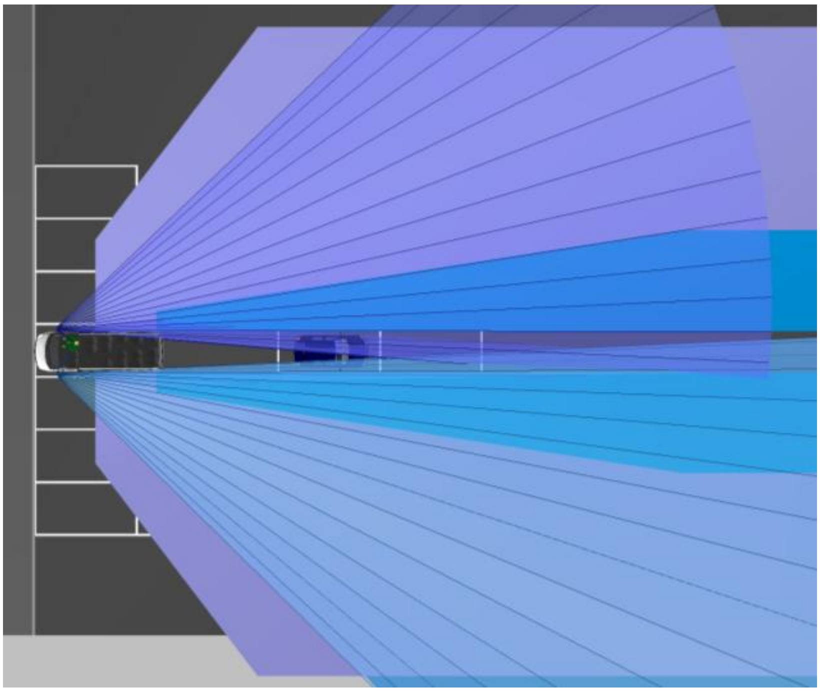

Figure 459. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class IV mirrors)

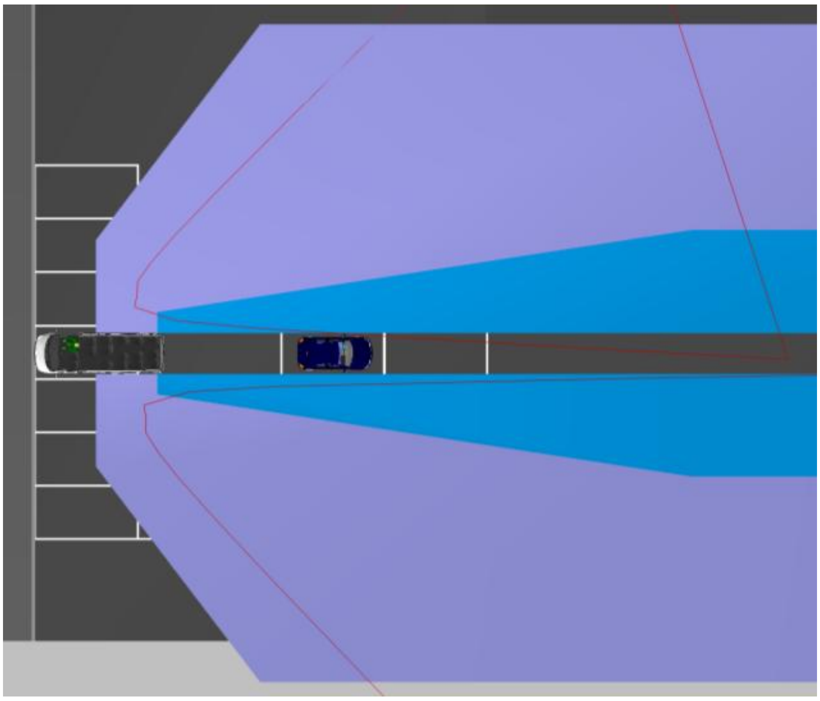

Figure 460. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class IV mirrors)

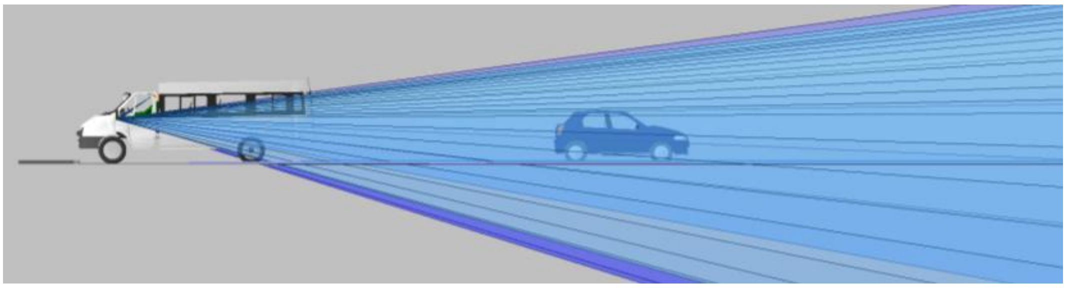

Figure 461. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class IV mirrors)

4.4.1.2 5th %ile UK female

4.4.1.2.1 Direct vision – human's view

The posture adopted to gain an appropriate rearward view is shown in Figure 462 below. The evaluative setup is as per the Dutch Male – see Section 4.4.1.1.

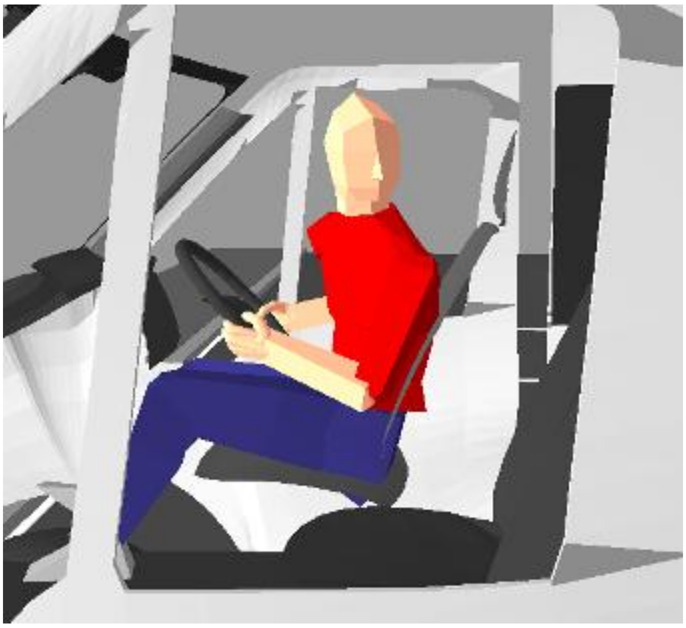

Figure 462. Rearwards view posture (5th%ile UK Female)

Figure 463. 1m Rearwards visibility with occupants (head restraints at highest setting)

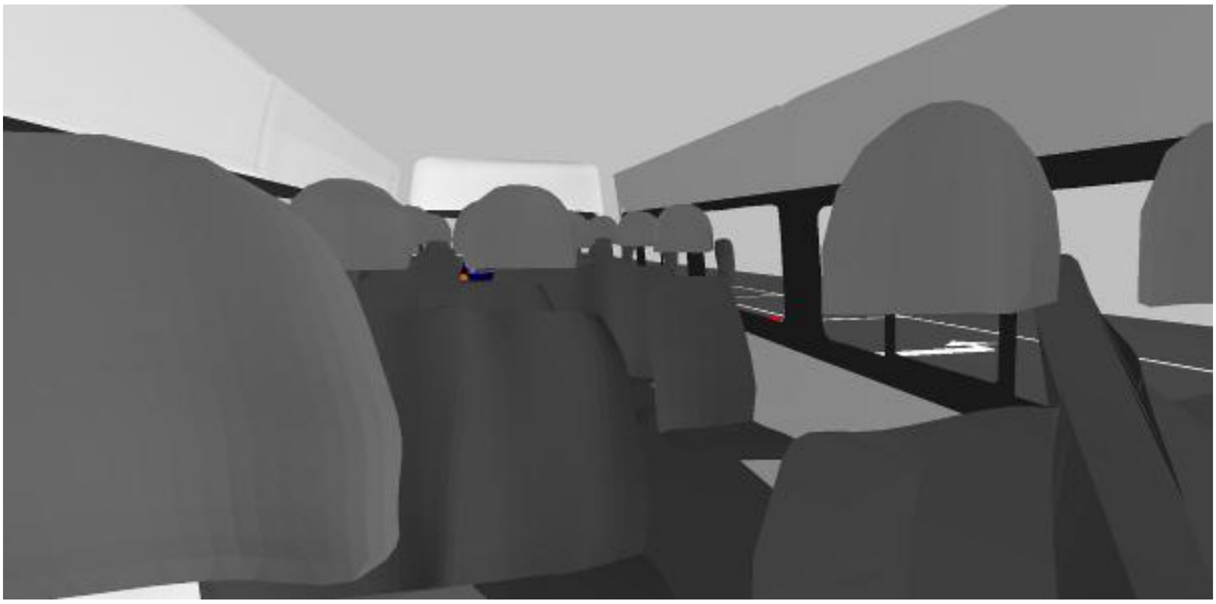

Figure 464. 1m Target Rearwards visibility unoccupied (head restraints at highest setting)

Figure 465. 1m Target Rearwards visibility unoccupied (head restraints at lowest setting)

Figure 466. 1.8m Target Rearwards visibility unoccupied (head restraints at lowest setting)

Again, target A is completely obscured (Figure 463, Figure 464, Figure 465 and Figure 466). Target B is barely visible to the nearside. Target B needs to be increased to 1800mm to be just visible through the rear windows (Figure 466 and Figure 467).

Figure 467. 1.8m Stature person (74%ile UK Male) rearwards of the vehicle

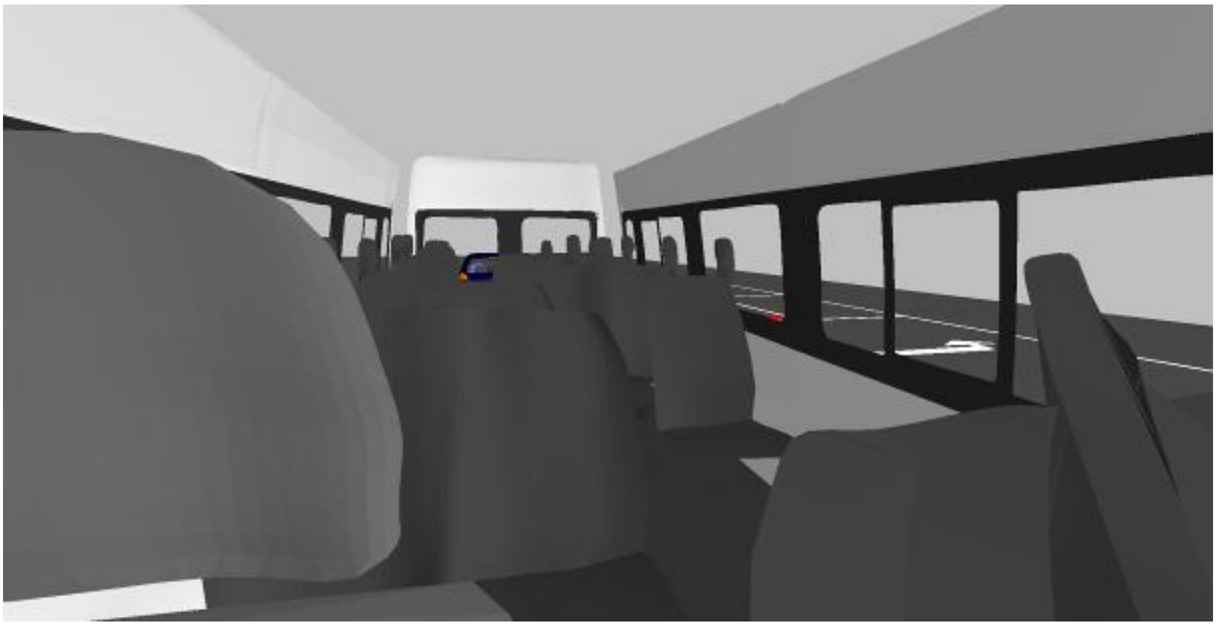

Figure 468. Rearwards view of targets with head restraints removed

Figure 469. Rearwards view of human with head restraints removed

Removal of the head restraints again increases rearwards visibility significantly (Figure 468 and Figure 469). However, full visibility from the rear windows is still not possible. In one area on the offside rear window, visibility is possible from 1400mm vertically upwards. Even in this configuration both targets A and B are not visible directly to the rear.

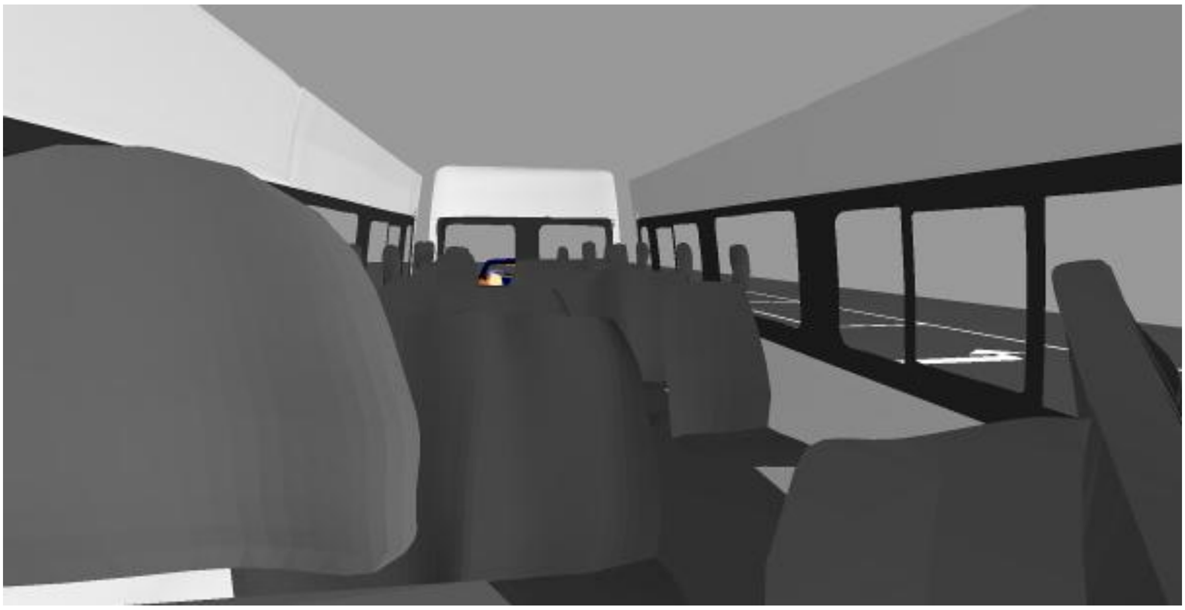

Figure 470. 1.47m Stature person (1%ile UK Female) rearwards of the vehicle (head restraints removed)

The figure shows that it is possible to see a 1%ile UK female from the rear of the vehicle in this configuration (Figure 470). This is also equivalent to a 5%ile 14 year old UK female (1480mm).

4.4.1.2.2 Direct vision – volume projections

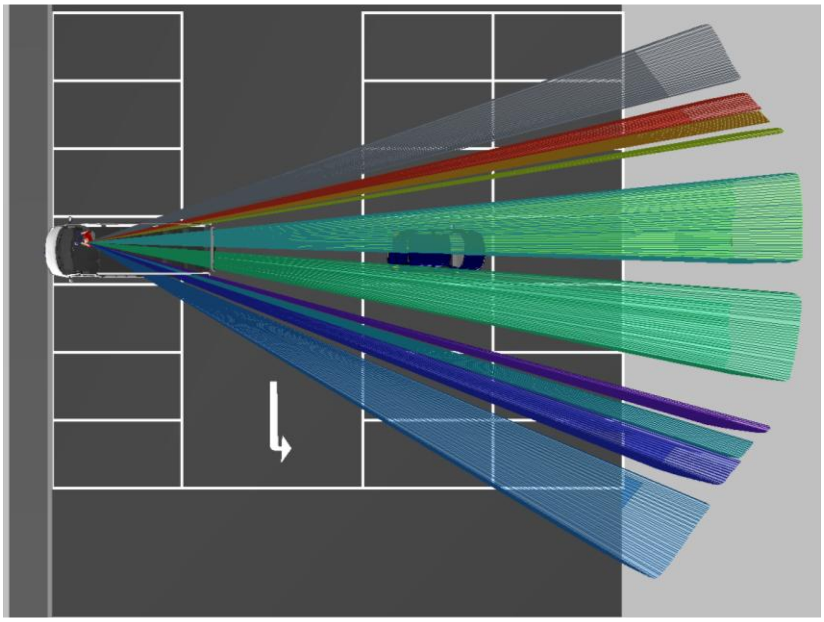

Figure 471. Rearwards view volume projections

The volumetric projection of rearwards visibility in Figure 471 shows a largely symmetrical field of view extending rearwards and to both near and offside at approximately 30 degrees.

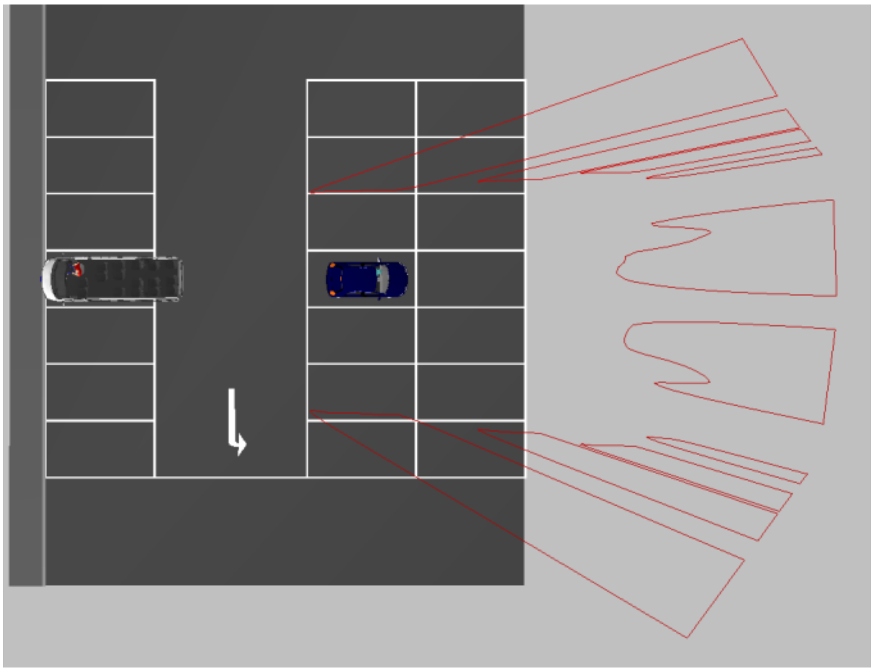

Figure 472. Rearwards view plane projections (ground plane)

Figure 472 shows the theoretically visible areas rearwards of the vehicle on the ground plane. Even in this idealised format, where the impact of any internal obscurations (head restraints, seats, seatbelt mountings etc.) is negated, there is still a significant area that is not visible directly to the rear. The size of this obscured zone extends for approximately 21m rearwards from the back of the vehicle (in comparison to 16m rearwards of the back of the vehicle for the 99%ile Dutch Male).

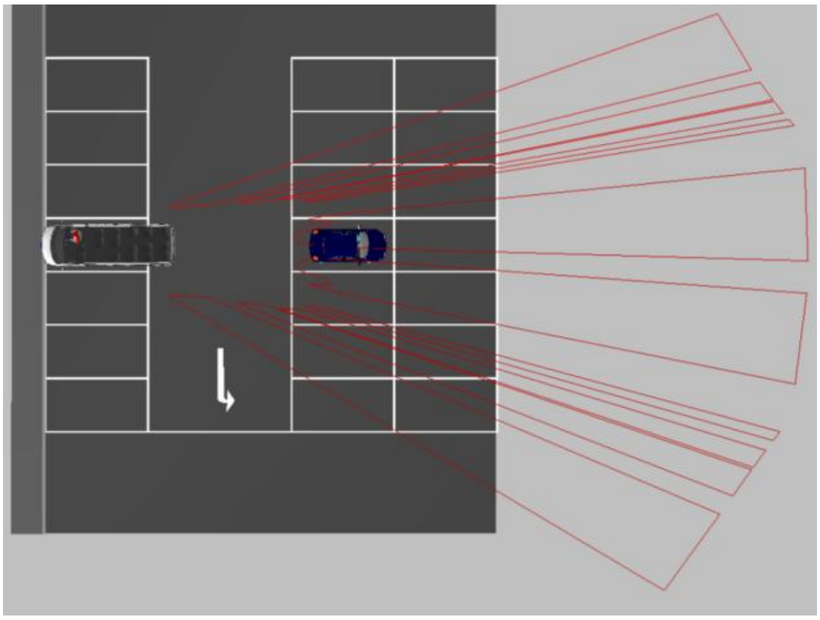

Figure 473. Rearwards view plane projections (ground plane + 1000mm)

Projecting on to a plane parallel to the ground at a height of 1m, provides a much improved area of visibility though there is still an area directly behind the vehicle that is not visible (Figure 473). This area extends approximately 5.5m rearwards of the back of the vehicle (in comparison to 4m rearwards of the back of the vehicle for the 99%ile Dutch Male).

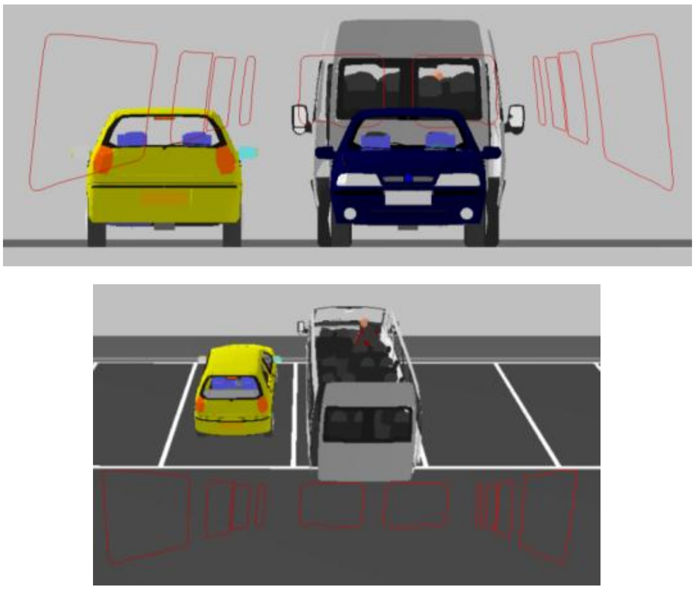

Figure 474. Rearwards view plane projections (vertical plane, rear of vehicle + 2000mm)

Figure 474 shows the projections on a plane parallel to the rear of the vehicle at 2m behind the vehicle. This provides an indication of the idealised 'windows' of visibility extending across the back of the vehicle.

4.4.1.2.3 Indirect vision

For indirect vision from Class I, II and IV mirrors the results are very similar to those of the 99%ile Dutch male. With Class I and II meeting or exceeding the standards (Figure 475, Figure 476, Figure 477, Figure 478, Figure 479, Figure 480 and Figure 481) and Class IV falling short due to insufficient width of the projection (Figure 482).

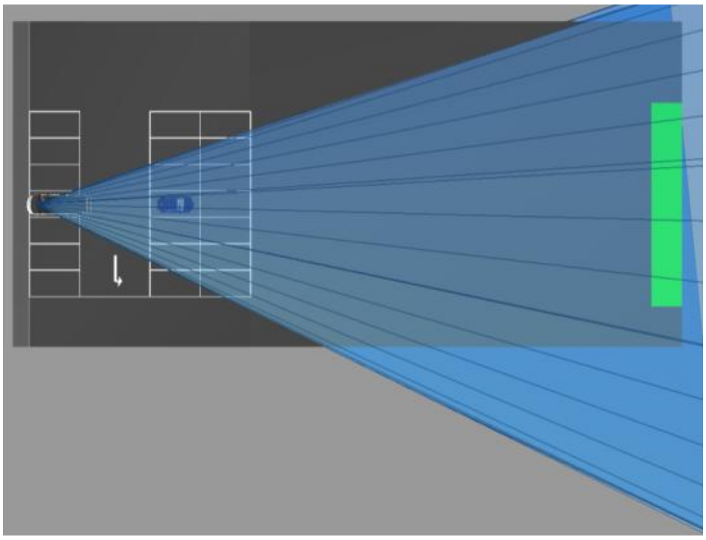

Figure 475. Idealised indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class I mirror)

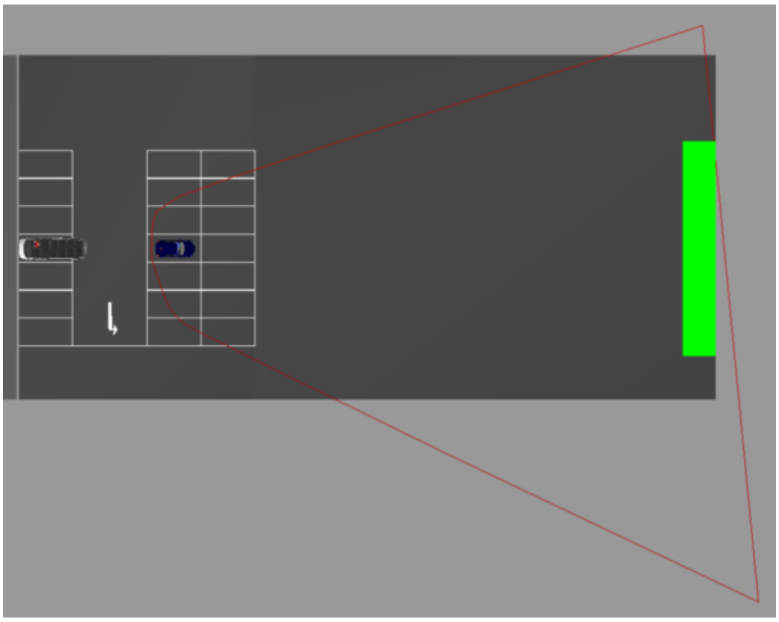

Figure 476. Idealised indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class I mirror)

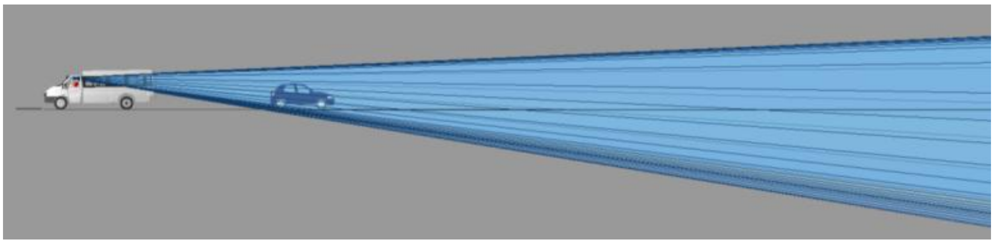

Figure 477. Idealised indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class I mirror)

Figure 475, Figure 476 and Figure 477 above show that the recommended area is clearly within the idealised projection.

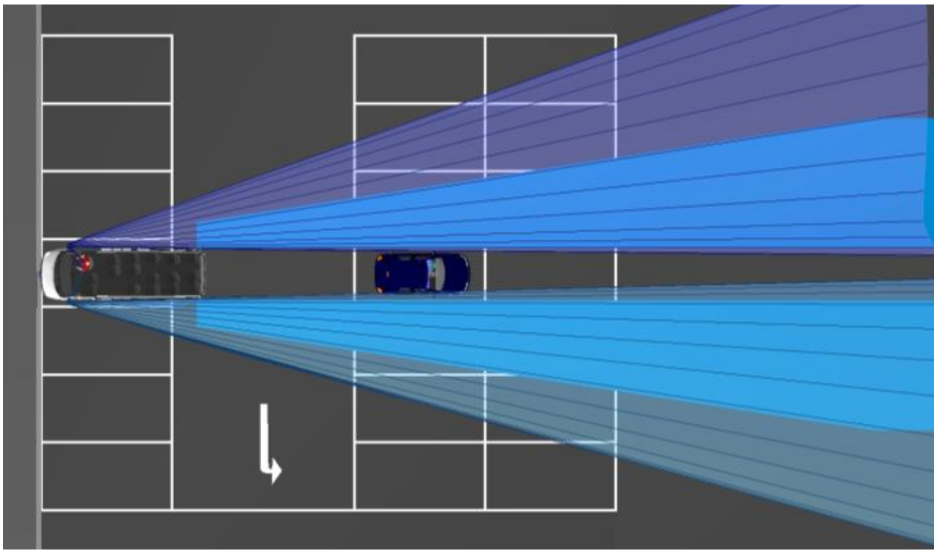

Figure 478. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class II mirrors)

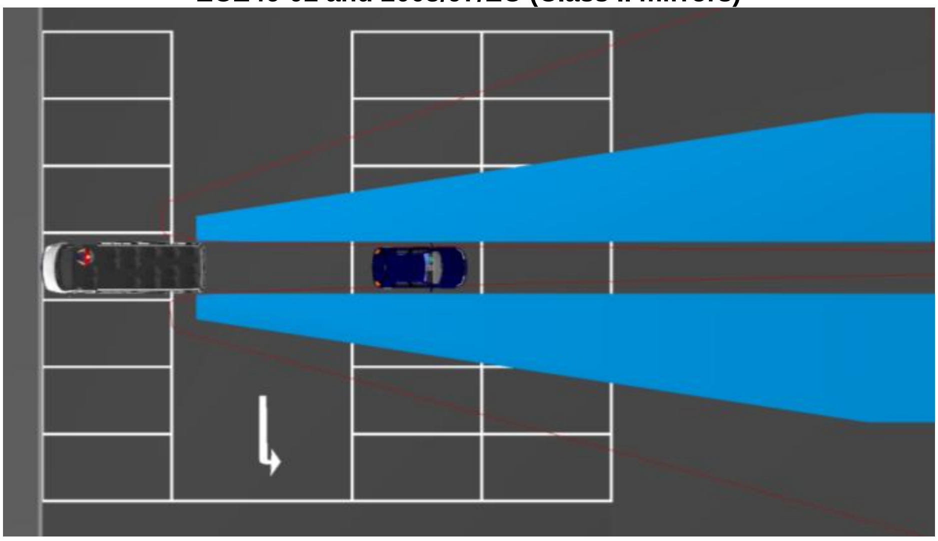

Figure 479. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class II mirrors)

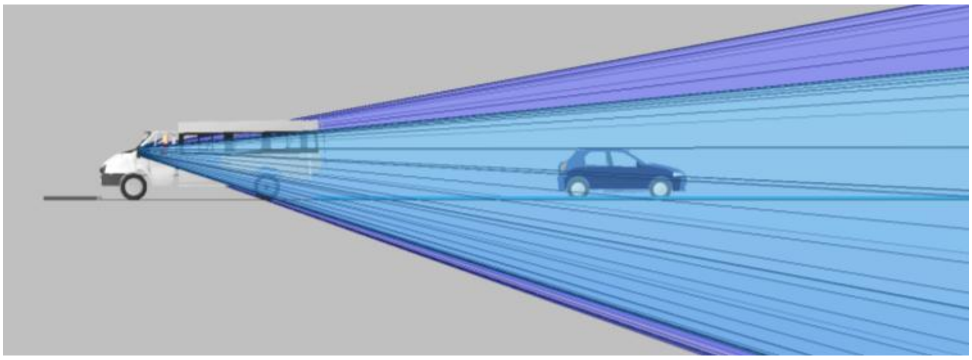

Figure 480. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class II mirrors)

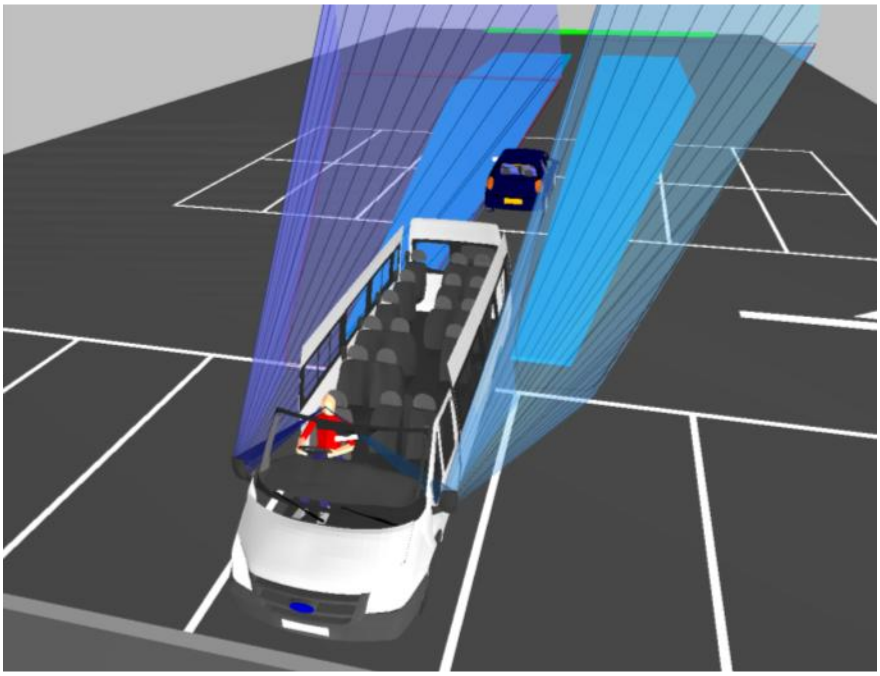

Figure 481. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class II mirrors)

From the figures it is clear to see that in comparison to the field of view specified in ECE46-02 and 2003/97/EC the rearwards field of view of the Class II mirrors also meets or exceeds the stated requirements (Figure 478, Figure 479, Figure 480 and Figure 481). Whereas in comparison to the field of view specified in ECE46-02 and 2003/97/EC the rearwards field of view of the Class IV mirrors falls short of the stated requirements (Figure 482, Figure 483 and Figure 484).

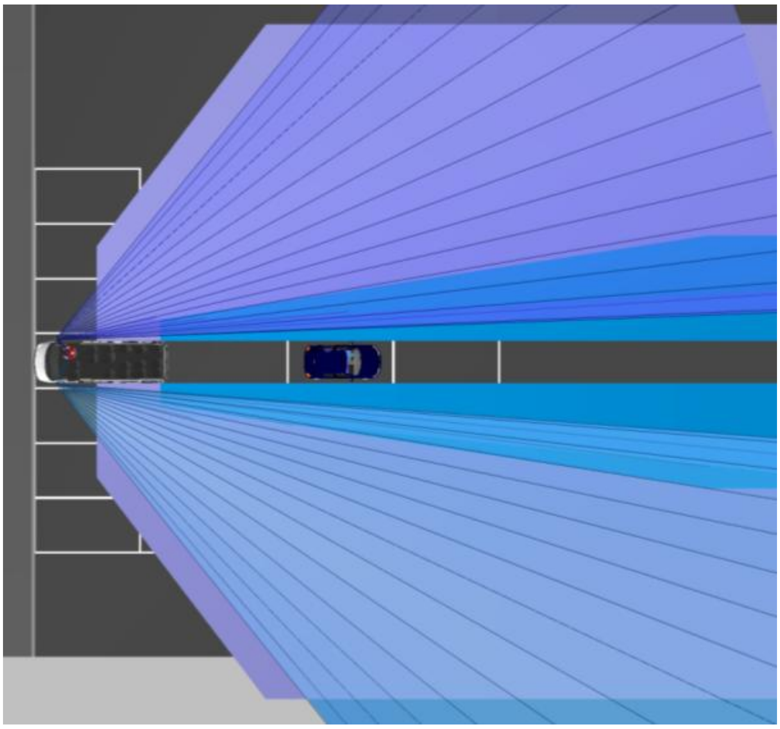

Figure 482. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class IV mirrors)

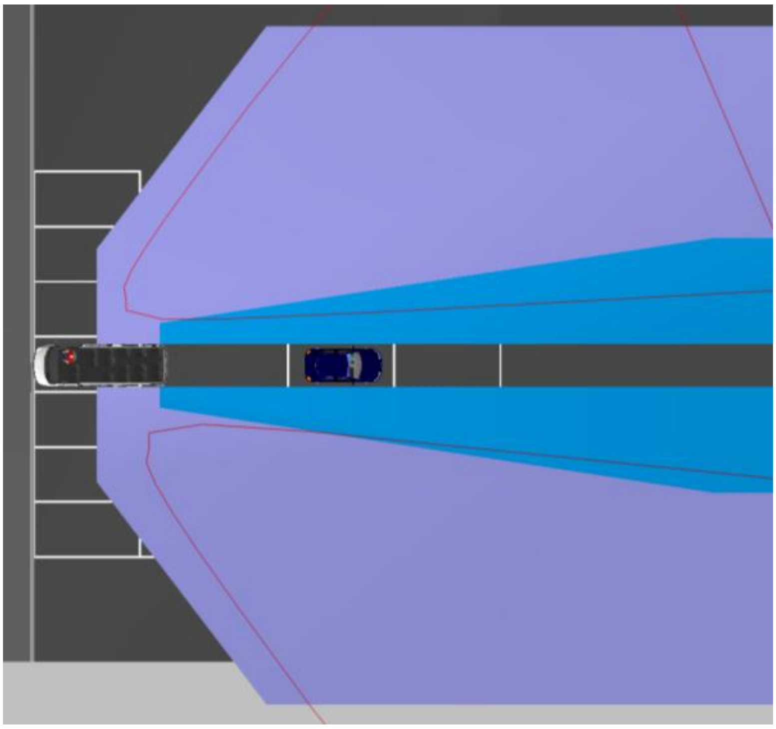

Figure 483. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class IV mirrors)

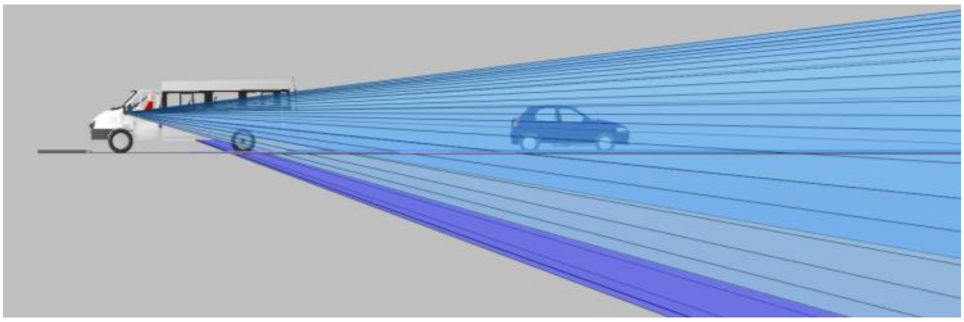

Figure 484. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class IV mirrors)

4.4.2 M_1 – Volkswagen Touran MPV

4.4.2.1 99th %ile Dutch male

4.4.2.1.1 Direct vision – human's view

The posture adopted to gain an appropriate rearward view is shown in Figure 485 below.

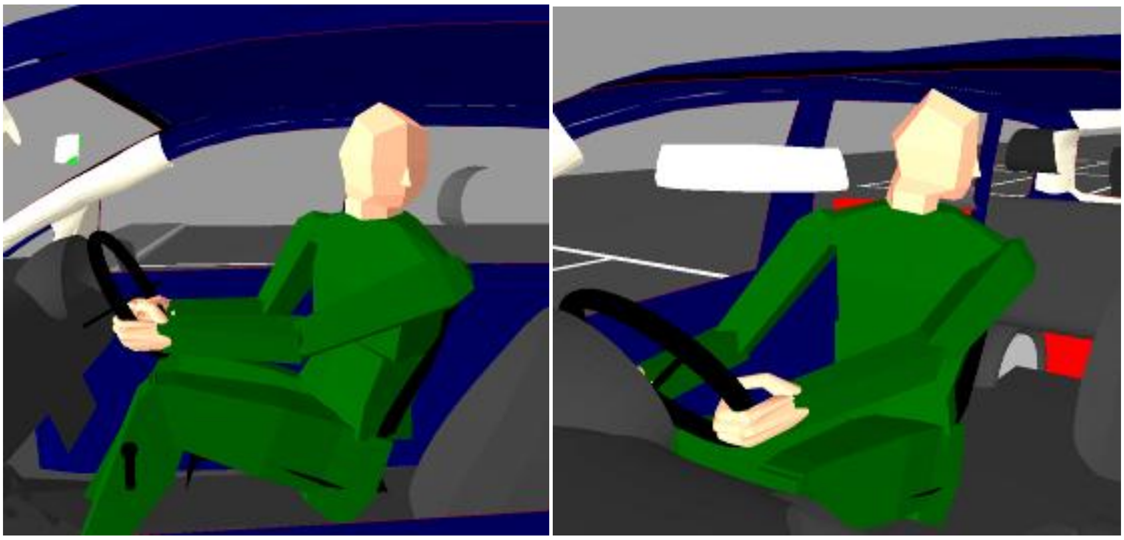

Figure 485. Rearwards view posture (99th%ile Dutch male)

The initial evaluative setup assesses the visibility of two configurations:

- A: 4 raised target markers 1100mm high and spaced 400mm inboard of either outside edge of the vehicle, in two rows, 600mm and 1600mm rearwards of the vehicle according to ISO/TR 12155, see Figure 486, Figure 487, and Figure 490.
- B: 1 wall-like target directly behind the vehicle. The target is 5m wide and is centred to be equidistant either side of the mid plane. Its initial height is 1000mm and will be increased to determine minimum requirements, see Figure 488, Figure 489 and Figure 490.

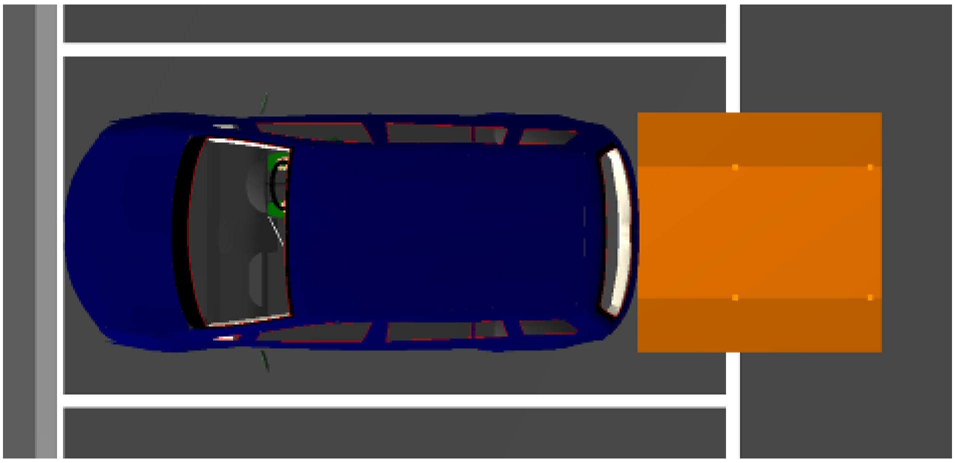

Figure 486. Rearwards visibility test A for 1100mm rearwards target (plan view)

Figure 487. Rearwards visibility test A for 1100mm rearwards target (side view)

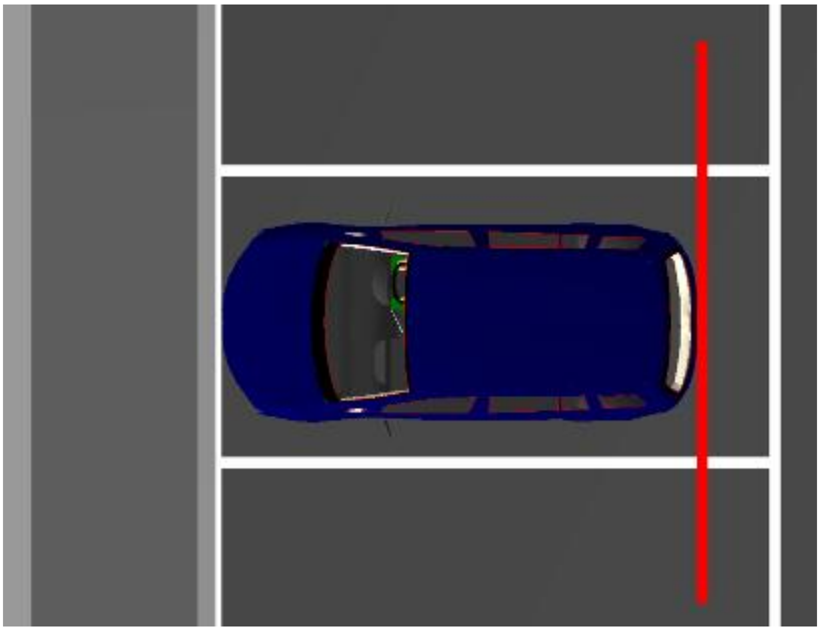

Figure 488. Rearwards visibility test B for 1000mm rearwards target (plan view)

Figure 489. Rearwards visibility test B for 1000mm rearwards target (side view)

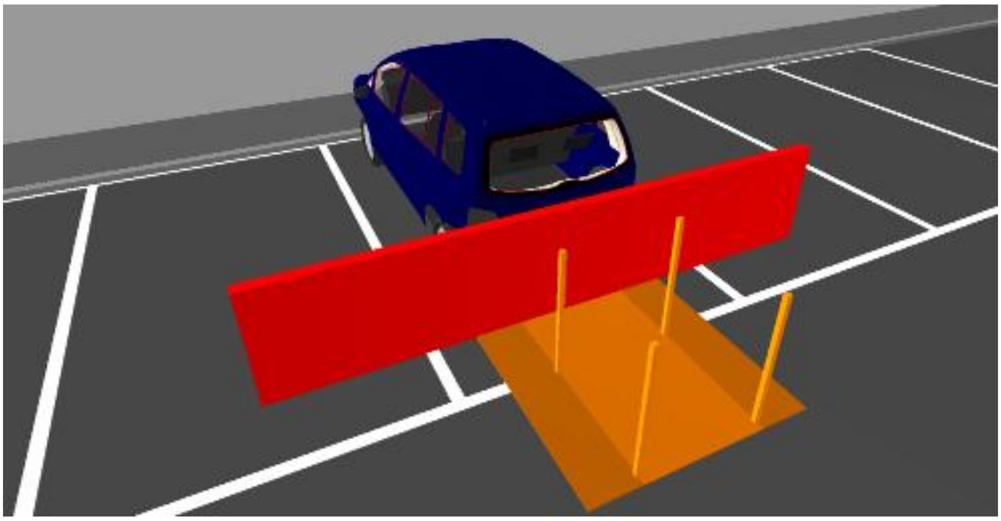

Figure 490. Rearwards visibility tests A and B located behind the vehicle.

Figure 491. 1m Rearwards visibility with occupants (head restraints at highest setting)

The direct rearwards view, for an occupied vehicle with the head restraints all set to their highest, is highly obscured, particularly if all seats are occupied (Figure 491). A portion of the nearside and offside is visible through the side windows. None of targets A or B is visible through the rear window.

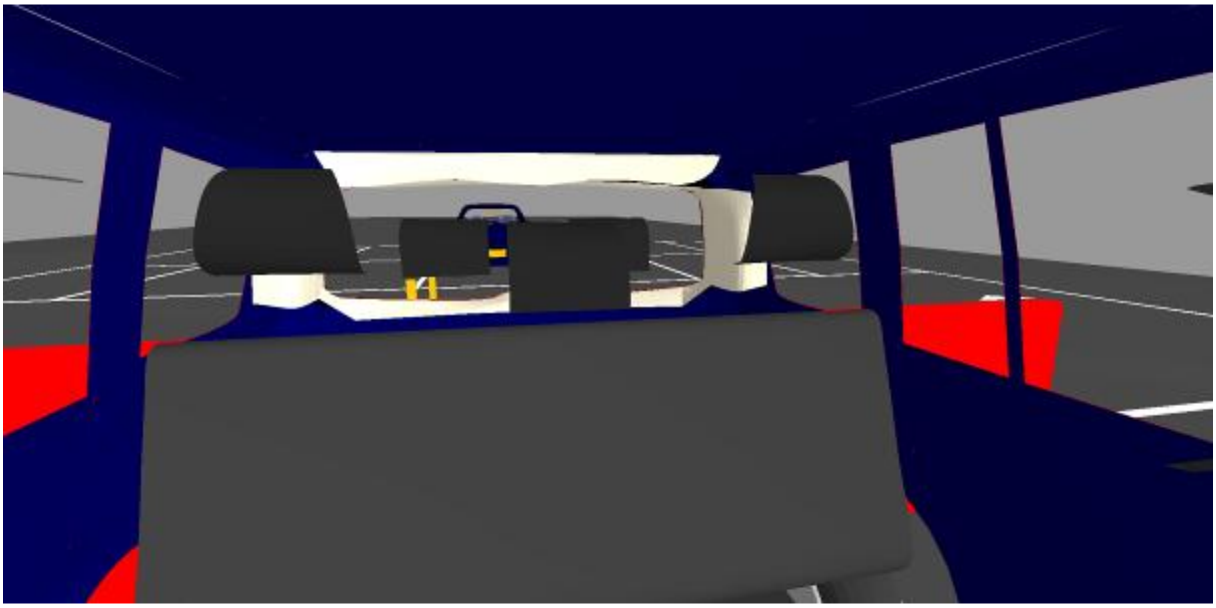

Figure 492. 1m Target Rearwards visibility unoccupied (head restraints at highest setting)

The direct rearwards view, for an unoccupied vehicle with the head restraints all set to their highest, is also marginally improved but only small elements of the rear view are visible between the obscurations (Figure 492). An increased area of the nearside is visible through the side windows. A very small amount of target A is visible below the rear headrest, though it is likely that the support for that headrest would make the view very marginal. Target B is visible at either end.

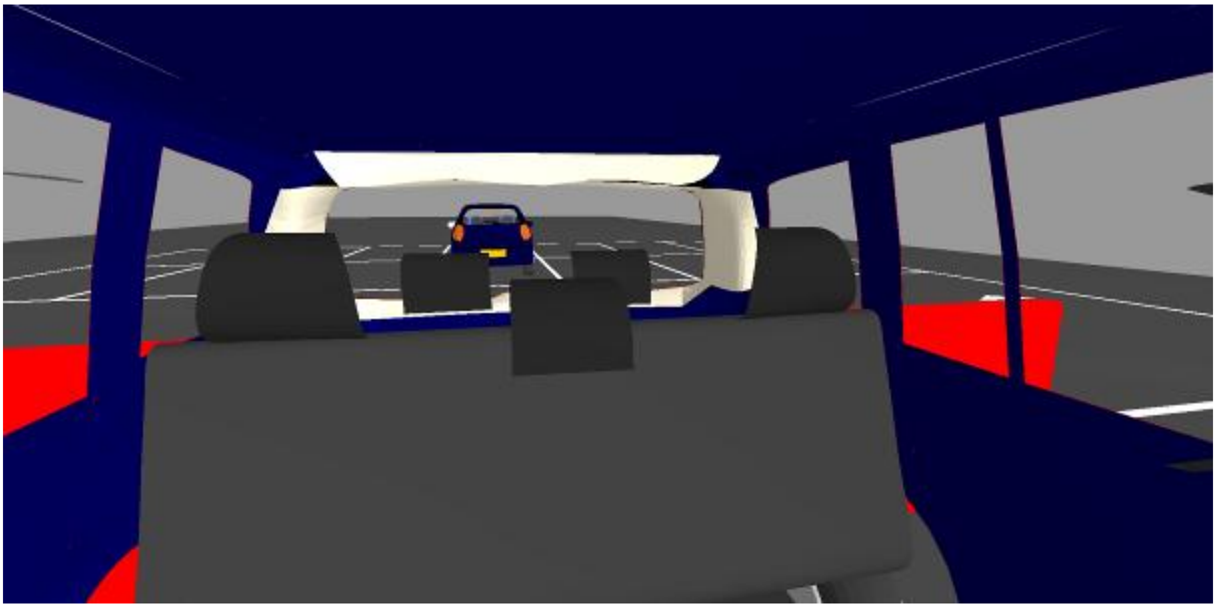

Figure 493. 1m Target Rearwards visibility unoccupied (head restraints at lowest setting)

Lowering the head restraints increases rearwards visibility but only in the top half of the rear window (Figure 493). This reduction has no appreciable difference on the visibility of either target A or B.

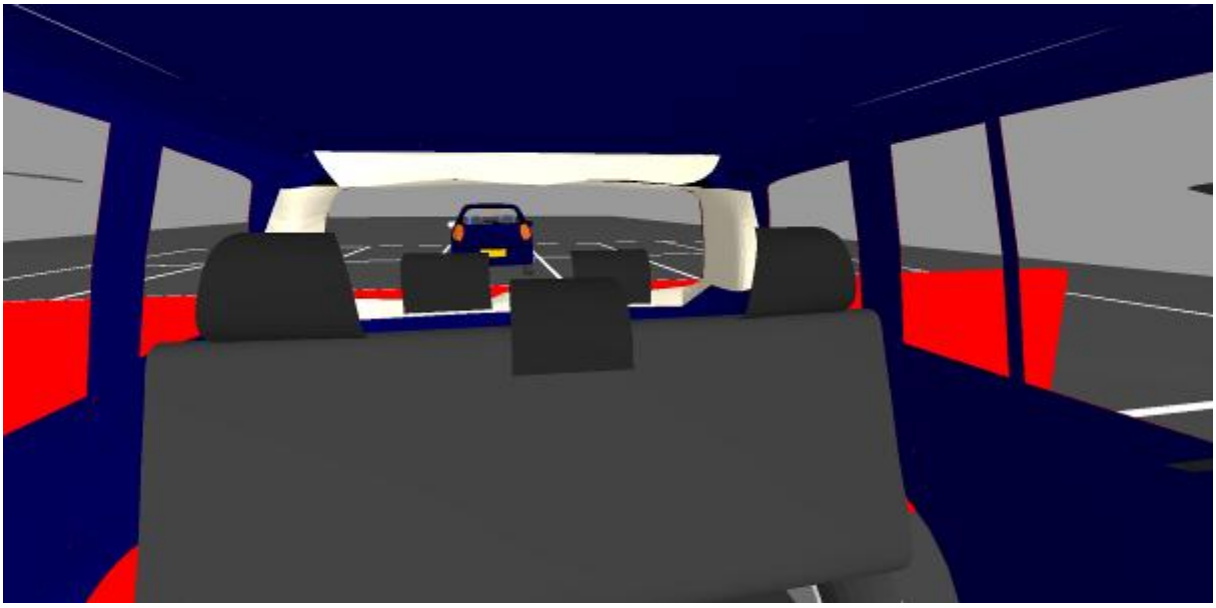

Figure 494. 1.15m Target Rearwards visibility unoccupied (head restraints at lowest setting)

Figure 494 above shows the height of target B required to be viewed directly out of the rear windows. This requires a target of 1150mm in height, equivalent to a 5%ile 7 year old UK male (1140mm). However, the amount of visible area of the target is negligible and it is unlikely that anything would actually be recognisable from this level of view.

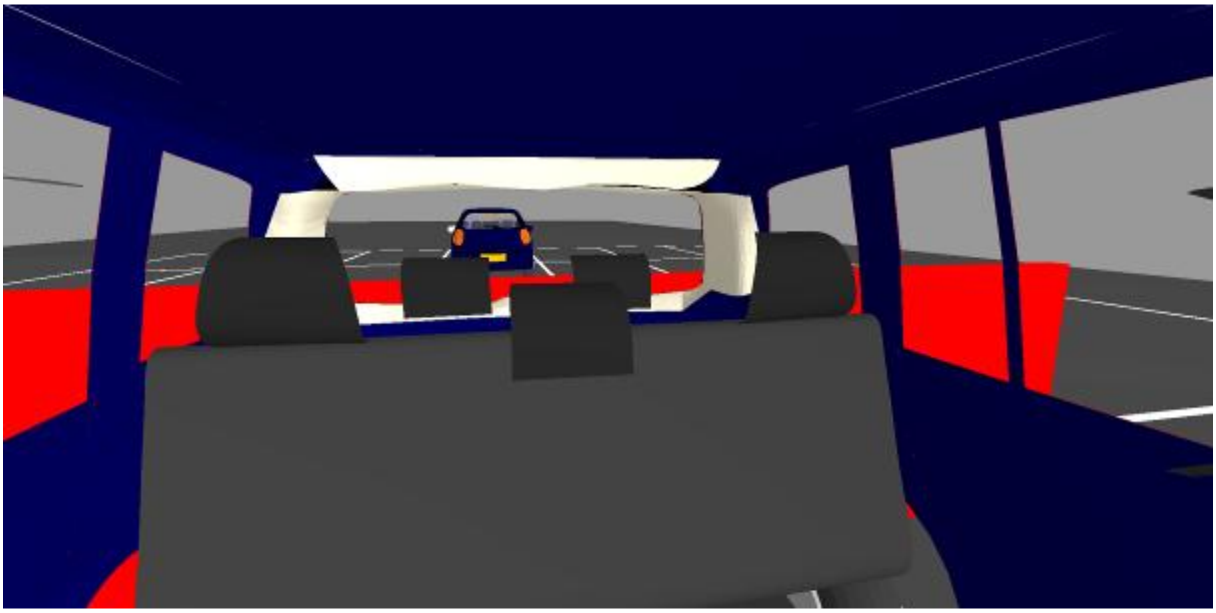

Figure 495. 1.2m Target Rearwards visibility unoccupied (head restraints at lowest setting)

Increasing the target height to 1200mm, equivalent to a 5%ile 9 year old UK male (1220mm), begins to provide a view in which a target may be recognisable out of the rear windows (Figure 495).

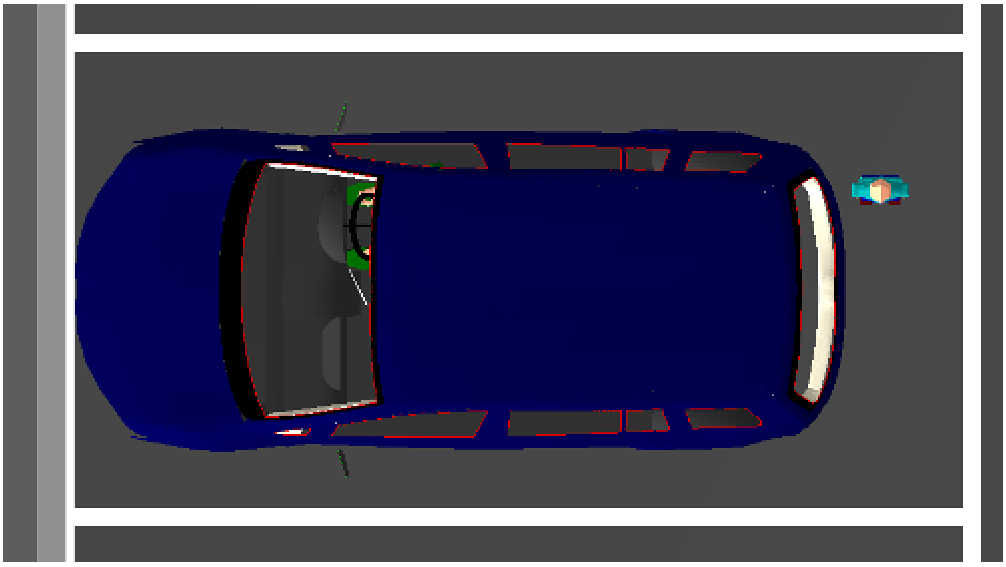

Figure 496. 1.22m Stature person (5%ile 9yr old UK Male) rearwards of the vehicle

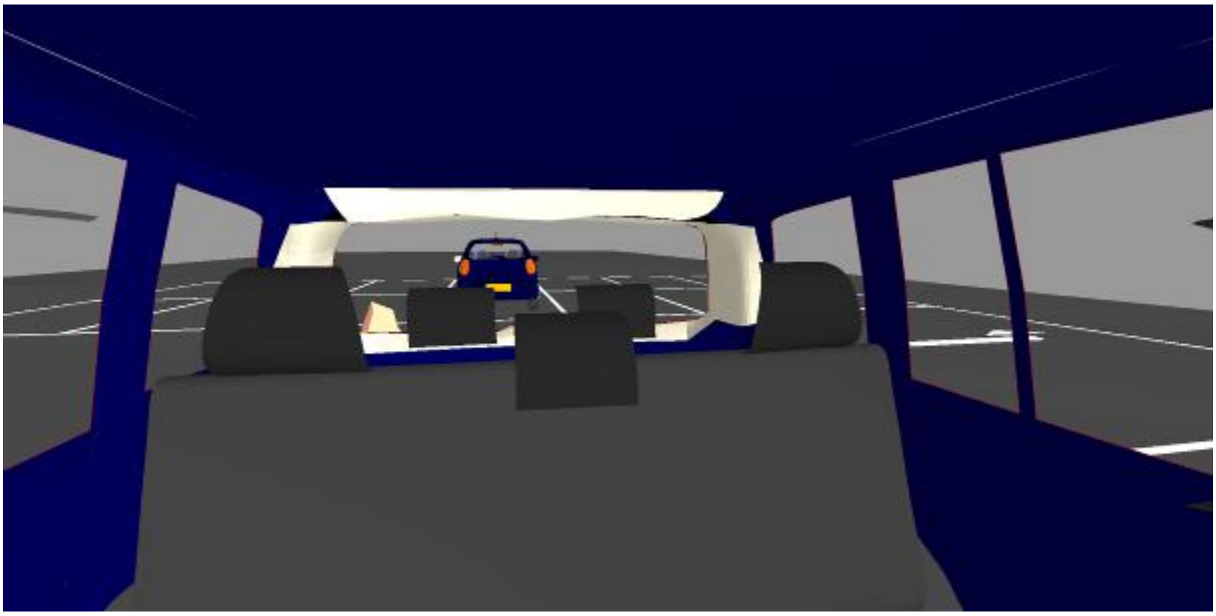

Figure 497. 1.22m Stature person (5%ile 9yr old UK Male) rearwards of the vehicle

In a practical test, a human with a stature of 1220mm (5%ile 9yr old UK Male) is barely visible out of the rear of the vehicle (Figure 496 and Figure 497).

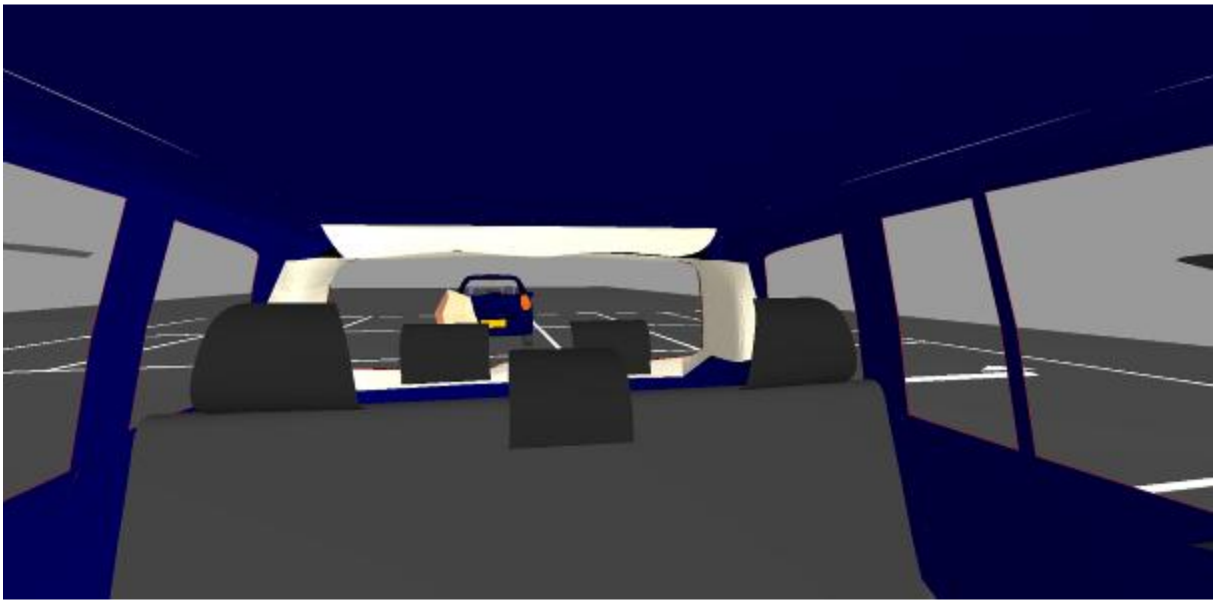

Figure 498. 1.4m Stature person (5%ile 13yr old UK Male) rearwards of the vehicle

Figure 498 shows a 5%ile 13yr old UK male (1400mm stature) visible in the rear windows. This gives an indication of the height necessary to clear the rear head restraints in their lowest position and be visible.

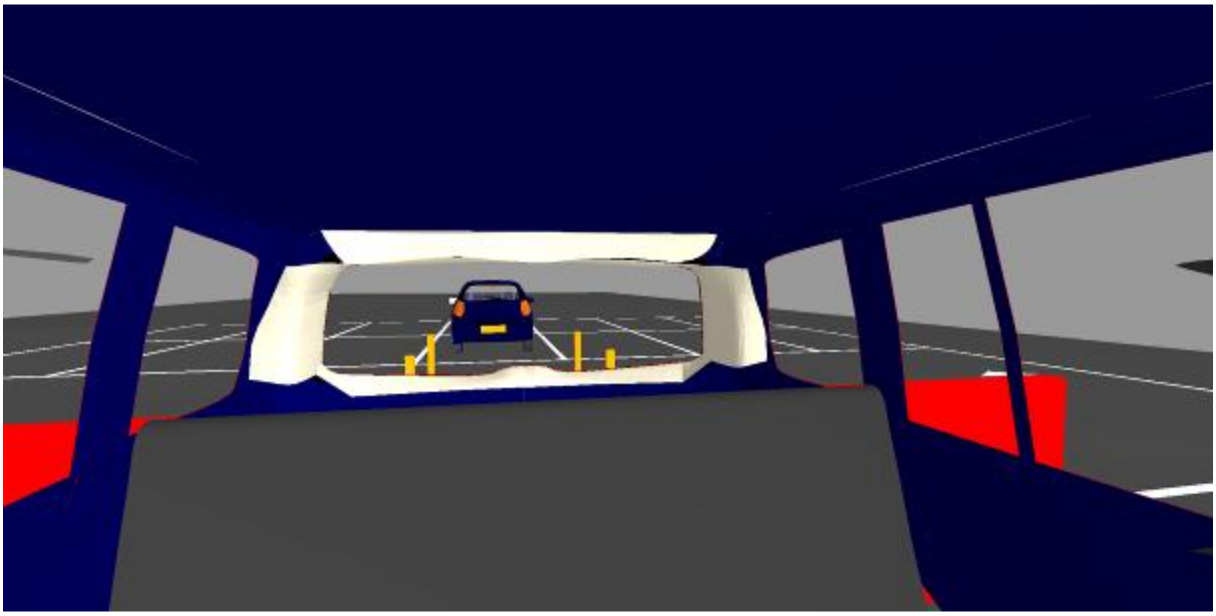

Figure 499. Rearwards view of targets with head restraints removed

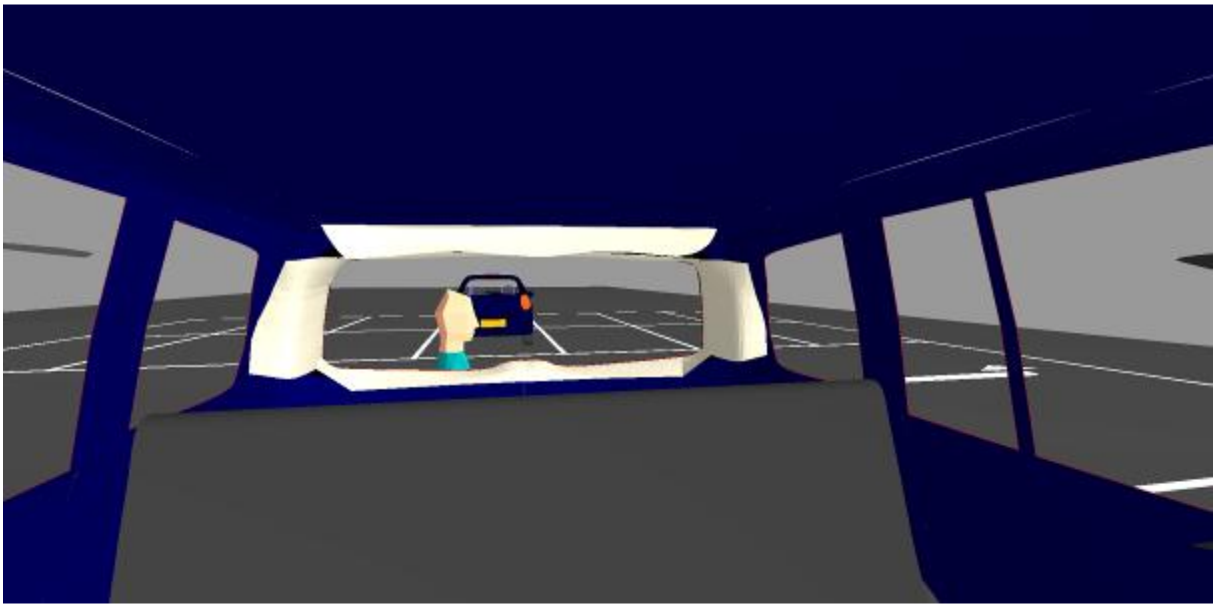

Figure 500. Rearwards view of human with head restraints removed

Whilst the head restraints are an important safety feature it is interesting to evaluate their impact on the rearwards visibility. Removal of the head restraints increases rearwards visibility significantly (Figure 499 and Figure 500). In this configuration the top of target A is now visible. However target B is still not visible directly to the rear.

4.4.2.1.2 Direct Vision – Volume Projections

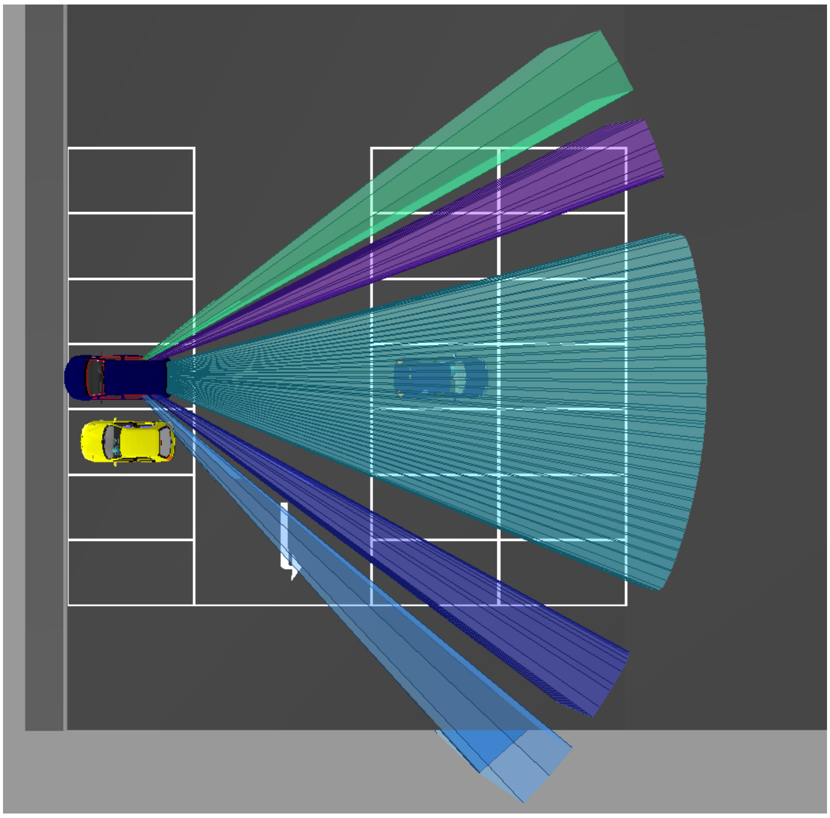

Figure 501. Rearwards view volume projections

The volumetric projection of rearwards visibility in Figure 501 shows a largely symmetrical field of view extending rearwards and to both near and offside at approximately 30 degrees.

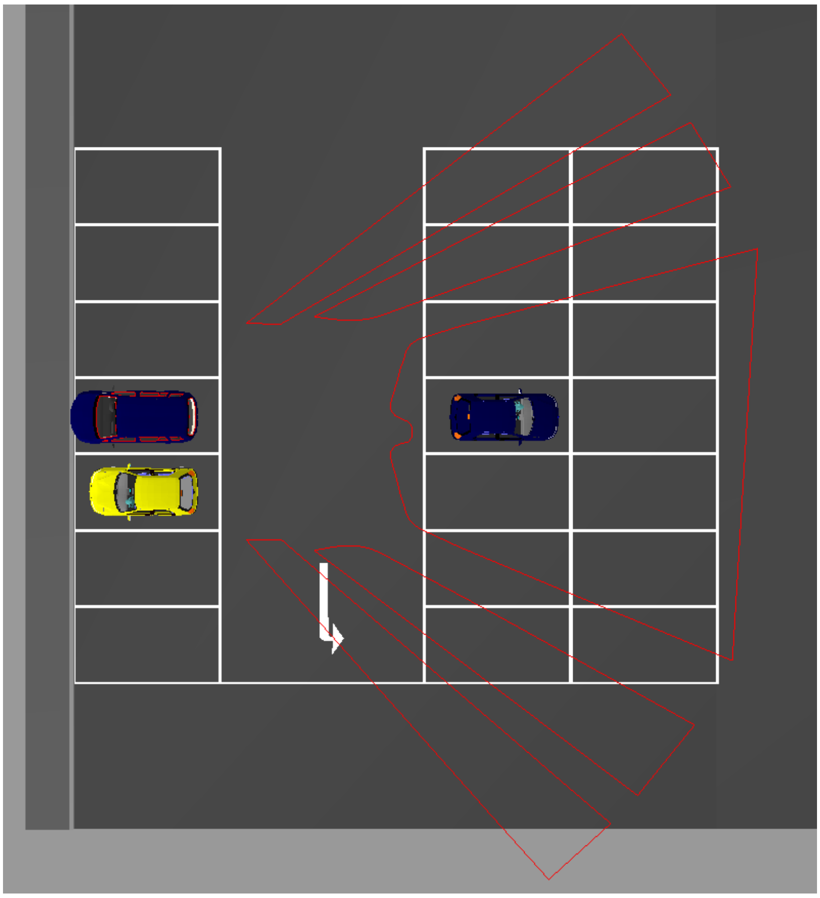

Figure 502. Rearwards view plane projections (ground plane)

Figure 502 shows the theoretically visible areas rearwards of the vehicle on the ground plane. Even in this idealised format, where the impact of any internal obscurations (head restraints, seats, seatbelt mountings etc.) is negated, there is still a significant area (extending approximately 6.5m rearwards of the back of the vehicle) that is not visible directly to the rear.

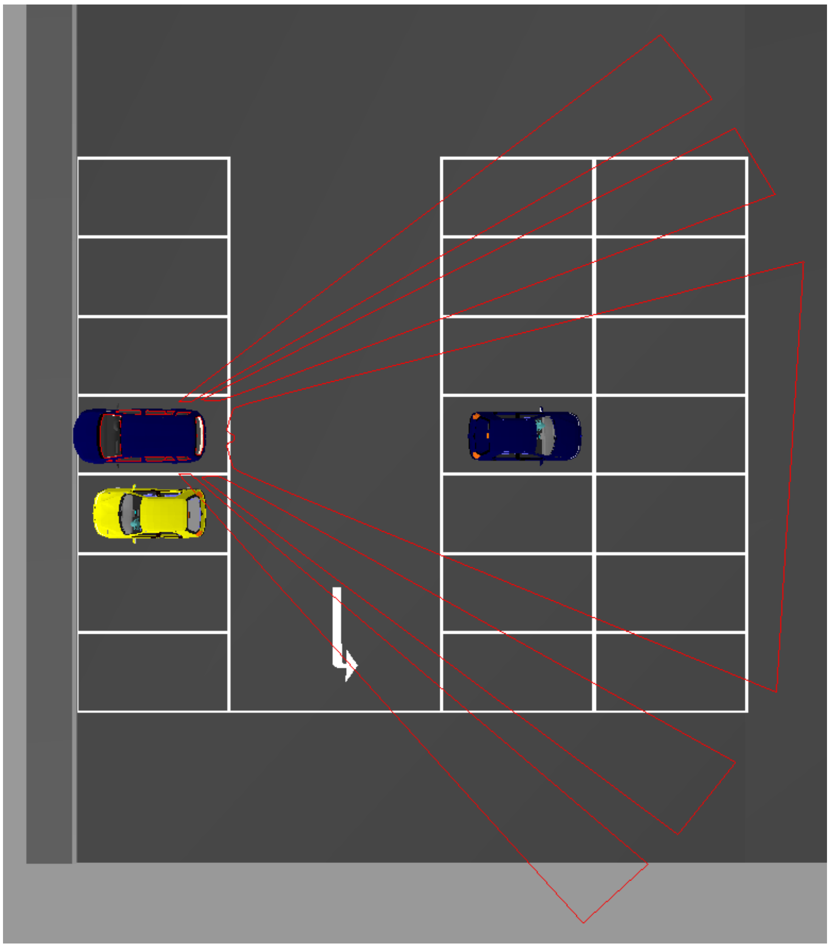

Figure 503. Rearwards view plane projections (ground plane + 1000mm)

Projecting on to a plane parallel to the ground at a height of 1m provides a much improved area of visibility though there is still an area directly behind the vehicle that is not visible (Figure 503). This area extends approximately 0.5m rearwards from the back of the vehicle.

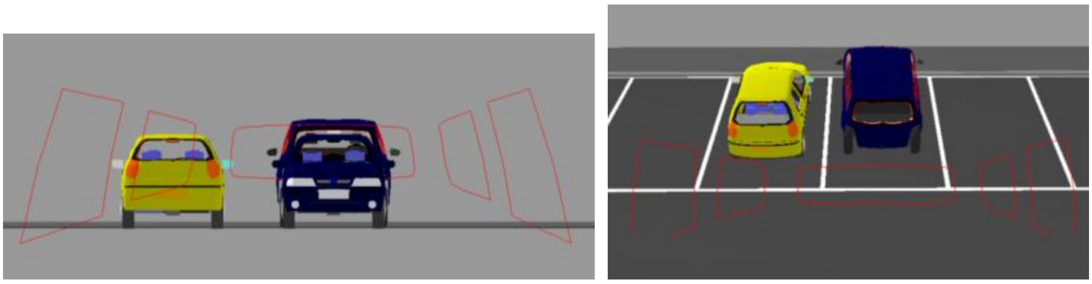

Figure 504. Rearwards view plane projections (vertical plane, rear of vehicle + 2000mm)

Figure 504 shows the projections on a plane parallel to the rear of the vehicle at 2m behind the vehicle. This provides an indication of the idealised 'windows' of visibility extending across the back of the vehicle.

4.4.2.1.3 Indirect vision

The posture adopted to gain an appropriate rearward view is shown in Figure 505 below.

Figure 505. Forwards view posture (99th%ile Dutch male)

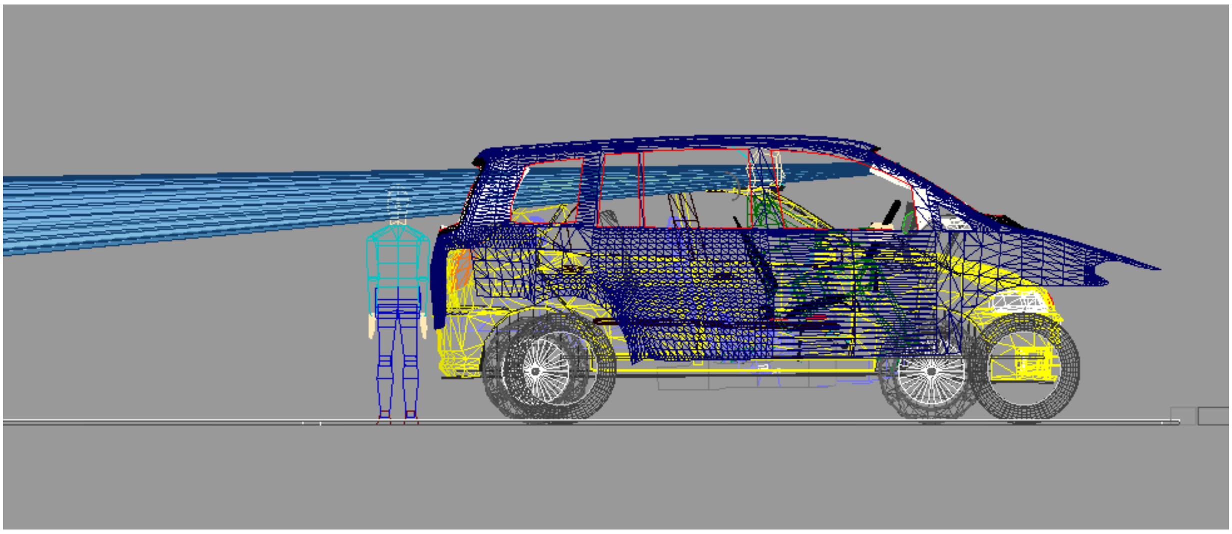

Figure 506. Idealised indirect rearwards view (Class I mirror)

Figure 506 and Figure 507 show the idealised rearwards projection of the indirect field of view from the Class I mirror. However it is also clear that the view would be obscured by internal elements in the same manner as the direct vision analysis shown earlier.

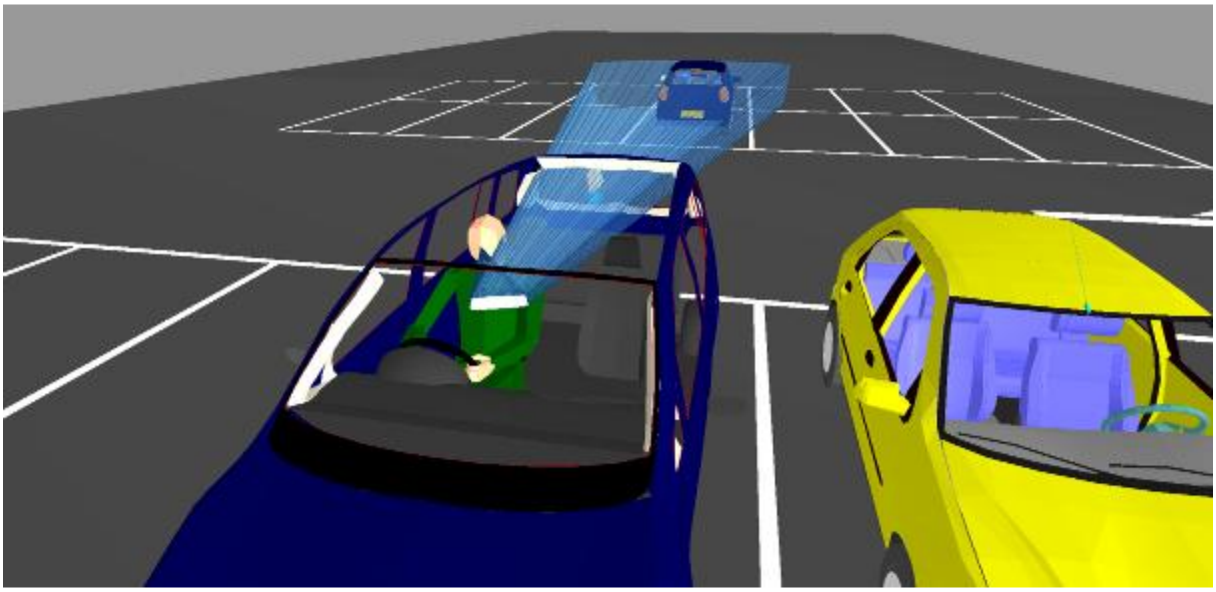

Figure 507. Idealised indirect rearwards view (Class I mirror)

In comparison to the field of view specified in ECE46-02 and 2003/97/EC the idealised rearwards field of view of the Class I mirror meets or exceeds the stated requirements. Figure 508 shows the relevant specification, with the corresponding requirements for passenger cars in FMVSS111 indicating that the ground must be visible 61m behind the vehicle, but with no overall width specified.

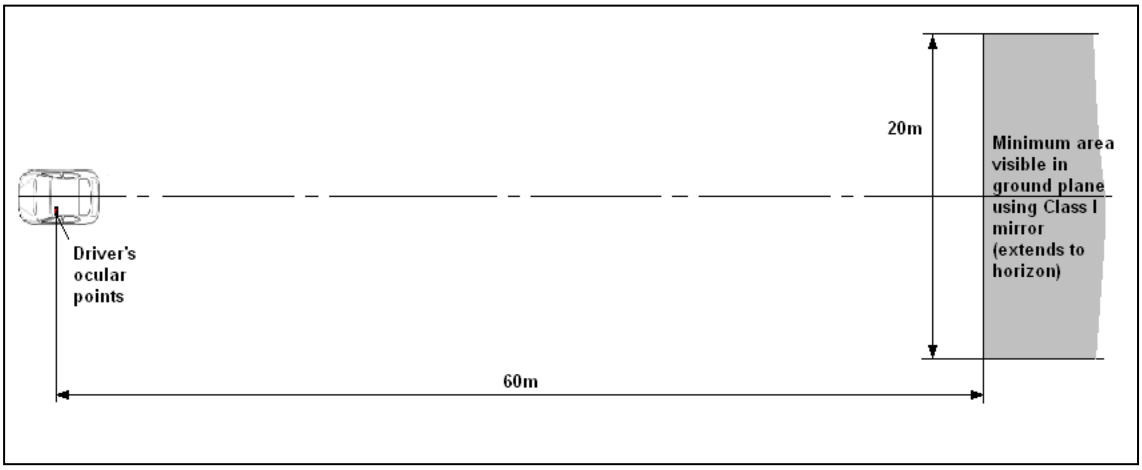

Figure 508. Minimum Field of View Specified in ECE46-02 and 2003/97/EC for Class I (Interior) Mirror

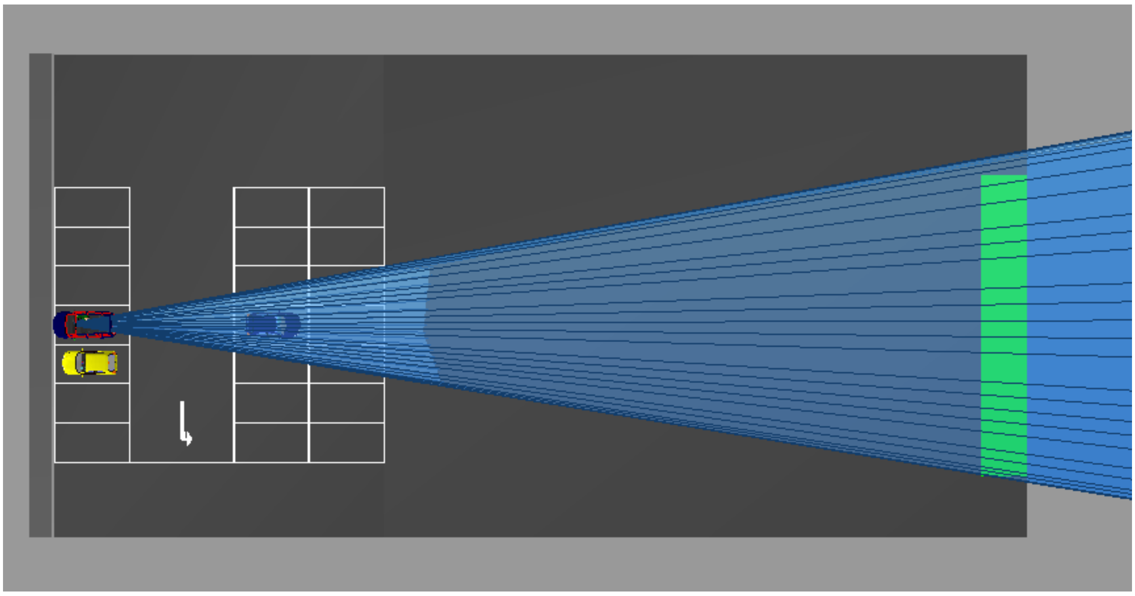

Figure 509. Idealised indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class I mirror)

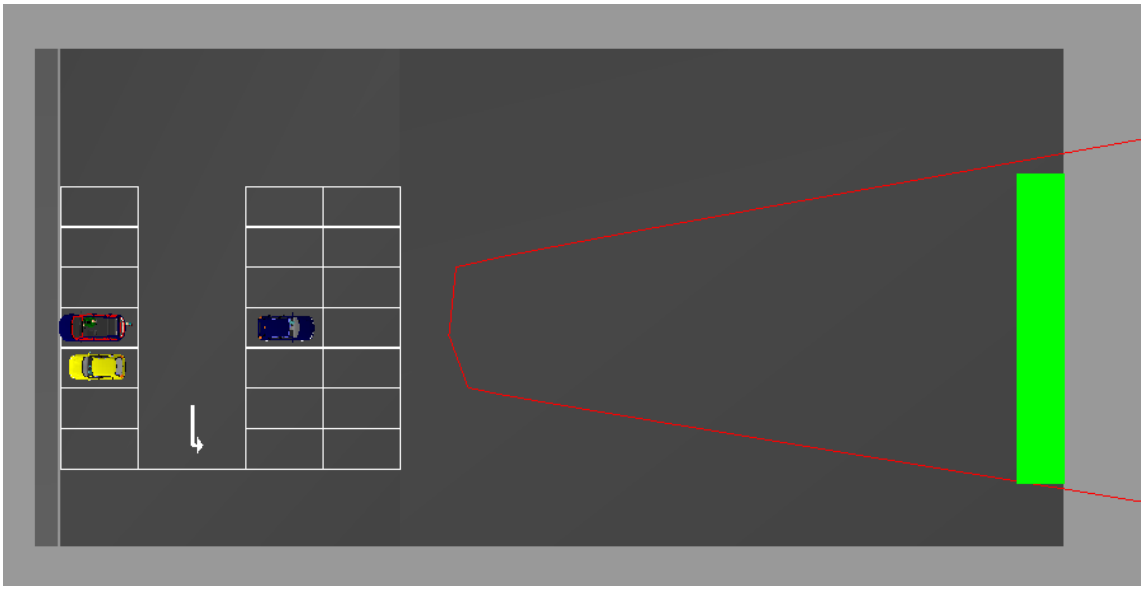

Figure 510. Idealised indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class I mirror)

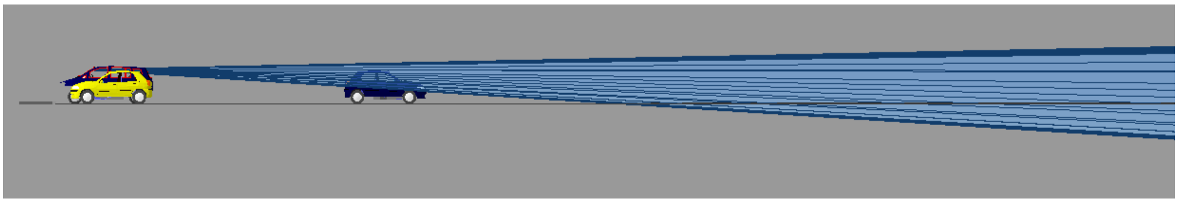

Figure 511. Idealised indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class I mirror)

Figure 509, Figure 510 and Figure 511 above show that the recommended area is within the idealised projection.

In comparison to the field of view specified in ECE46-02 and 2003/97/EC (Figure 512) the rearwards field of view of the Class III mirrors also appear, in the first instance, to meet or exceed the stated requirements (Figure 513, Figure 514 and Figure 515).

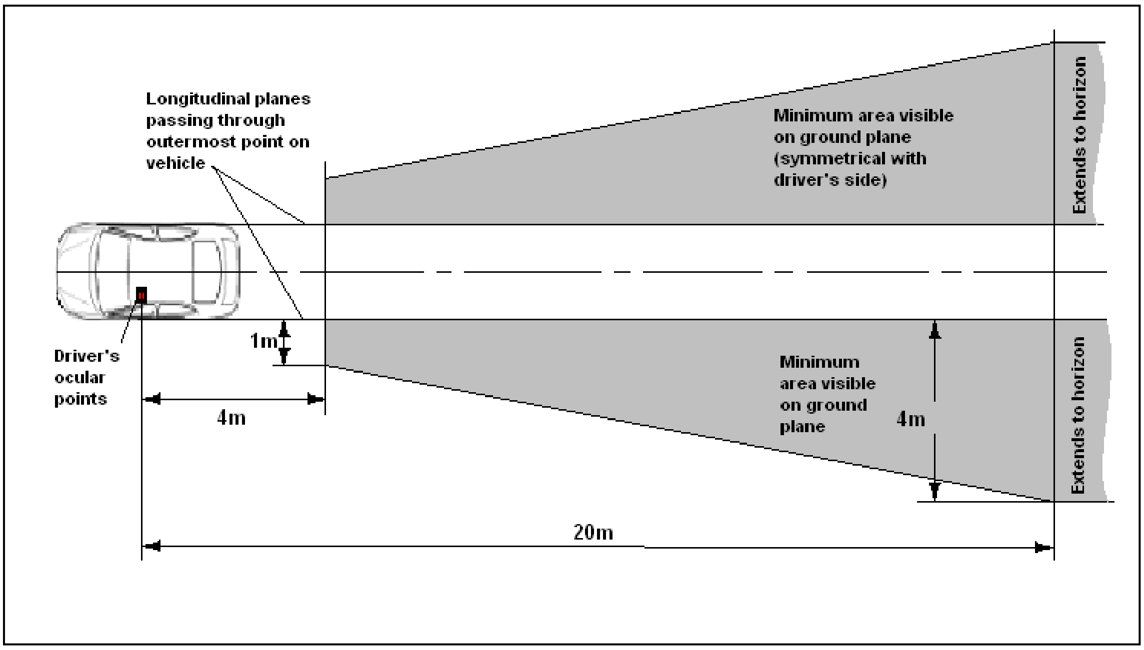

Figure 512. Minimum Field of View Specified in ECE46-02 and 2003/97/EC for Class III (Exterior Small) Mirrors

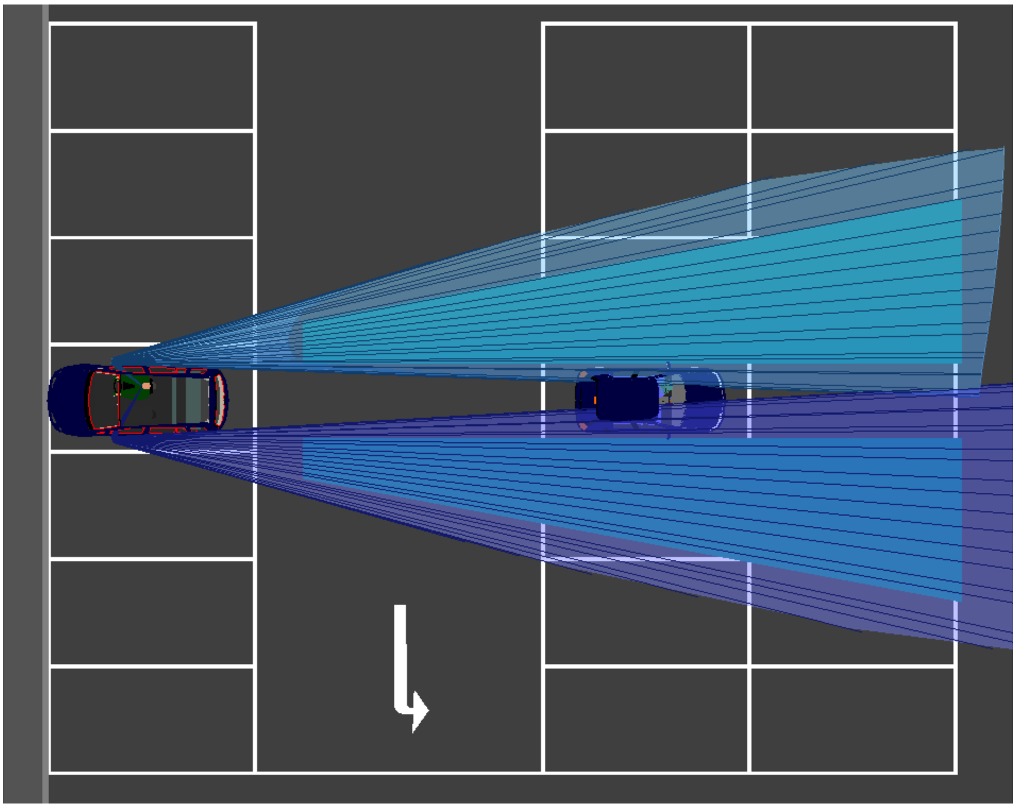

Figure 513. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class III mirrors)

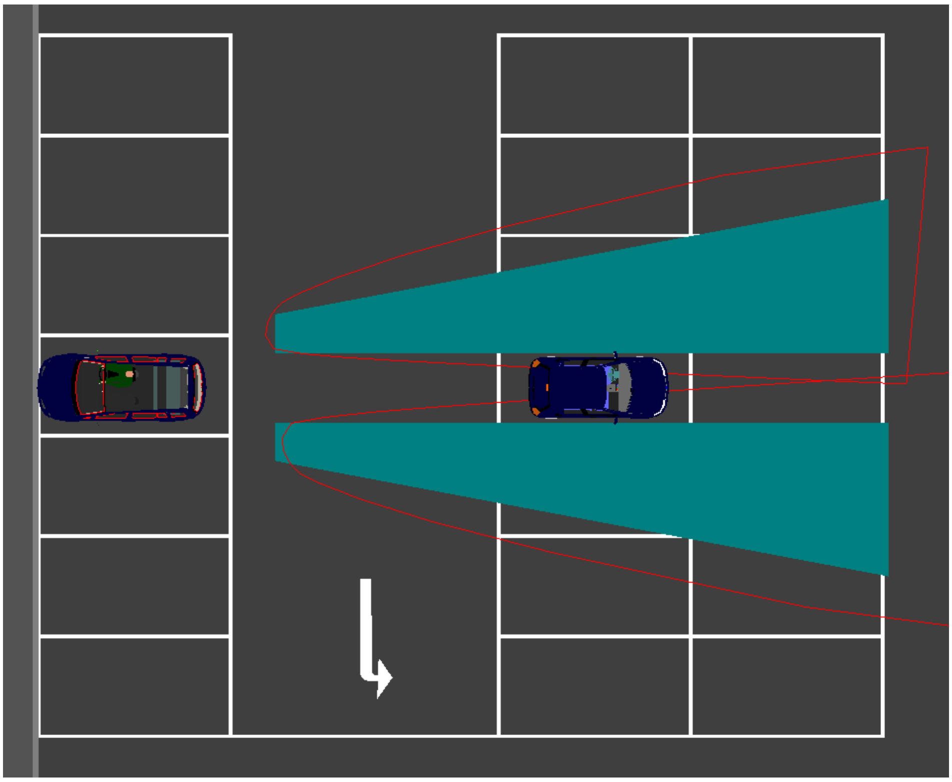

Figure 514. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class III mirrors)

On closer inspection however it is clear that the ground plane projections do not fully comply with the necessary minimum field of view specified in ECE46-02 and 2003/97/EC for Class III mirrors, falling short in the areas closest to the rear of the vehicle, particularly for the nearside (left) mirror.

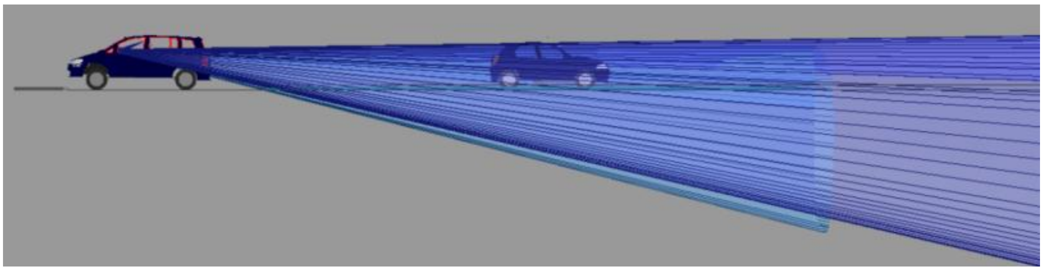

Figure 515. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class III mirrors)

Figure 515 shows that the Class III mirrors have been set to give a balanced view of the area rearward of the vehicle. Increasing the relative downward angle of the mirrors would increase the compliance with ECE46-02 and 2003/97/EC but also reduced the effectiveness of the rearwards view afforded by the Class III mirrors.

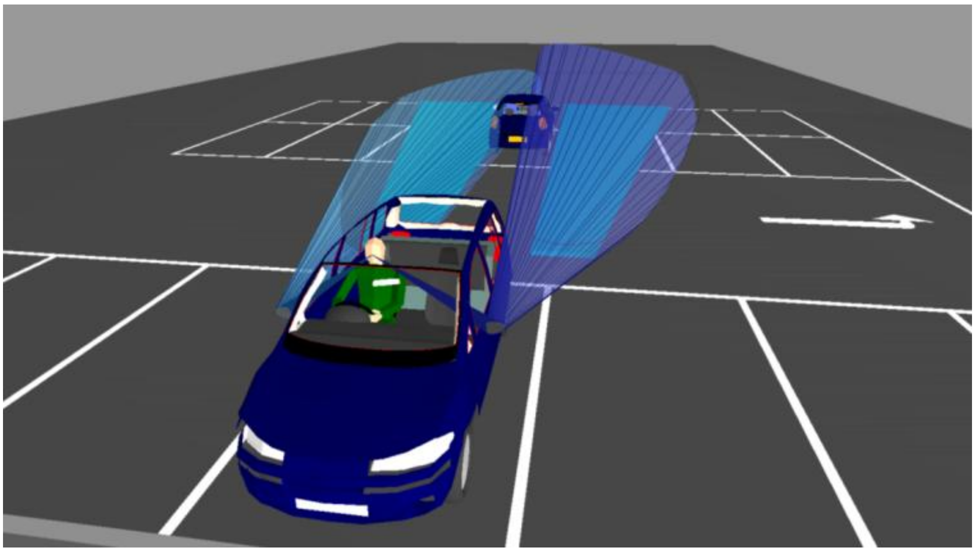

Figure 516. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class III mirrors)

Factoring in the field of view specified in ECE46-01 (Figure 517) shows that the field of view of the Class III mirrors meets or exceeds the alternative requirements (Figure 518 and Figure 519).

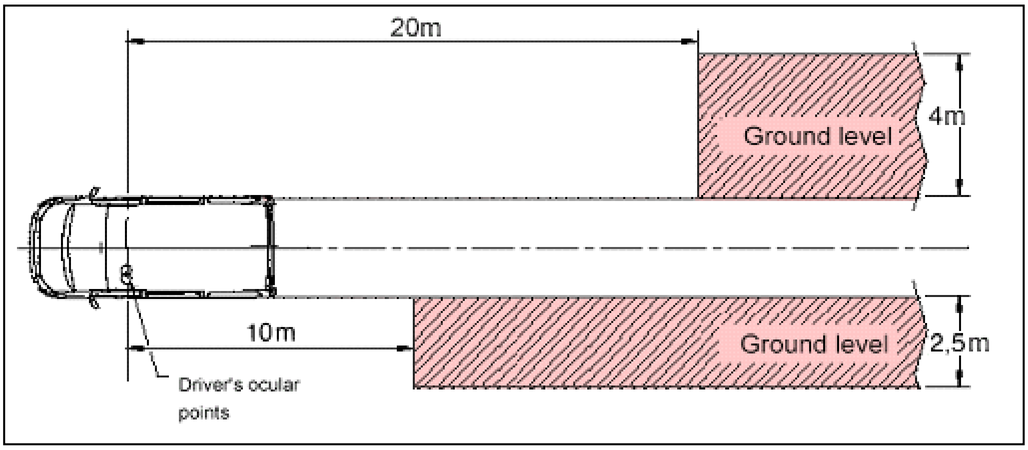

Figure 517. Requirements for Exterior Mirrors in ECE46-01

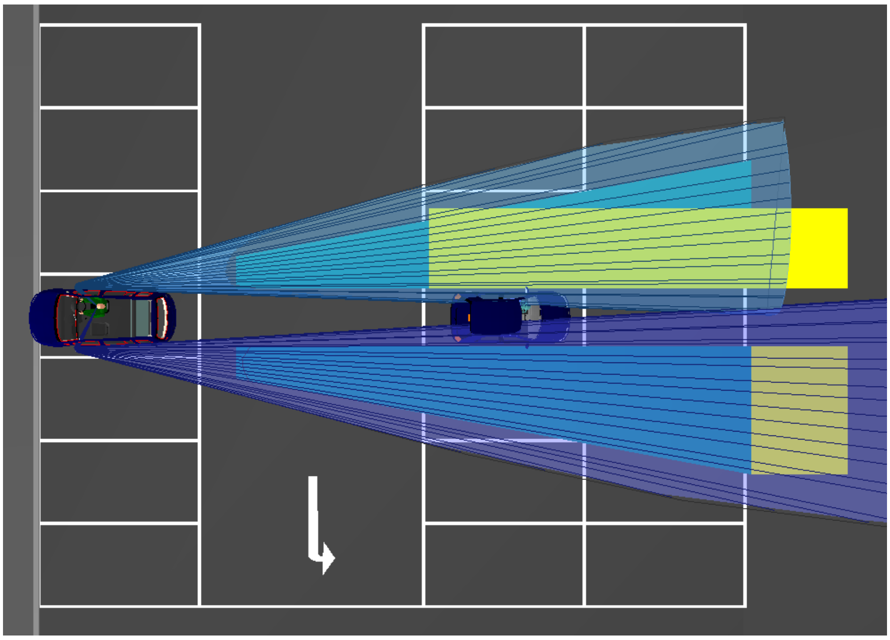

Figure 518. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-01, ECE46-02 and 2003/97/EC (Class III mirrors)

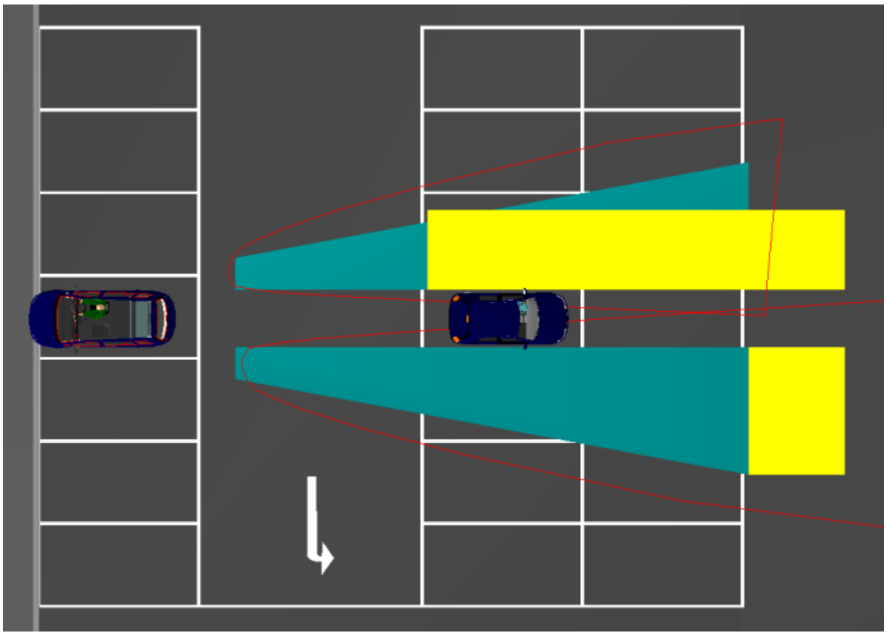

Figure 519. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-01, ECE46-02 and 2003/97/EC (Class III mirrors)

4.4.2.2 35th %ile UK female

4.4.2.2.1 Direct vision – human's view

The posture adopted to gain an appropriate rearward view is shown in Figure 520 below. The evaluative setup is as per the Dutch Male – see Section 4.4.2.1.1.

Figure 520. Rearwards view posture (35th%ile UK Female)

Figure 521. 1m Rearwards visibility with occupants (head restraints at highest setting)

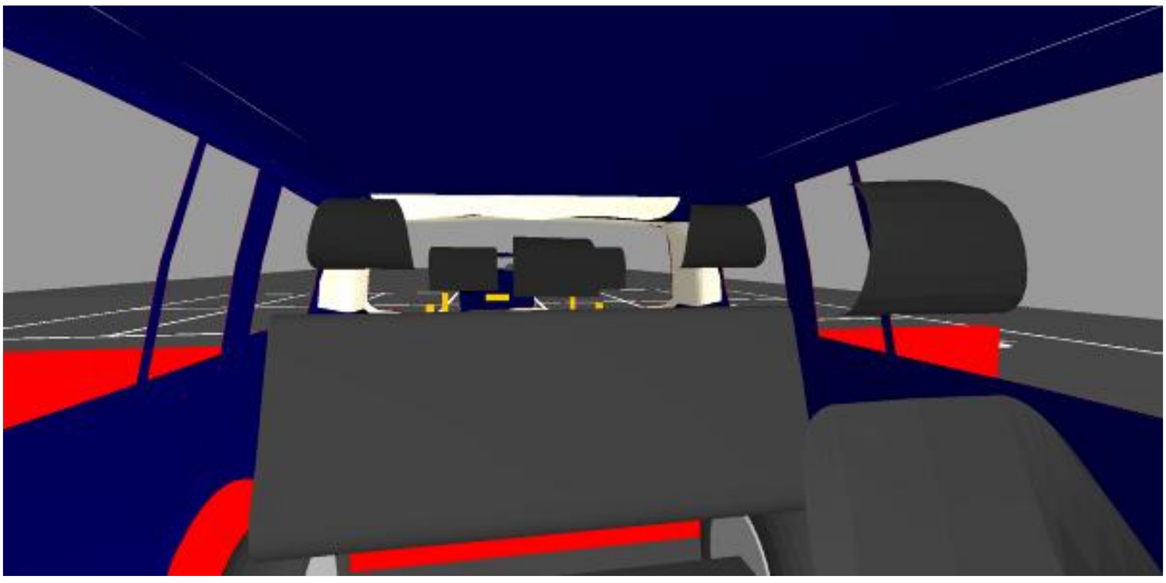

Figure 522. 1m Target Rearwards visibility unoccupied (head restraints at highest setting)

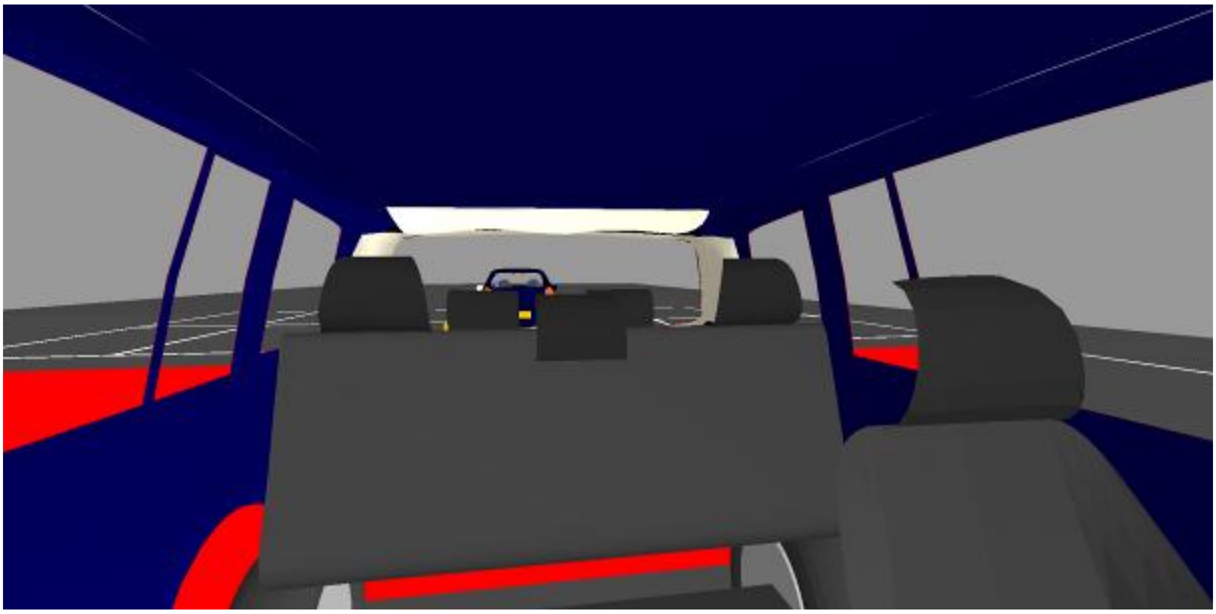

Figure 523. 1m Target Rearwards visibility unoccupied (head restraints at lowest setting)

Again, target A is almost completely obscured (Figure 521 and Figure 523) apart from with the head restraints in their highest position (Figure 522) where a small amount may be visible under the headrest. Target B is visible to the offside and marginally to the nearside.

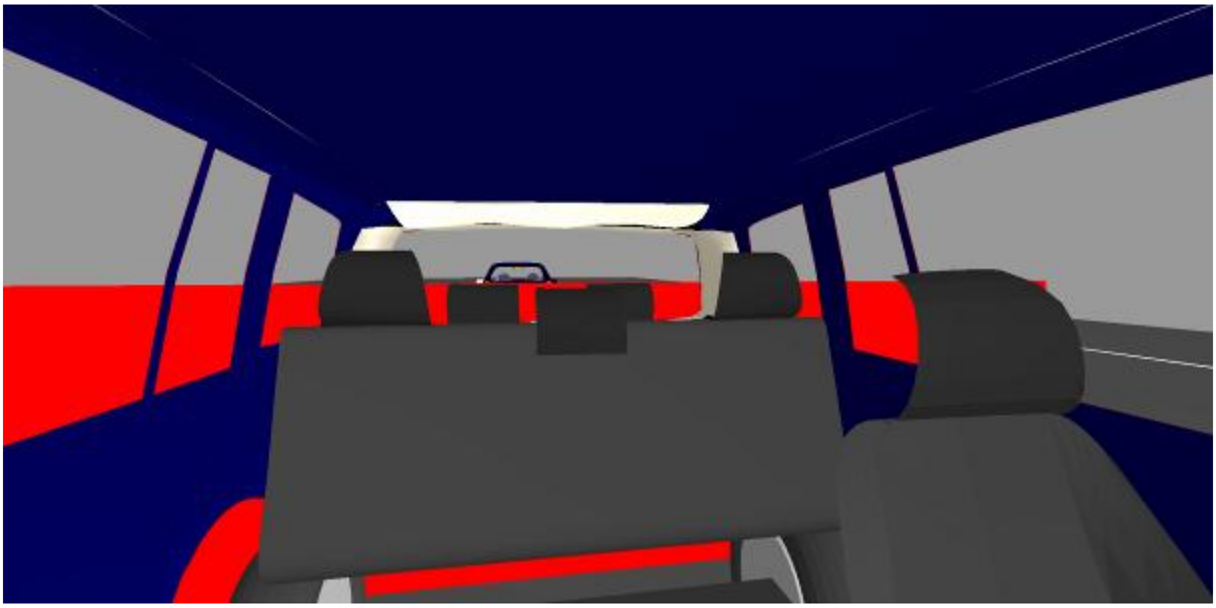

Figure 524. 1.3m Target Rearwards visibility unoccupied (head restraints at lowest setting)

Target B needs to be increased to 1300mm to be clear the rear head restraints through the rear windows (Figure 524).

Figure 525. 1.22m Stature person (5%ile 9yr old UK Male) rearwards of the vehicle

Figure 526. 1.4m Stature person (5%ile 13yr old UK Male) rearwards of the vehicle

Figure 525 and Figure 526 show a 5%ile 9yr old (1220mm stature) and a 13yr old UK male (1400mm stature) visible in the rear windows. This gives an indication of the height necessary to clear the rear head restraints in their lowest position and be visible. The lower eye point of the 35%ile UK female has reduced the visibility.

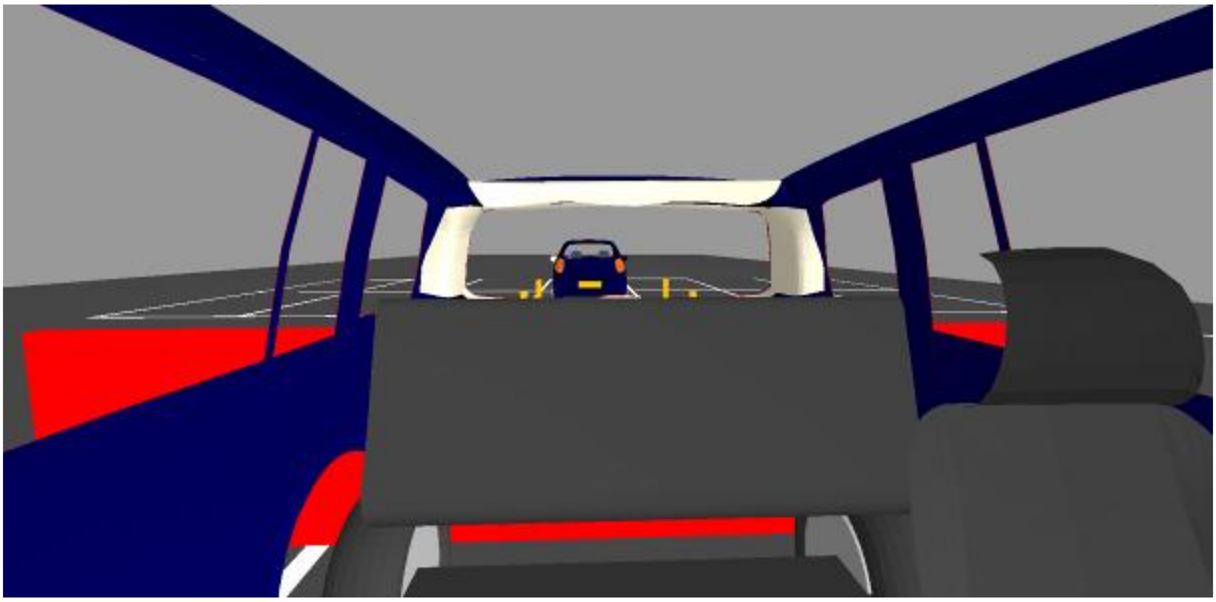

Figure 527 . Rearwards view of targets with head restraints removed

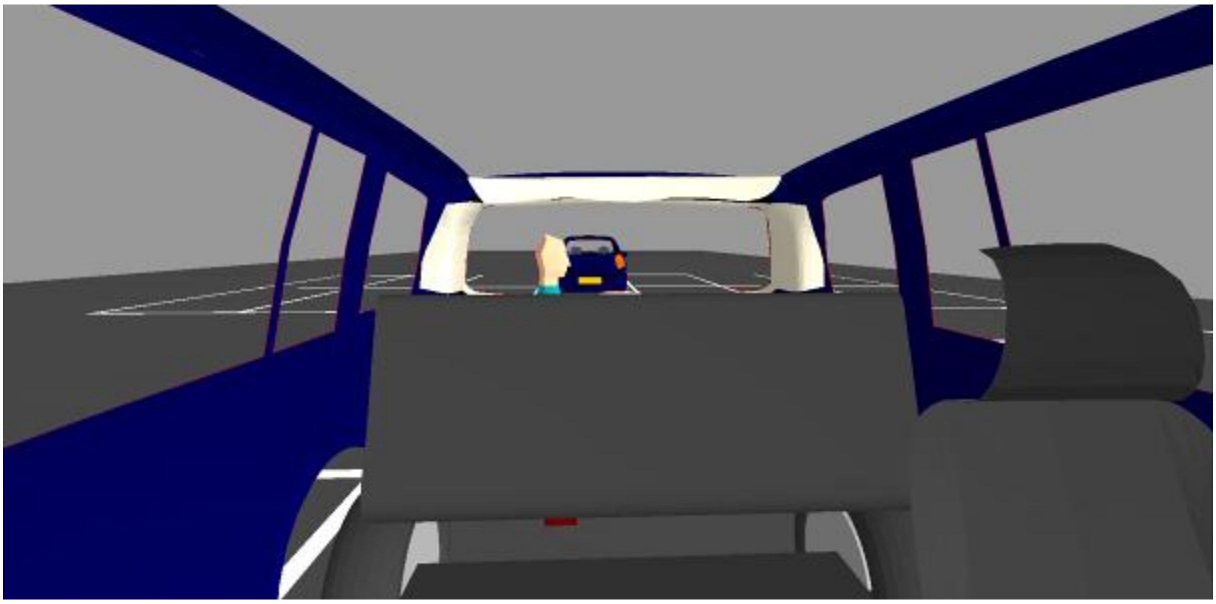

Figure 528. Rearwards view of human with head restraints removed

Removal of the head restraints again increases rearwards visibility significantly with similar results to the 99%ile Dutch Male (Figure 527 and Figure 528).

4.4.2.2.2 Direct vision – volume projections

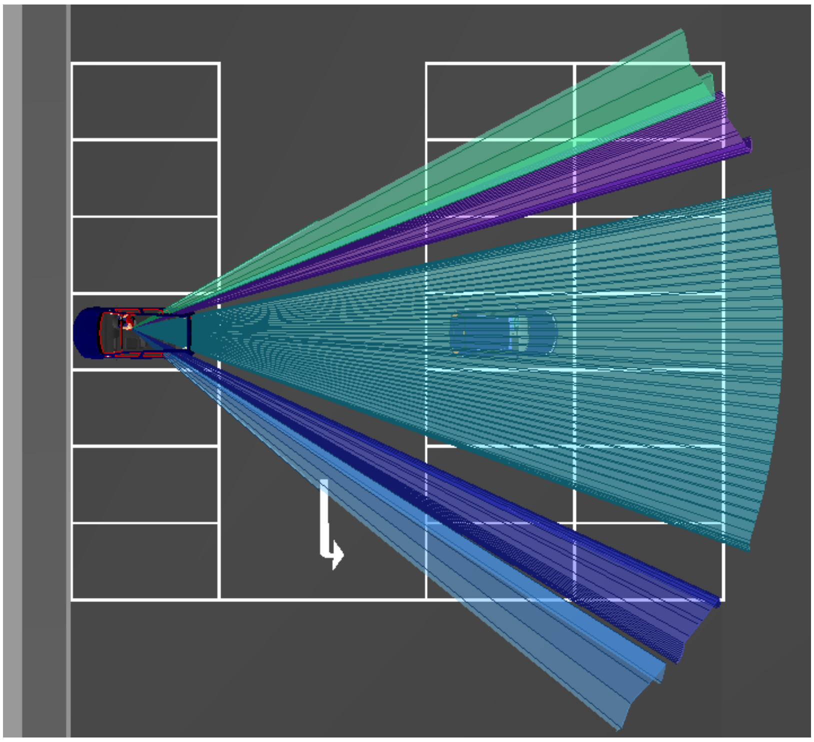

Figure 529. Rearwards view volume projections

The volumetric projection of rearwards visibility in Figure 529 shows a largely symmetrical field of view extending rearwards and to both near and offside at approximately 30 degrees.

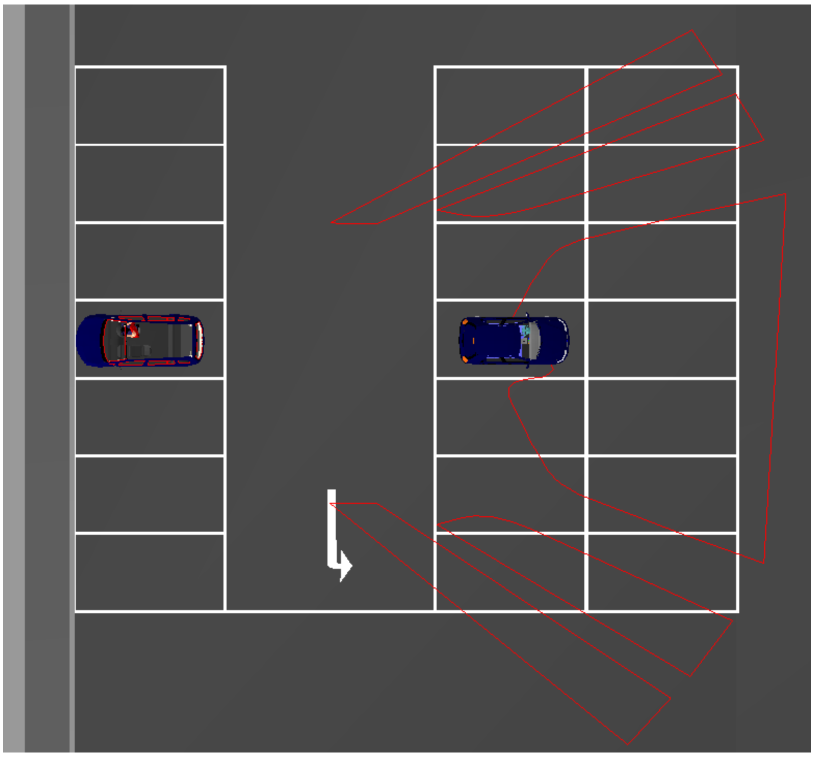

Figure 530. Rearwards view plane projections (ground plane)

Figure 530 shows the theoretically visible areas rearwards of the vehicle on the ground plane. Even in this idealised format, where the impact of any internal obscurations (head restraints, seats, seatbelt mountings etc.) is negated, there is still a significant area that is not visible directly to the rear. The size of this obscured zone extends for approximately 10m rearwards from the back of the vehicle (in comparison to 6.5m rearwards of the back of the vehicle for the 99%ile Dutch Male).

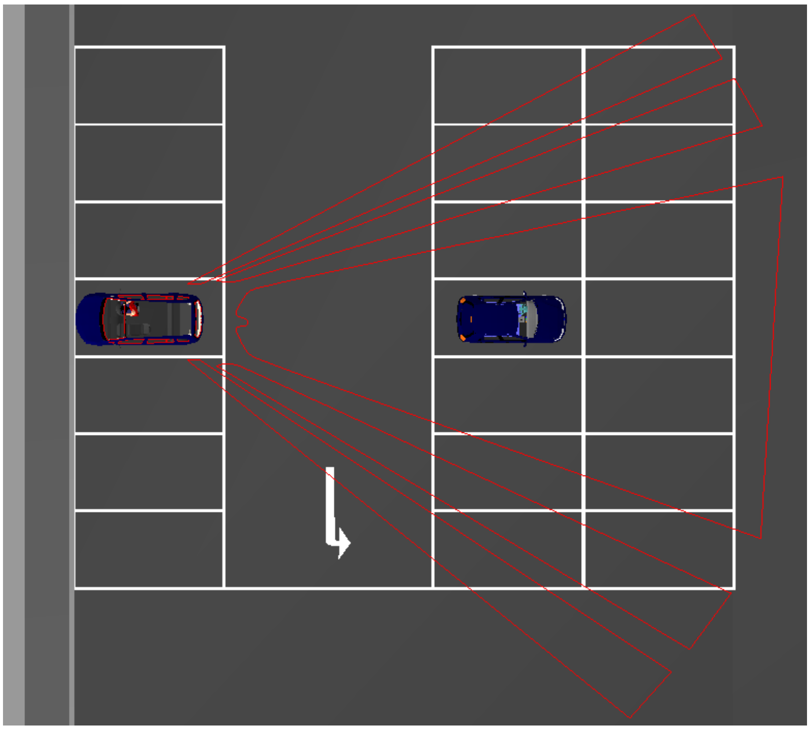

Figure 531. Rearwards view plane projections (ground plane + 1000mm)

Projecting on to a plane parallel to the ground at a height of 1m, provides a much improved area of visibility though there is still an area directly behind the vehicle that is not visible (Figure 531). This area extends approximately 1.1m rearwards from the back of the vehicle (in comparison to 0.5m rearwards of the back of the vehicle for the 99%ile Dutch Male).

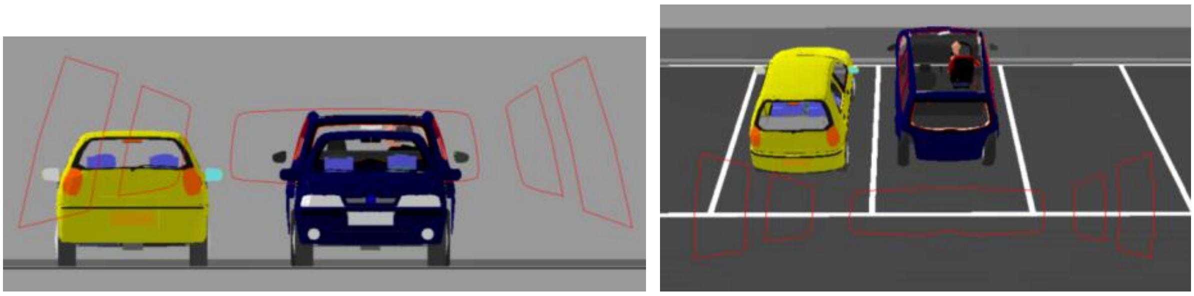

Figure 532. Rearwards view plane projections (vertical plane, rear of vehicle + 2000mm)

Figure 532 shows the projections on a plane parallel to the rear of the vehicle at 2m behind the vehicle. This provides an indication of the idealised 'windows' of visibility extending across the back of the vehicle.

4.4.2.2.3 Indirect vision

For indirect vision from Class I and III mirrors the results are very similar to those of the 99%ile Dutch male. The field of view afforded by the Class I mirror meets or exceeds that detailed in the standard (Figure 533, Figure 534 and Figure 535). The field of view afforded by the Class III mirrors again falls short of that specified in ECE46-02 and 2003/97/EC but meets that specified in ECE46-01 (Figure 536, Figure 537, Figure 538 and Figure 539).

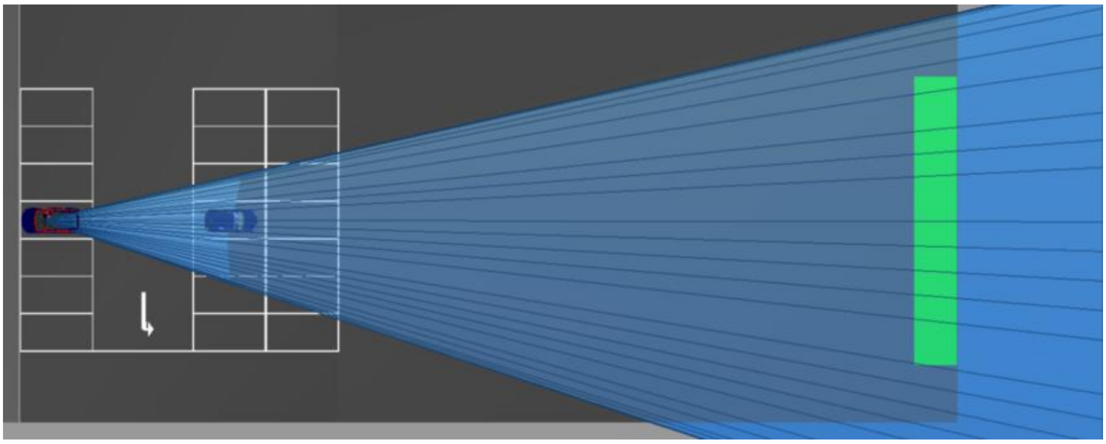

Figure 533. Idealised indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class I mirror)

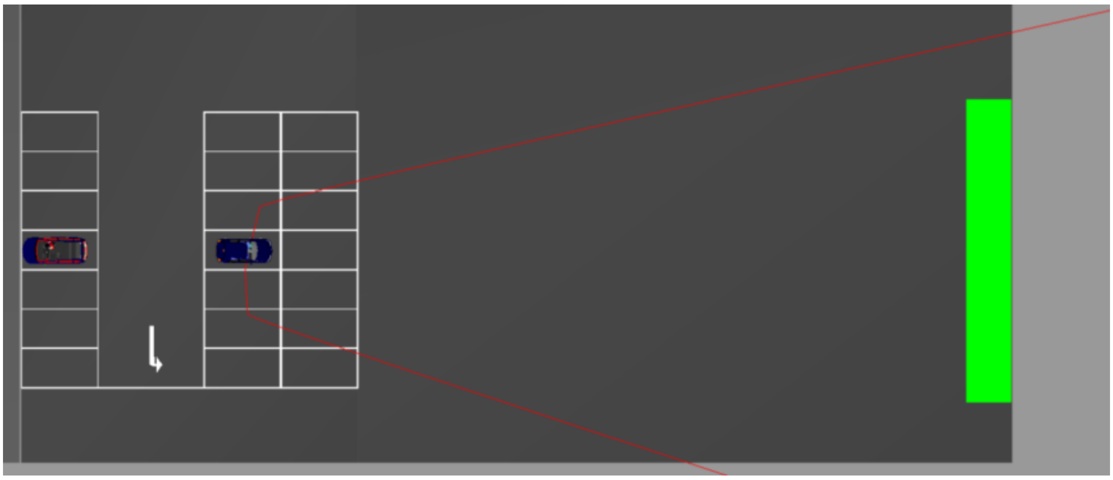

Figure 534. Idealised indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class I mirror)

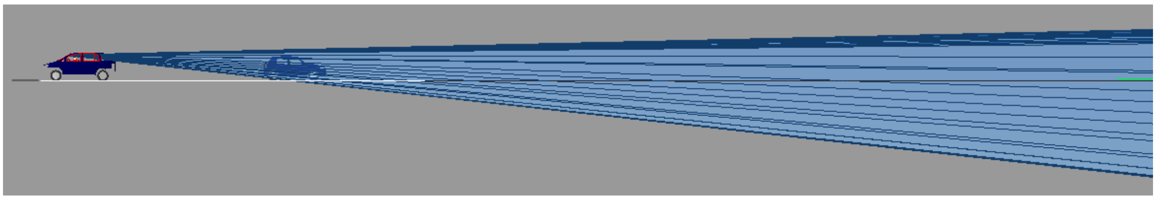

Figure 535. Idealised indirect rearwards view and correlation with the minimum field of view specified in ECE46-02 and 2003/97/EC (Class I mirror)

Figure 533, Figure 534 and Figure 535 above show that the recommended area is clearly within the idealised projection.

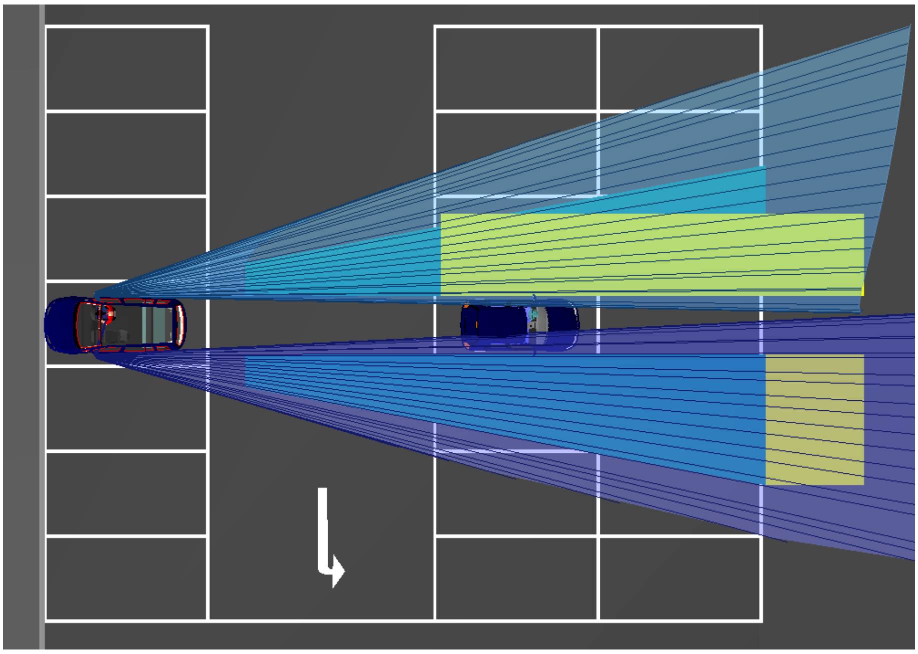

Figure 536. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-01, ECE46-02 and 2003/97/EC (Class III mirrors)

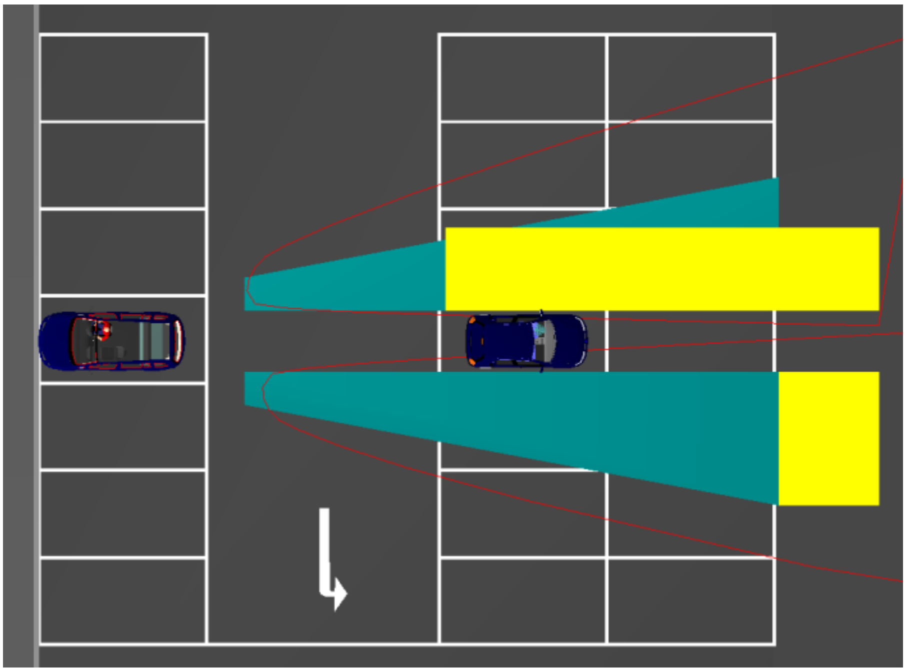

Figure 537. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-01, ECE46-02 and 2003/97/EC (Class III mirrors)

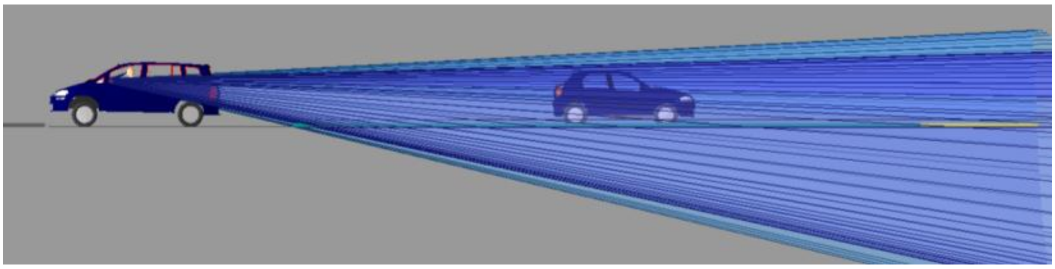

Figure 538. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-01, ECE46-02 and 2003/97/EC (Class III mirrors)

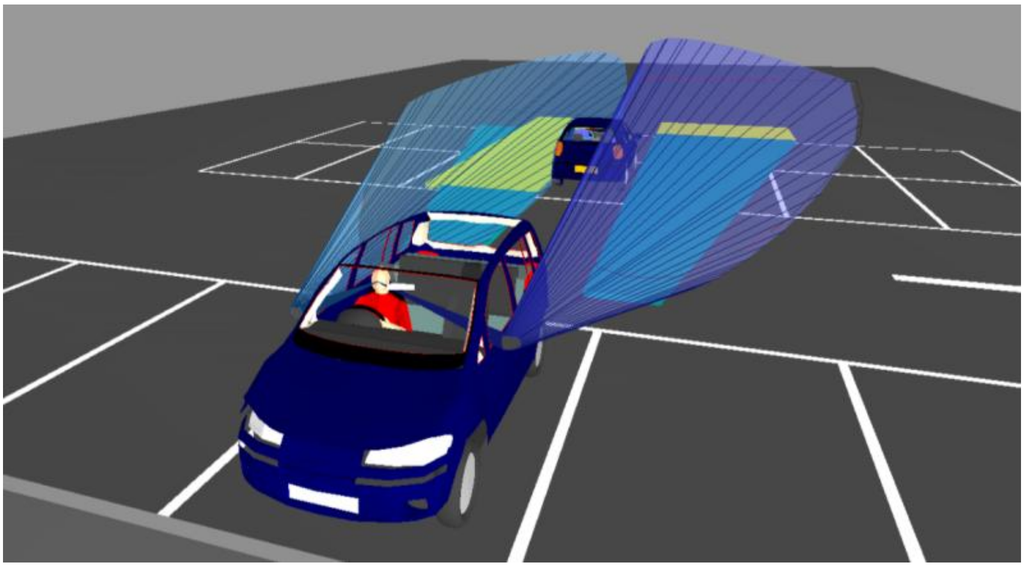

Figure 539. Indirect rearwards view and correlation with the minimum field of view specified in ECE46-01, ECE46-02 and 2003/97/EC (Class III mirrors)

The evaluation for the 35%ile UK female (Figure 536, Figure 537, Figure 538 and Figure 539) is very similar to that of the 99%ile Dutch male in compliance with in ECE46-01, ECE46-02 and 2003/97/EC for Class III mirrors.

4.4.2.3 Summary

In this section two vehicles were evaluated for their rearwards field of view

- M_1: a current (2010 on) model Volkswagen Touran – this MPV style vehicle is based upon the current Golf VI platform.
- M_2: a current (2006 on) model Ford Transit in long wheelbase mini-bus configuration.

4.4.2.3.1 M_1 Volkswagen Touran MPV

The indirect field of view for this vehicle appears to comply with the relevant standards for:

- Class I mirrors: the field of view complies with that shown in ECE46-02 and 2003/97/EC.
- Class III mirrors: when set up optimally to provide an appropriate rearwards view, the Class III mirrors fall marginally short of the field of view requirements for ECE46-02 and 2003/97/EC in relation to the areas closest to the rear of the vehicle, particularly on the nearside. It is likely that they could be adjusted to comply, but only with compromising rearwards view.

These findings are applicable for both extremes of the driver range with adjustability in mirrors allowing compliance for both the 35th %ile UK female and 99%ile Dutch male that were evaluated. Given the degree of adjustability it is likely that any intermediate human size and proportionality would also be accommodated.

It should be noted that the Class I mirror only theoretically complies with the standard. The field of view provided is only possible with no rear obstruction from bodywork or interior fixtures and fittings. In reality the rearwards field of view is compromised by internal fixtures such that rearwards view in the Class I mirror is only applicable to the uppermost half of the rear window.

This rearward limitation is also applicable to direct vision. Only objects greater than 1400mm in height could be guaranteed to be seen directly behind the vehicle. As such, the standard test as shown in ISO/TR 12155 is failed with none of the target markers being visible. The area of obscuration directly to the rear of the vehicle ranges from 6.5m to 10m rearwards of the back of the vehicle on the ground plane, and between 0.5 and 1.1m rearwards on a plane 1m above the ground plane. Thus it is quite possible that a small child, seated child or other obstacle lower than 1m could quite easily be obscured from the driver in a reversing manoeuvre.

4.4.2.3.2 M_2 Ford Transit minibus

The indirect field of view for this vehicle appears to comply with the relevant standards for:

- Class I mirrors: the field of view complies with that shown in ECE46-02 and 2003/97/EC (Note: this standard refers to N_1 and M_1 vehicles where Class I mirror fitment is compulsory. For the M_2 Transit, the Class I is optional).
- Class II mirrors: the field of view complies with that shown in ECE46-02 and 2003/97/EC.

This is applicable for both extremes of the driver range with adjustability in mirrors allowing compliance for both the 5^{th}%ile UK female and 99%ile Dutch male that were evaluated. Given the degree of adjustability it is likely that any intermediate human size and proportionality would also be accommodated.

In addition this vehicle has a Class IV mirror fitted on both the nearside and the offside. This mirror is not mandatory on this category of vehicle and indeed the relevant part of the ECE46-02 and 2003/97/EC standards is aimed at N_2 / N_3 vehicles. In this case the mirror does not comply with the standard, providing an insufficiently wide field of view.

It should be noted that the Class I mirror only theoretically complies with the standard. The field of view provided is only possible with no rear obstruction from bodywork or interior fixtures and fittings. In reality the rearwards field of view is heavily compromised by internal fixtures such that rearwards view in the Class I mirror is minimal. As such the mirror actually fails to comply with the standard in all practical applications.

This rearward limitation is also applicable to direct vision. Only objects greater than 1800mm in height could be seen directly behind the vehicle and then only to a small degree. It would be fair to suggest that rearwards visibility of this vehicle is essentially zero and could not be relied upon. Clearly the standard test as shown in ISO/TR 12155 is failed with none of the target markers being visible.

Directive 2001/85/EC (para 7.6.4.6)[14] implies an acceptable direct field of view in terms of detecting the presence of a person 1.3m tall standing 1m behind the vehicle. It has been shown that in the best case condition with the head restraints removed that it is possible to see an individual of 1.48m stature directly to the rear and that it is possible to see a plane projected at 1m height at a distance of 5.5m to the rear of the vehicle. This would suggest that a person of 1.3m stature at 1m would not be detectable.

4.5 Solutions

The evaluations performed have shown how it is possible for a vehicle to comply with the relevant standards and still provide a very limited rearwards field of view. For direct rearwards vision including the minimum field of view specified in ECE46-02 and 2003/97/EC for Class I mirrors it is clear that the specified area is much too limited to provide close proximity visibility. Both vehicles evaluated could not provide a view directly rearwards of the vehicle even for a 1m high target. A similar result is also observable in the 1m plane plots taken of the Volkswagen Golf (Figure 200) and the Hyundai i10 (Figure 248). It is recommended that a more specific rear visibility standard is investigated and implemented that identifies the necessary degree of rear visibility for category M_1 and M_2 vehicles and to also include N_1 vehicles which were not considered here but are assumed to have even greater reduced rearwards visibility.

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[14] which states 'If the direct view is not adequate, optical or other devices shall be installed to enable the driver to detect from his seat the presence of a passenger in the immediate interior and exterior vicinity of every side service door which is not an automatically operated service door. In the case of a service door in the rear face of the vehicle not exceeding 22 passengers, this requirement is satisfied if the driver is able to detect the presence of a person 1,3 m tall standing 1 m behind the vehicle.

Technical report ISO/TR 12155 provides an alternative test for vehicles fitted with detector systems. The results of this evaluation highlight the limitations of the rearwards field of view from the vehicles evaluated, with the test markers not visible in any of the tests. Head restraints and other fixtures and fittings provide a significant component of the problem. It is interesting to note that compliance with the standards for Class I mirrors would be not be possible in the M_2 vehicle if not taken in an idealised manner (clear unobstructed view through the rear windows). However it is acknowledged that these features are often necessary elements directly related to passenger safety and are unlikely to be able to be significantly reduced.

The Phase 1 report discussed the work on driver vision captured in the PNCAP study. Regarding rearward vision the PNCAP recommendations were that 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".

The evaluations performed here confirm these earlier findings with the vehicles being assessed not meeting this requirement. However, it is recognised that the driver is unlikely to be able to see the 1m target in any easily implemented manner. Thus the recommendation is that the driver is aided in detecting an obstruction within the blind spot through a non visual method.

Due to the limited rearwards view it is unlikely that additional inboard mirrors (e.g. Fresnel lenses) would offer a solution. After a brief investigation into Fresnel lenses that can be purchased for retrofitting to vehicles, one particular example, the Summit Wide Angle Rear Window Lens[15] was found to provide a view such that the angle subtended downwards from the lens was found to be 18° from the horizontal. Figure 540 below shows this if the Fresnel lens was applied to the Ford Transit. Additional

[15] http://www.autouseful.co.uk/motoring/Reversing-Mirrors/Summit---Rear-Window-Lens---Large

issues for these type of devices appear to be that they are not recommended for heated windows, and also appear to suffer from glare.

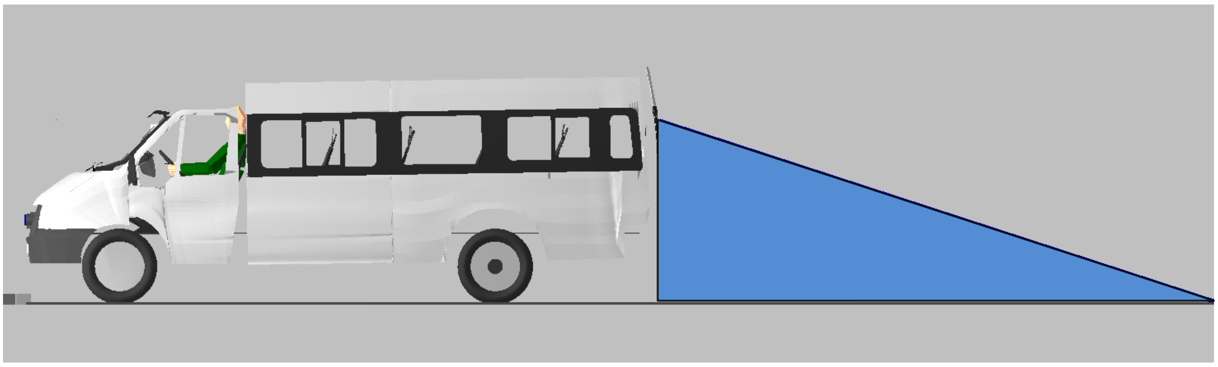

Figure 540. Angle of lower limit of visible area afforded by a Fresnel lens applied to the rear screen of the Transit (the blue area is not visible to the driver)

Alternative, outboard, mirrors such as the Velvac Rear Cross View Mirror[16] are capable of providing a view directly to the rear of a vehicle through a high level externally mounted convex mirror. This mirror is visible through the Class III mirror, bending the view to the rear of the vehicle. However, these mirrors are fitted on a tripod like mounting that protrudes from the bodywork of the vehicle. This would then be subject to regulations for impact resistance and also have a potential impact on aerodynamic performance. Due to these limitations it is unlikely that these types of system could be mandated to address this issue particularly for the M_1 vehicles.

Rear facing cameras would provide the necessary rearwards view. These could be mounted discretely and could be located in an optimum location based on vehicle type. However camera systems are not without their own issues. The most significant of which would be the investment required to install such systems. In addition, issues such as mounting the screen, the camera lens being clean, the focus of attention for the driver e.g. direct vision or reversing using the camera screen only, and so on, would all need to be investigated and a judgement taken on whether a camera based solution is appropriate.

It is the primary recommendation of this Work Package that the effective blind spot rearwards of these categories of vehicles is addressed through already existing rear detector systems as reviewed in Section 2.6.5 and Section 2.6.8.1.4 . These systems are

[16] http://www.truckntow.com/pc-10850-147088-rear-crossview-mirror-system-straight-van-chassis-white.aspx

increasingly common on M_1 vehicles either as standard fit, an additional option, or as a retro-fit option. The technology is mature and their function appears to be robust, in addition their cost is relatively modest. Finally, there is already a suitable technical report in place (ISO/TR 12155) to assist manufacturers in installing and configuring the systems to achieve an appropriate coverage of the obscured area.

For vehicles with essentially zero direct rearwards field of view such as the M_2 vehicle evaluated these should be considered to be mandatory to afford some rearwards coverage. For M_1 vehicles, mandatory fit may be less clear with the prevalence of serious accidents needing to be evaluated against the ability for the technology to have prevented the accident and the ultimate cost of forcing manufacturers to fit this technology. It may be true that this technology will be sufficiently ubiquitous in a few years time to be considered standard equipment on new vehicles. However, reversing accidents are still clearly a major concern as illustrated by the 2008 RoSPA report on Children In and Around Cars that highlights the problems with reversing off driveways and the potential for accidents to occur to small children not visible to the driver.

Intentionally Blank

5 WORK PACKAGE 4: MIRROR IMAGE QUALITY

5.1 Aim

The quality of vision provided to drivers through the regulation prescribed mirrors is dependent on a range of factors that includes, but is not limited to:

- The optical performance of the mirrors fitted
- The adjustment of the mirrors with respect to driver eye height and seat adjustment
- The impact of environmental factors (weather and lighting conditions) on the mirrors and vision
- The performance of drivers with respect to mirror checking.

The aim of this Work Package was to evaluate the quality of the image produced by Class IV, V and VI mirrors typically fitted to category N_3 vehicles through a series of controlled trials. The trials were designed to assess the quality of vision offered to drivers from regulation compliant mirrors with particular reference to target detection and identification. This aim recognises the risk that an increased field of view achieved through a wide angle mirror may compromise image quality as a result of distortion, particularly at the field of view boundaries.

The question addressed in the Work Package was intended to determine whether a representative sample of LGV drivers could detect and correctly identify appropriate targets under realistic but controlled conditions. The trials described in this section can be seen as complementary to the digital modelling of specific vehicle / mirror combinations undertaken to establish the maximum possible fields of view.

5.2 Rationale

There is a perception that the Class IV, V and VI mirrors fitted to category N_3 vehicles may not provide a clear image of the area covered. This Work Package investigated the quality of image and the impact this may have on drivers' interpretation of what they see in the mirror. As such, this Work Package builds upon Work Package 1 by assuming that there are no physical barriers to drivers detecting a hazard (i.e. the indirect viewing devices (mirrors) eliminate blind spots) and so investigate drivers' perceptual failure to *detect* a target which is visible and/or their failure to *identify* what they are able to see.

5.3 Experimental design

5.3.1 Pilot testing

Extensive preparatory work and pilot testing preceded the testing programme to ensure that the test method was adequately rigorous, practicable and capable of providing an unbiased answer to the research question.

5.3.1.1 Vehicle selection

A number of vehicles were used in the pilot testing and it was recognised that vehicle selection would be a material factor in the results achieved. The vehicle finally selected was a Volvo FH tractor unit, an N_3 category vehicle first registered in 2007 and fitted with mirrors compliant with Regulation ECE46-02 and Directive 71/127/EEC, as amended by 2003/97/EC (see Figure 541). It is acknowledged that different results may have been obtained if a different LGV /mirror combination had been employed but as the mirrors were regulation compliant the results achieved are representative within the variation accepted by the standard.

Figure 541. Volvo FH tractor unit used in trials

5.3.1.2 Initial mirror testing

In order to determine the measurements to be taken in the trials a series of preparatory measurements were undertaken to ensure the testing procedure was robust and effective. This comprised a methodical test of the quality of the field of view for each of the mirrors (Classes IV, V and VI). The test vehicle was positioned on a flat plane and a grid was marked on the ground adjacent to the vehicle that corresponded to the required field of view for each mirror (nearside and offside to the rear, cab front and cab near side, see Figure 544, Figure 545 and Figure 546). Each bounded area was then subdivided using a 1-metre grid for Class IV mirrors and a half-metre grid for Class V & VI mirrors. The mirrors were adjusted so that a test driver was able to see the full prescribed area from the driving position (in some cases this required a head and / or body movement). Finally, the quality of vision was assessed through the repeated presentation of a standard test target at each grid intersection.

The test target comprised a cylinder (900mm high & 300mm diameter), see Figure 542. The cylinder was painted black and white and had a top plate marked with black and white quadrants and can be seen as consistent with the dimensions of a child pedestrian.

Figure 542. Test target used to validate prescribed field of view

The test procedure involved presenting the test target at each grid point in turn and asking a driver to make a glance observation in the appropriate mirror. The driver was asked to report the presence / absence of the test target and the degree of distortion/visibility if perceived. This procedure enabled the production of detection plots indicating areas of the field of view that were likely to be more prone to detection failure or image distortion. It was established that the view afforded by Class IV mirrors was generally adequate and undistorted, poor vision was only reported for test locations at the maximum tested distance.

5.3.1.3 Test procedure piloting

As the assessments comprised a set of subjective judgements about targets perceived in the driver's field of view it was recognised that careful definition of the test procedure would be necessary for consistency as well as ecological validity. Furthermore, the tests were all undertaken in a static vehicle and the participant drivers would need to be given clear guidance on the required task. Factors that were considered and tested included:

- The purpose of the inspection (e.g. "an offside mirror check before changing lanes"; "a blind spot check before pulling away at a junction").
- The glance duration for each observation: The use of occlusion techniques was ruled out as it was considered to be inappropriate to artificially constrain driver behaviour (eye glance data from on-road driving studies suggests an upper limit for voluntary eyes-off-road episodes of some 2.0 seconds; there are no published data for glance times to mirrors for LGV drivers therefore fixing the glance duration might fix it to an unrealistic measure). It was therefore agreed that drivers would

be given a scenario and asked to make what they judged to be an appropriate glance to the mirror. Furthermore, all glances would be timed by stopwatch to provide a check that identification and interpretation performance was not simply a function of duration of observation.

- Priming: Although each mirror would be tested in sequence the presentation of test targets in the field of view would need to be randomised and there would need to be a sufficient number of 'empty' presentations in order to prevent drivers anticipating the next presentation outcome. Attention would also need to be paid to reducing opportunities for the drivers to pick up relevant information via the mirrors not being tested or from direct vision (and hearing).
- Standardising the driver response: To ensure consistency of response between participants it was necessary to ensure that each observation was not only presented in a consistent fashion but that each question and subsequent response was also given in a standardised fashion.

5.3.2 Participants

Advertisements were placed in a range of locations (local road haulage companies; truck stops; networking contacts; etc.). These enabled 20 drivers to be recruited who met the following minimum criteria:

- Class C licence holders, licensed to drive N_3 vehicles (i.e. >12 tonnes)
- Regular driving history in the last 12 months
- Eyesight consistent with licence requirements.

5.3.3 Procedure

All testing took place at a local disused airfield, now a centre for a range of automotive activities. The disused runways provided the necessary flat and open space required to mark out the field of vision grids and to complete the subsequent testing with a minimum of visual distraction.

The test vehicle was positioned on the grid with respect to a reference point marked on the ground that corresponded to the driver's eye position. Drivers were met, had their licences and eyesight checked and then briefed on the project. The test targets which they would be required to detect and identify in the mirrors were then shown to them.

Participants were then invited to mount into the vehicle's cab and adopt a comfortable driving position. A photograph was then taken of the driver through the open cab door from a tripod-mounted camera located at a defined position. This image allowed driver eye position (height) to be estimated as a check that the sample of drivers did not have skewed stature and hence a-typical eye height. Test targets were selected that were considered appropriate for the mirror under assessment. For the Class IV mirrors these were a car (Hyundai i10; metallic grey) and a cyclist. (Whilst it is recognised that the cyclist may have limited direct relationship to the Class IV mirrors, their dimensions are similar to those of motorcyclists which are more pertinent to this mirror. It was considered that if the cyclist could be detected and recognised then so to would a motorcyclist under the same conditions as most motorcycles will have a stronger visual profile). For the Class V and VI mirrors the test items were a cyclist, a child dummy and a black bag which was used to introduce a realistic target that might be mistaken for a child from a top-down view. The cyclist was presented in forward facing (f/f) orientation for Class IV and V mirror testing and both forward facing and transverse, or left-right (l/r), orientation for Class VI tests.

Figure 543. Target items used in trials

The locations for test item presentation were determined on the basis of the pilot testing and use-case scenarios. In the case of Class IV mirrors, targets were presented at locations that corresponded to two nearside and two offside 'lanes' relative to the vehicle. Within each 3m wide 'lane', three longitudinal locations were selected; at the front of the prescribed area, at a mid distance approximating to the rear of an attached trailer and a distant point at the rear of the 25m prescribed area. Two further test locations were also selected that corresponded to the most distant lateral locations within the prescribed area, one 8.5m behind the start of the prescribed area and one at the rear of the prescribed area. The 8 separate test locations covered the prescribed areas to either side of the vehicle and were consistent with realistic driving scenarios (i.e. an LGV operating in a multi-lane environment with cars and two wheeled vehicles in adjacent lanes). See Figure 544.

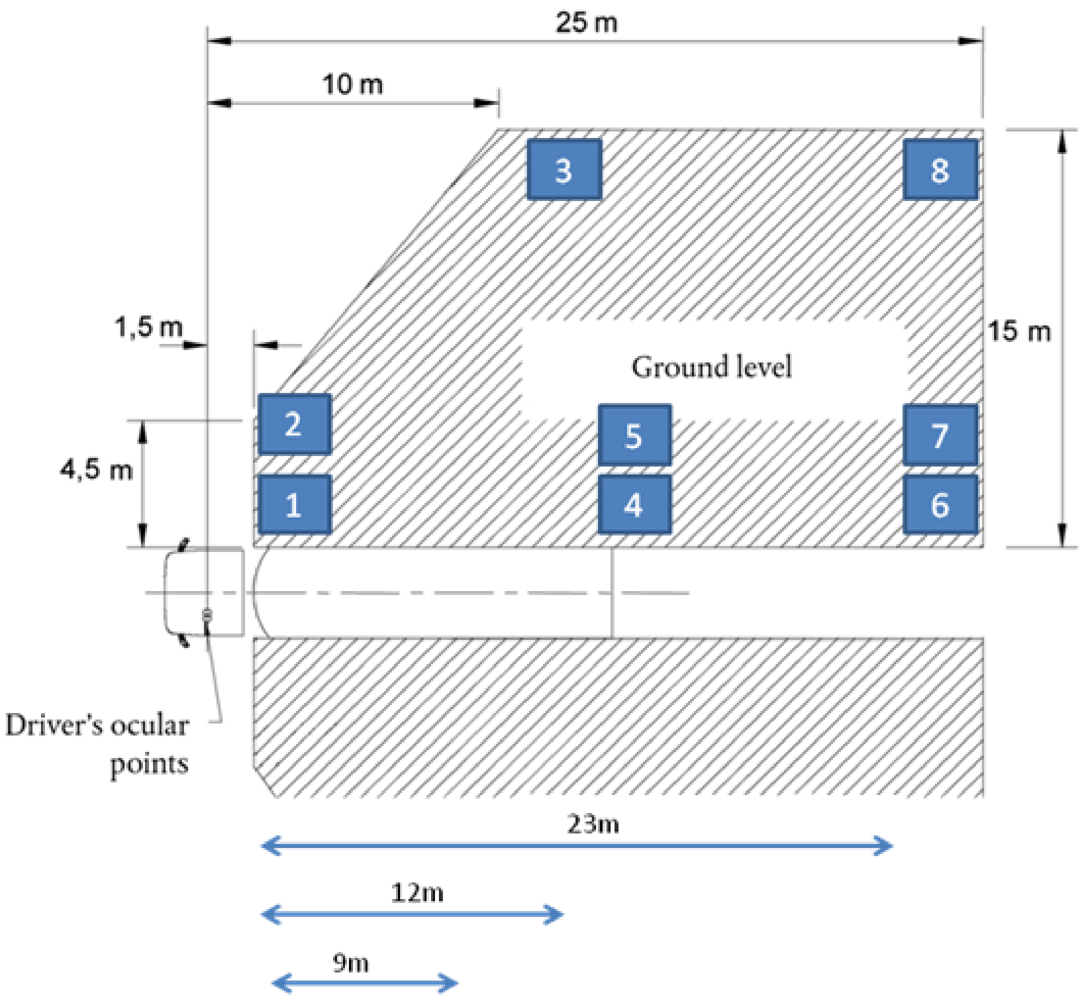

Figure 544. Class IV trial target locations
(offside only shown, near side are exactly opposing locations)

Test locations for Class V assessments were also selected based on the prescribed area and use-case scenarios. The primary scenarios involved the detection of a child pedestrian (or bag) close to the vehicle (0.5m) or a cyclist at an appropriate distance away from the vehicle (1m and 2m). Three longitudinal locations were defined; parallel with the driver's eye point, at the leading edge of the prescribed area and at the rear of the prescribed area. See Figure 545.

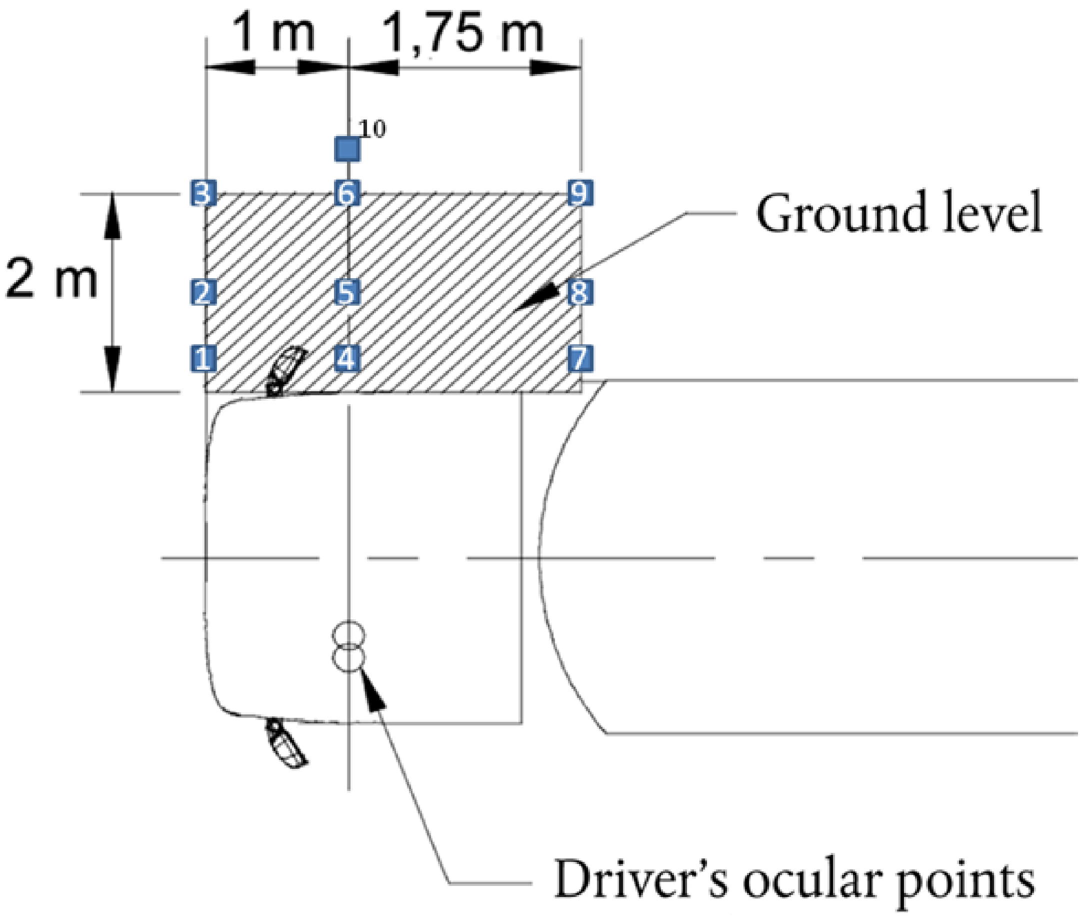

Figure 545. Class V mirror presentation locations
(NB Diagram shows an offside orientation image from reference document;
a nearside mounted mirror was tested)

A similar approach was used in defining the test locations for the Class VI assessment. The test targets were chosen to reflect concerns about the detection of vulnerable road users in the blind spot in advance of a LGV and comprised a cyclist (in longitudinal and transverse orientation), the child manikin and the black bag. Presentation locations were chosen within the prescribed areas at distances of 0.5, 1.0, 1.5 and 2.0m in advance of the vehicle cab. The test locations were spread laterally across the prescribed area to reflect realistic use case scenarios. See Figure 546.

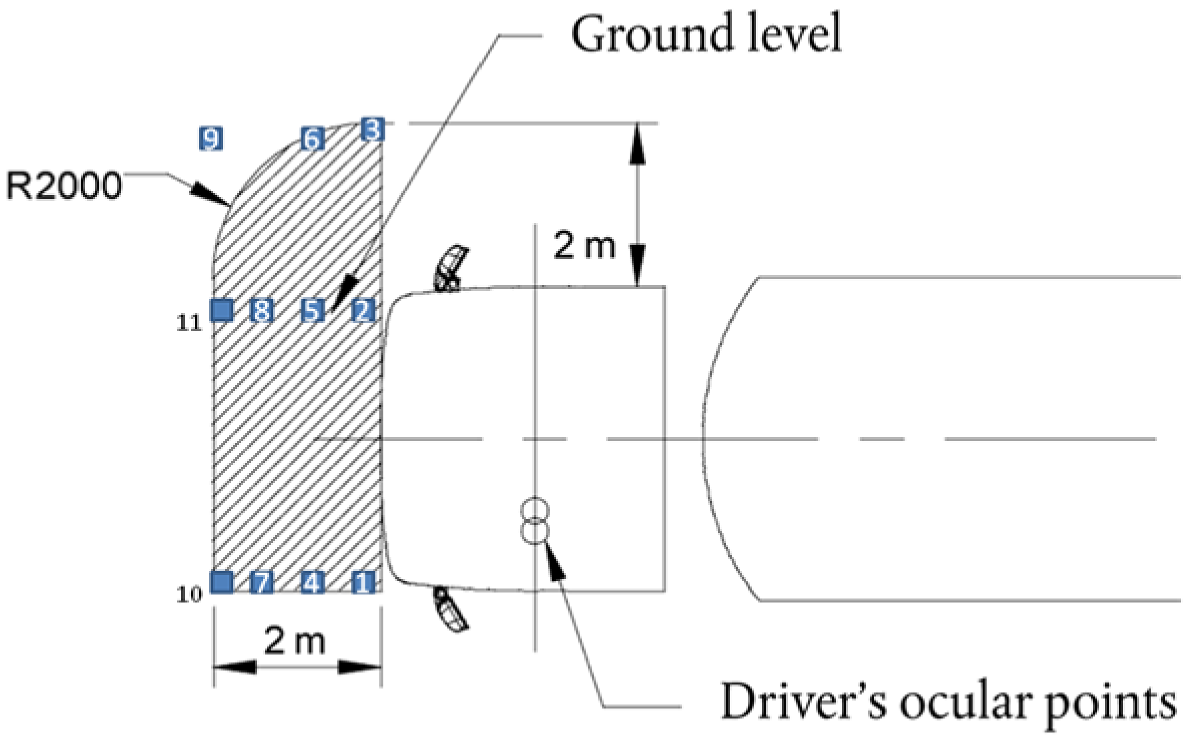

Figure 546. Class VI Mirror presentation locations
(NB Diagram shows an offside orientation image from reference document;
a nearside oriented mirror was tested.)

A schedule of presentations was devised that randomly allocated a test item to each location to ensure that all items were presented in all required locations. Each location was also associated with a blank presentation during each participant's assessment. The order of presentation was reversed for half of the participants. This approach ensured that all test items and locations were involved in presentations and that participants had a minimum chance of predicting where an item might be presented next or if there would be any presentation at all.

The participants were instructed to look to the front of the vehicle (except in the case of Class VI mirror testing, where they were asked to look out of the offside window) in between presentations. All non relevant mirrors were masked. When a presentation was ready, the participant was given a countdown and asked to make a glance in the relevant mirror and to report in the following standard manner:

- Was target visible ("Yes or No")
- What the target was (Car, bicycle, child, bag)
- Their confidence in that identification (1-7 scale)
- Whether the target was visible through direct vision (i.e. directly through a window).

The elapsed time from the prompt to look to the first verbalised response was noted (See Appendix 3). After each response was noted an instruction was passed to the assistants outside the vehicle and the next presentation was prepared. This process was repeated for each mirror tested. The total procedure took some 90-120 minutes for each participant.

5.4 Results

5.4.1 Class IV mirror (nearside)

There were a total of 240 test presentations for this mirror (10 car, bike and blank presentations at each of 8 locations). A very high detection rate was achieved with a slightly lower recognition rate, see Table 29

Class IV Mirror (nearside)	%
Correct detection rate	99.38
Correct recognition rate	93.75

Table 29. Class IV (nearside) target detection and recognition rates

All the cars were detected and only one car was missed but bikes were more likely to be incorrectly identified than cars (8 bikes, 2 cars). It is likely that target size was a factor in the latter difference, see Table 30 and Table 31

Detection performance	**Target type**	
	Bike	**Car**
Presentations	80	80
Incorrect	0	1
% incorrect	0	1.25

Table 30 Class IV (nearside) target detection by target type

Recognition performance	**Target type**	
	Bike	**Car**
Presentations	80	80
Incorrect	8	2
% incorrect	10	2.5

Table 31. Class IV (nearside) target recognition by target type

Whilst detection performance was uniformly accurate across the test locations, the distribution of recognition failures suggested that target distance was a factor. A total of 8 of the 10 recognition failures were associated with the three most distant points within the prescribed area (locations 6, 7 and 8), See Table 32.

Location number	Failures in:	
	Target detection	Target recognition
1		
2	1	1
3		
4		
5		1
6		2
7		2
8		4

Table 32. Class IV nearside failures of detection and recognition by location

5.4.2 Class IV mirror (Offside)

There were a total of 240 test presentations for this mirror (10 car, bike and blank presentations at each of 8 locations). The detection and recognition rates were similar to those found with the near side mirror, see Table 33.

Class IV Mirror (Offside)	%
Correct detection rate	98.75
Correct recognition rate	96.25

Table 33: Class IV (offside) target detection and recognition rates

Whilst bikes and cars were all detected correctly, bikes were more likely to be incorrectly identified (5 bikes and 1 car), See Table 34 and Table 35.

Detection performance	Target type	
	Bike	Car
Presentations	80	80
Incorrect	0	0
% incorrect	0	0

Table 34: Class IV (offside) target detection by target type

Recognition performance	Target type	
	Bike	Car
Presentations	80	80
Incorrect	5	1
% incorrect	6.25	1.25

Table 35. Class IV (offside) target recognition by target type

As with the near side mirror performance, the participants were able to detect targets throughout the prescribed area. Recognition failures also appear to have been influenced by distance from the mirror. There were 6 recognition failures associated with locations 6, 7 and 8 – the most distant locations, see Table 36.

Location number	**Failures in:**	
	Target detection	**Target recognition**
1	1	1
2	1	2
3		
4		
5		1
6	1	3
7		1
8		2

Table 36. Class IV offside failures of detection and recognition by location

In summary, the participants were able to correctly detect and recognise targets presented at locations throughout the prescribed area with a slight performance reduction at the most distant locations. The participants were slightly quicker when making correct identifications and recognition judgements than when making incorrect judgements. The confidence of the participants when making correct judgements was higher than when making incorrect judgements.

5.4.3 Class V mirror

The participants were each presented with a total of 500 trials across ten test locations defined in Figure 545. The nine locations within the prescribed area were selected on the basis of realistic use case scenarios; pedestrians close to the vehicle and cyclists positioned adjacent to the vehicle at a range of distances. A bag that might be confused with an oblique view of a pedestrian was also employed along with a number of blank presentations and a vehicle positioned just outside the prescribed area. An additional test location (number 10) was also defined just outside the prescribed area at a mid-point longitudinally. The rationale for including a point outside the test area was to give an indication of the mirror's ability to provide a usable field of view beyond the area prescribed in the regulations. This was considered important because an understanding of the impact of distortion at the boundary of the mirror's field of view would provide insight into the potential impact of incorrectly adjusted mirrors on detecting and recognising targets in the prescribed area. The exact location of point 10 was adjusted for each participant in an iterative fashion to ensure the location was on the boundary of detectable vision.

Compared with participant performance with Class IV mirrors, the observed detection rate for the Class V mirror was inferior to that achieved for the Class IV mirrors. Of the 500 presentations, only 470 were correct, see Table 37.

Class V Mirror	%
Correct detection rate	90.0
Correct recognition rate	82.3

Table 37. Class V target detection and recognition rates

When detection performance across the different target types was analysed it appeared that detection performance was not uniform with some targets being detected much more frequently than others, see Table 38.

Detection performance	Target type			
	Bike	Car	Child	Bag
Presentations	140	20	80	60
Incorrect	9	10	9	2
% incorrect	6.4	50	11.25	3.33

Table 38. Class V target detection by target type

The relatively poor detection rate for cars is explained by the fact that this target type was only presented in location 10, outside the prescribed area and was therefore unlikely to be adequately visible in the mirror for most participants. However, target location clearly had a major impact on all the detection results as 83.3% of all the detection errors were associated with a single location, location 10.

Recognition performance	Target type			
	Bike	Car	Child	Bag
Presentations	140	20	80	60
Incorrect	15	11	17	10
% incorrect	10.7	55	21.25	16.66

Table 39. Class V target recognition by target type

The participants were substantially less successful in correctly recognising targets than in detecting that a target had been presented, see Table 39. However, with the exception of the bag, there were similarities with detection performance in the recognition performance across different target types. Car recognition was the least successful followed by child, (bag) and then bike. Again, differences in presentation location accounted for the majority of differences in recognition performance with 29 of the 53 recognition failures associated with location 10, see Table 40. When data for location 10 were removed the detection rate and recognition rates improved to 97.92% and 90% respectively.

Location number	Failures in:	
	Target detection	Target recognition
1		5
2		1
3		2
4	1	7
5		0
6		1
7	3	6
8		1
9	1	1
10	25	29

Table 40. Class V failures of detection and recognition by location

In summary, target identification was strong across all test locations in the prescribed area. In contrast, recognition rates were weaker with a number of target and location combinations at the periphery of the prescribed area generating recognition failures. Both target detection and recognition are depressed compared with Class IV mirror results. However, the vast majority of the detection and recognition failures were found at location 10. The results obtained may indicate that the field of view provided by the mirror is closely bound to the prescribed area with a rapid reduction in mirror performance at the periphery of the field of view provided. Thus a target just outside (or approaching) the prescribed area is more difficult to detect and interpret correctly. This makes the extent of the prescribed area and the appropriate adjustment of the mirror particularly important.

5.4.4 Class VI mirror

A total of 660 presentations were made to participants in the Class VI mirror trial. The targets comprised the child, bag and bike in two orientations – forward facing (f/f) and left-right (l/r) to simulate cyclists travelling in the same lane as the vehicle and cyclists crossing the path of the vehicle. The global level of target identification and recognition was very similar to that achieved by the participants with the Class V mirror, see Table 41.

Class VI Mirror	%
Correct detection rate	92.67
Correct recognition rate	84.67

Table 41. Class VI target detection and recognition rates

Detection performance	Target type			
	Bike f/f	Bike l/r	Child	Bag
Presentations	100	100	120	120
Incorrect	3	1	9	9
% incorrect	3.0	1.0	7.5	7.5

Table 42. Class VI target detection by target type

The results suggest that the child (7.5% detection failures) and bag (7.5%) were more likely to be missed than the bike in f/f or l/r orientation (3 and 1% respectively), see Table 42. This difference was also found with respect to target recognition where the child had an incorrect recognition rate of 17.5%, the bag 12.5%, the forward facing bike 6.0% and the left-right facing bike 4.0%, see Table 43.

Recognition performance	Target type			
	Bike f/f	Bike l/r	Child	Bag
Presentations	100	100	120	120
Incorrect	6	4	21	15
% incorrect	6.0	4.0	17.5	12.5

Table 43. Class VI target detection by target type

As with the other mirrors tested, an analysis of target identification and recognition by target location indicated that a small number of locations accounted for the majority of the detection and recognition failures. Across all target types 13 (59.1%) of the detection failures were associated with presentations at location 9 which was situated just outside the prescribed area. The remaining failures occurred at locations 3 (22.7%) and 6 (13.63%). These latter two locations were at the nearside boundary of the prescribed area, the most distant part of the field of view provided by the Class VI mirror.

An analysis of detection errors by location and target type revealed a non-uniform distribution of errors. The errors associated with location 9 (outside the prescribed area) were only found with child and bag presentations (31.8% and 27.3% of the detection errors respectively). A smaller proportion of the child and bag detection errors were also found at location 3 (9.0% and 13.6% respectively). Bike detection errors were found at locations 6 and 11, but in small numbers. A further analysis of the data indicated that most participants were able to see the cyclist, or part of the cyclist, via direct vision at these locations (62.5% detection at location 6; 90% at location 11). It is possible that their response was influenced by direct detection through peripheral vision.

Target location also impacted the participants' poorer recognition performance but there was a slightly greater distribution of failures across the test locations. Location 9 accounted for 36.9% of the failures and locations 2, 3 and 6 accounted for 19.6%, 15.2% and 10.9% respectively. As with the detection results, weaker recognition performance was associated with locations that were more distant from the driver, see Table 44. When data for location 9 was removed the detection rate improved to 97.8% and the recognition rate improved to 92.1%.

Location number	**Failures in:**	
	Target detection	**Target recognition**
1		1
2		9
3	5	7
4		1
5		2
6	3	5
7		1
8		1
9	13	17
10		
11	1	2

Table 44. Class VI failures of detection and recognition by location

As with the detection data for the Class V mirror, the target recognition results show an effect for target type. Again, the failures associated with location 9 were associated with presentations of the child (15.2%) and bag (21.7%) but not the bike (0.0%). In contrast, there were no failures in cyclist recognition at locations 2 & 3 but there were for child (26.1%) and bag (8.7%). Bike detection and recognition failures of both types were also found at location 6 (10.8%) although there were no failures for child or bag at this location.

In summary, while gross detection and recognition rates were similar to the Class V mirror performance there were variations with respect to both location and target type. The majority of detection and recognition failures were associated with the external test location but locations at the periphery of the prescribed area also performed poorly. This suggests that there is not only a steep reduction in indirect vision at the field of view boundary but the quality of vision at the perimeter was also compromised. The differences in detection and recognition between target types at different locations suggest that differential capture of target height and degree of distortion may have a significant impact on the quality of vision afforded by this type of mirror.

5.5 Conclusions

5.5.1 Mirror performance

The results across all 3 classes of mirror suggest that it is possible to detect (Class IV nearside = 93.75%; Class IV offside = 96.25%; Class V = 97.92% and Class VI = 97.75%) and correctly identify (Class IV nearside = 99.38%; Class IV offside = 100%; Class V = 90% and Class VI = 92.08%) a range of representative target types throughout the prescribed areas. The task undertaken by the participant drivers was an approximation of the task undertaken under normal driving conditions and a degree of discrepancy must be accepted. However, the response time and recognition confidence data consistently indicated that (i) participants were not achieving greater detection accuracy by allocating more time to achieve correct decisions and (ii) the participants were aware that their judgements were likely to be less accurate when they were incorrect. Both results support the view that participants undertook the task in line with the task requirement.

The results are clearly limited to static situations under day-light conditions and different results, particularly to Class IV mirrors, might be obtained in dynamic driving conditions. Similarly, real world performance may be reduced by rain on the windscreen and/or dirt on the mirrors (as mentioned by some of the trial drivers) and also by other task demands such as time pressure. While the detection and recognition performance data may seem reassuring, the participants made a number of relevant comments about difficulties experienced in real world conditions. In addition to problems of adjustment and cleanliness there was also a difficulty associated with checking multiple mirrors. Before pulling away at a junction it is necessary to check all mirrors and the direct view through a combination of windows. In the time taken to complete this procedure it is possible for a target to enter a field of view that has already been checked and thus become vulnerable when the vehicle starts to move. It was suggested that a video based system might be less vulnerable to this danger. Irrespective of any advantages achieved through a potentially greater field of view, a single camera display with an integrated image would enable a combination of prescribed areas to be checked with a single glance.

5.5.2 The significance of mirror adjustment

The degraded performance associated with the peripheral region of the Class VI mirror and the consistently poor performance associated with test locations immediately outside the prescribed area both suggest a rapid decline in performance at the edge of the field of view.

At the start of each trial session for each mirror the participants were asked to check and adjust the appropriate mirror to ensure that (i) the driver was able to see the whole of the prescribed area and that (ii) the image of the the prescribed area was centred on the mirror. This procedure was intended to provide a standardised condition for each set of measurements and to provide minimum image distortion. The procedure adopted involved a traffic cone being placed at the corners of the prescribed area and the mirror adjusted until all cones were visible, see Figure 547.

Figure 547. Class VI mirror adjustment procedure

While inadequate mirror adjustment has been recognised (Niewoehner, 2009) as a significant contributor to truck blind spots there is no current data on the prevalence of this problem within the vehicle fleet. Comments made by participants in the current trial suggested that mirror adjustment and cleaning was also recognised as a problem by drivers, particularly in the case of vehicles driven by multiple drivers. Test adjustments made in the current trial indicated that the Class IV mirror could be adjusted to show a range of views that all included the prescribed area. The most extreme adjustments provided a significant view of the cab body but displaced the prescribed area from the central portion of the mirror to the periphery which is subject to greater distortion and as the trials have shown, greater reductions in detection and recognition performance.

5.6 Recommendations / solutions

The results reported in this section suggest that Class IV, V and VI mirrors are capable of providing good indirect vision of the prescribed areas. However, in order to achieve the maximum visual benefit, correct adjustment is essential.

At present it is not clear what proportion of the UK fleet is currently being operated with inadequate mirror adjustment for the population of drivers who are using them. A national level survey of mirror adjustment would provide valuable data on the scale of the problem.

To encourage adjustment, drivers' awareness of its importance must first be raised. Drivers then need to be encouraged and helped to make such adjustments. The difficulties faced by a driver adjusting mirrors on their own was noted in the Phase 1 report (see p 148) and demarked set-up areas such as those shown in Figure 548 can assist the driver in this respect. However a means for the driver to adjust the mirrors from their seat is also important. Mirrors which are not remotely adjustable require the lone driver to get in and out of their seat and traverse the cab interior (or in the case of the Class VI mirror, exit the cab and climb a ladder to the front) possibly a number of times before the correct adjustment is achieved. This is time consuming and physically challenging; a problem that will become more significant as the ageing population reflects itself in the driver population.

Figure 548. Mirror adjustment guidance (from Niewoehner, 2005)

An alternate solution would be to specify a mirror capable of accommodating a broad range of driver eye heights (1^{st}- 99^{th} percentile) and then requiring that the mirror be mounted on a fixed bracket. This would prevent the problem experienced by a tall driver taking control of a vehicle after a much shorter driver had previously adjusted the mirror to suit their eye height. This solution assumes that the problems created by poor adjustment are greater than those arising from a non-adjustable mirror; an assumption that would need to be investigated.

Finally, the observation of multiple mirrors and the external road-scene presents a significant challenge to drivers when negotiating junctions in traffic. The potential replacement of mirrors with cameras, supplemented by short range ultra-sound detectors presents a significant opportunity.

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6 WORK PACKAGE 5: RELIABILITY OF DETECTION SYSTEMS

6.1 Aim

The aim of this Work Package is to physically test the performance of a range of detection systems designed to improve driver awareness of targets to the front, side and rear of a category N_2 / N_3 vehicle. The rationale for this Work Package is grounded in a perception that (i) current mirrors may not provide the quality of vision required to accurately detect and interpret vulnerable road users in close proximity to the vehicle and (ii) drivers faced with considerable visual demand would benefit from a system that drew their attention to a potential risk. Physical testing was performed in daytime and night time conditions across three classes of detection aid technologies:

- Standard Class V and VI mirrors and an extended view Class V mirror
- Camera systems
- Sensors.

The aim of the assessment covered the range of the detection field and the accuracy of each system's detection. Pertinent issues relating to interpretation of information conveyed via the images / systems were also recorded and are presented as discussion points in Section 6.4. The systems' abilities to attract the driver's attention were not within the scope of the agreed work plan.

6.2 Method

6.2.1 Systems tested

In total three detection systems were assessed that covered the front area of the vehicle (Table 45) and four systems were assessed that covered the side of the vehicle (Table 46). Systems providing coverage to the rear of the vehicle were not included specifically as part of this assessment, as the systems used on the rear would be identical to the systems used on the front of the vehicle to provide front coverage. Therefore all results for the front area (excluding Class VI standard mirror) can be applied to provide detection areas and accuracy measures for a rear system. However it should be noted that the camera system to the rear would typically be mounted at a higher location than the mount position of the camera on the front of the vehicle, thus a rear camera system would provide a slightly wider field of view and reduce the size of target image presented on the monitor.

Camera and mirror systems are listed as visual systems whereas sensor systems are listed as ultrasonic (audio) detection systems. Slightly different methodologies were used to assess the visual and audio systems, this is presented later in Section 6.2.4. However, all observations were made by a panel of expert human factors assessors who had been involved in all aspects of the work programme.

Detection technology	Type of system	Name	Manufacturer	Characteristics
Mirror	Visual	Class VI mirror compliant with Directive 2003/97/EC. (As used in Work Package 4)	Standard make provided by vehicle manufacturer.	N/A
Camera and viewing screen	Visual	Camera - BE 500VC Viewing Screen - BE 870 FM Backeye	Brigade	Screen
Sensor	Audio	Backscan AW Class parking Sensor	Brigade	Detection distance up to 2.5m, Accuracy < +-5cm. Three stage warning system with different sounding audio (Table 47)

Table 45. Technology assessed to the front of the vehicle

Detection technology	Type of system	Name	Manufacturer	Characteristics
Mirror	Visual	Class V mirror compliant with Directive 2003/97/EC. (As used in Work Package 4)	Standard make provided by vehicle manufacturer.	N/A
Mirror	Visual	Spafax extended view Class V mirror	Spafax International Limited	
Camera and viewing screen	Visual	Camera – BE L110A0803. Viewing Screen - BE 870 FM Backeye	Brigade	Screen
Sensor	Audio	Backscan BS 445 AW Class parking Sensor	Brigade	Detection distance up to 2.5m, Accuracy < +-5cm. Three stage warning system with different sounding audio (Table 47)

Table 46. Technology assessed to the side of the vehicle

Distance of target from sensor	Audio Signal
0 to 0.6m	Continuous
0.6 to 1m	1/8 second
1 to 2.5m	½ second

Table 47. Sensors audio signal warnings

6.2.2 Fitment of the systems

Each system was set up to optimise detection in the Class V and Class VI prescribed areas (and, in the case of the Spafax mirror, the extended area specified in the GRSG proposal amendment to regulation No. 46 (January 2011)). The camera and sensor systems were fitted to the Volvo FH tractor (as used within the quality of vision trials) by a qualified fitter provided by the manufacturer of the product. The vehicle used in the study was a hired vehicle and therefore permanent changes could not be made. The temporary fitting of the devices was discussed with the manufacturers and the following methods of temporary adhesion were subsequently employed. The front camera was mounted on the vehicle's upper front panel, below the cab windscreen. As this panel was made from a composite material a metal disc was stuck to the panel so that the camera could then be attached using magnets. The side camera was fixed directly to the vehicle magnetically. The side sensors were attached using a plastic 'U' shaped bracket and double sided tape between the bracket and the vehicle. Prior to the assessment, the mirrors and camera systems were adjusted such that each expert conducting the assessment could see the appropriate areas (either Class VI or Class V) as prescribed in Directive 2003/97/EC.

6.2.2.1 Class VI Mirror

Class VI mirrors can be mounted either centrally, in the middle above the front windscreen or laterally, to the nearside. For the purposes of the trials the mirror was positioned in the lateral position, as this is preferred by some drivers since it is possible to access it via the near side door rather than needing to use a ladder for cleaning and adjustment (Figure 549).

Figure 549. Class VI mounted in lateral position (Mirror within red box)

6.2.2.2 Extended Class V mirror – Spafax

The extended view Class V mirror, which incorporates a glass of 300mm radius of curvature (which is common across Class V mirrors) but has a greater height and so covers a larger area to the side of the vehicle if adjusted properly, was mounted in the same position as the Class V mirror (Figure 550).

Figure 550. Spafax mirror mounted in Class V mirror position

6.2.2.3 Front camera system

The camera was mounted by the manufacturer to provide Class VI coverage. The camera was mounted 1800mm above the ground in the middle of the front of the vehicle. Due to the temporary nature of the fitting, the camera protrudes the front body work by approximately 50mm (Figure 551). In a permanent fitting a small hole would be made and the camera would be mounted flush with the bodywork of the front panel. For the purposes of this assessment this difference would have minimal effect.

Figure 551. Camera fitted to the front of the vehicle

6.2.2.4 Front sensors

A series of four front sensors were mounted onto the front lower portion of the cab (Figure 552). These were mounted by the manufacturer to provide Class VI coverage.

Figure 552. Sensors fitted to the front of the vehicle.

6.2.2.5 Side camera system

The camera was mounted by the manufacturer to provide Class V coverage. The camera was mounted 2650mm above the ground. Due to the temporary nature of the fitting the camera protruded slightly, by approximately 30mm (Figure 553). In a permanent fitting a small hole would be made and the camera would be mounted flush with the bodywork. For the purposes of this assessment this difference would again have minimal effect.

Figure 553. Camera fitted to the side of the vehicle

6.2.2.6 Side sensors

A series of four sensors were mounted along the side lower portion of the cab (Figure 554) and just beyond. These were mounted by the manufacturer to provide Class V coverage.

Figure 554. Sensors fitted to the side of the vehicle

6.2.3 Test area

A grid was marked out on the ground to the front and nearside of the vehicle using one metre intervals. The grid encompassed an area three metres in front of the vehicle, five metres out to the near side of the vehicle and two metres to the off side of the vehicle. This area was sufficiently large to capture detection ranges beyond those specified in Directive 2003/97/EC but restricted to the point at which detecting objects by direct vision was potentially possible. In addition, this test area also covered that prescribed in the GRSG proposal. Figure 555 shows the grid used to assess front detection systems and Figure 556 shows the grid area used to assess the side detection systems. The area highlighted in yellow represents the area as prescribed in Directive 2003/97/EC and the area highlighted in orange represents the area as recommended in the GRSG proposal. The black area represents the LGV.

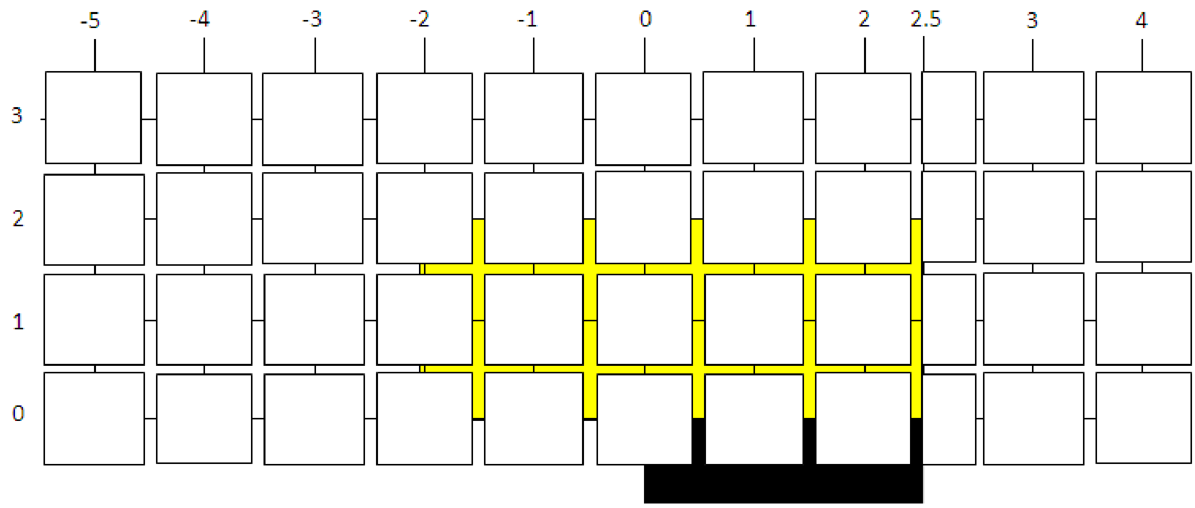

Figure 555. Grid used to assess front detection systems

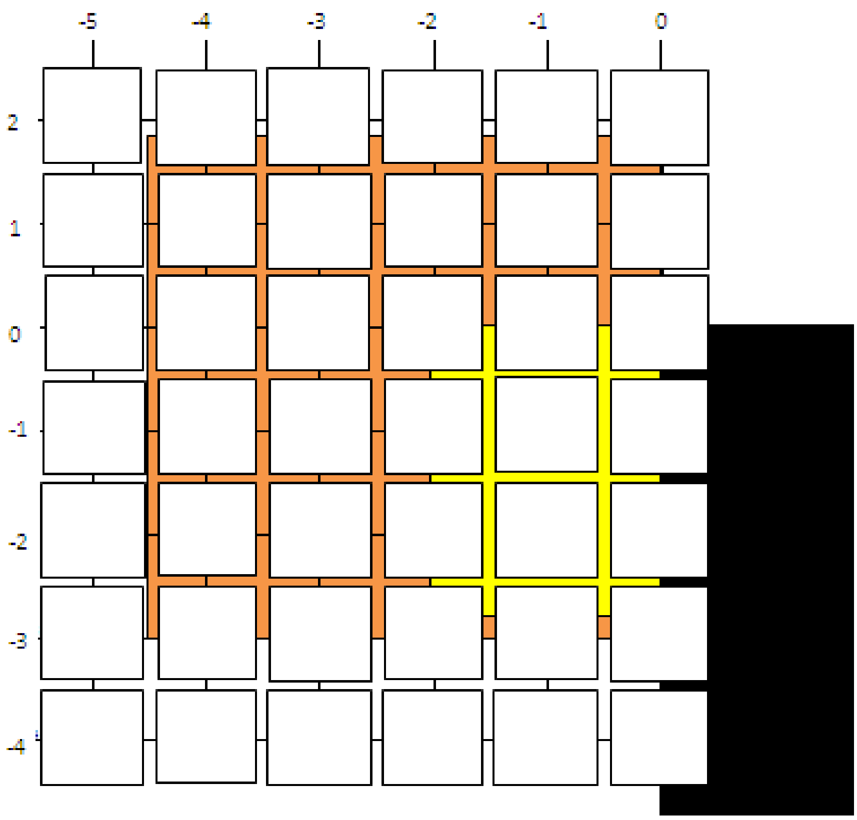

Figure 556. Grid used to assess side detection systems

6.2.4 Daytime assessment

6.2.4.1 Test target

The areas covered by Class VI and Class V mirrors are primarily used in slow driving manoeuvres, such as to check that the way is clear before turning at junctions or pulling off. The accident data analysis in Work Package 1, Task 1, shows that the main casualties involved in these slow driving scenarios are cyclists and pedestrians.

A test target representing a vulnerable road user (a manikin of a small child, height 1100mm) was used in all the trials (side and front assessments). This target was selected based as providing the worst case scenario, the smallest visible target. For the side assessment additional observations were also made using a car as a target (Renault Megane Scenic). This additional assessment was conducted to investigate side swipe accident scenarios and was only conducted to provide a comparison of images presented by the standard Class V mirror and the Spafax mirror. The results of this additional assessment / set of observations are presented in section 6.3.7

6.2.4.2 Visual systems

The child manikin was systematically placed at each node of the grid. For each target location three experts assessed the system in terms of the following six aspects:

1. Could the target be seen via direct vision?
2. Approximately what proportion of the target could be seen through direct vision?
3. Could the target be seen via the system (Mirror or Camera)?
4. Approximately what proportion of the target could be seen via the system?
5. The approximate orientation of the target presented by the system (ranging from an upright position (0 degrees) to an upside down position(180 degrees), Figure 557)

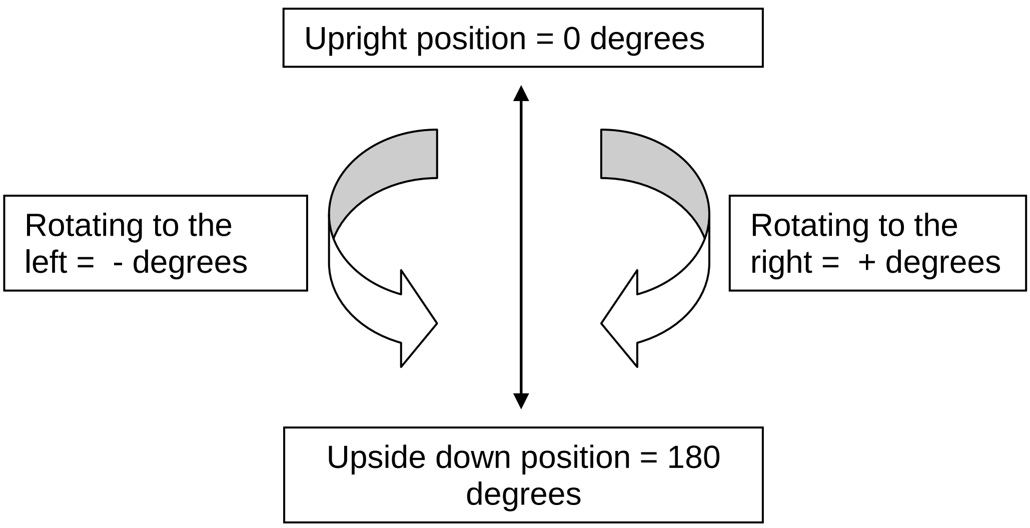

Figure 557. Diagram illustrating target orientation in degrees from the upright 0 degree position

6. Rate the level of confidence in recognising the target via the system (0-7 rating scale, 0 being not at all recognisable to 7 complete confidence in recognising the target)
7. Where pertinent, photos were taken of views depicted by the systems which were of particular interest or worthy of further discussion.

From the data collected two maps were constructed; a detection map and a recognition map. The detection map presents the areas where the worst case scenario (the smallest visible) target was detected using a colour coding system, the number of experts that detected the target in that location and what proportion of the object they observed. The recognition map presents the mean recognition score for each location in which the target was detected.

This process was repeated for each system. It was also conducted for the standard mirror to provide comparative data.

6.2.4.3 Audio systems – sensors

Using the same grid as used in the visual system test a target representing a vulnerable road user (a human pedestrian) was systematically placed at each node of the grid. It was then recorded if:

1. A signal indicating detection of the target was made - Yes/ No
   i. If yes - the target was detected - the assessor recorded:
      a. that the system had detected the target
      b. the type of signal that was made (either continuous signal, 1/8 second repeated signal or a ½ second repeated signal)
      c. whether this signal was the appropriate warning signal for the distance zone in which the target had been presented.
   ii. If no - the target was not detected - the test target was moved to the left (by the width of the test object) and then to the right (by the width of the test object). This procedure is similar to that specified in ISO TR 12155.

      If the target was not detected in either adjustment locations then a miss was then recorded. If the signal was detected in at least one of adjustment places then the same data as collected in (i) was recorded.

From this data a map of the sensor systems range of detection was constructed depicting areas where the target was detected and whether this was with the appropriate warning signal for the distance zone in which the target had been presented.

6.2.5 Night time assessment

In addition to the daytime assessment, the team was keen to probe the systems' performance under night time unlit ambient lighting conditions with a wider range of test targets. Test targets of a child manikin, cyclist and car were observed in the night time conditions. Within the time and resource constraints of the project, it was only possible to undertake this in the form of exploratory observations rather than adopting the detailed, systematic approach of the daytime assessments. The reduced ambient illumination had the effect of reducing the contrast of the targets (child manikin, cyclist and car) against the background. This was to such an extent that visual detection by direct or indirect means was almost negligible unless the target had a form of integral lighting e.g. cycle light, or was within the beam of the vehicle's headlamps. The observations were therefore aimed at identifying the factors of relevance to night time visual detection rather than quantifying them. The night time observations reported in later sections must therefore be considered in this context and present only the findings of interest under the observed conditions.

6.2.5.1 Observation conditions

Observations were conducted at the same site as used for the daytime assessments, on an airfield away from street or other external lighting. The observations were conducted with the HGV headlights on dipped beam and with the side marker lamps on. The test target of the child pedestrian was dressed in a non reflective black school uniform (the same as used in the daytime assessment). The bicycle had no reflective additions but was observed with its front and rear lights switched on. Observations of the car were made with the cars headlights on dipped beam. All targets were observed to the front and side grid areas of the HGV.

6.3 Results

Please note: the results presented here are dependent on the systems' mounting position on the vehicle used to make the assessments and the applicability of the following results to other vehicles using identical systems will vary. Furthermore, the assessments made for the mirrors vary across individual assessors, as viewing angles and objects viewed through the mirrors depend on the position of the viewer's eye point. This varied across the three experts assessing the equipment, resulting in varying values for the 'percentages of visible areas of the target viewed' and 'reported orientation of the viewed target'.

6.3.1 Front area (including area specified for Class VI mirrors (2003/97/EC Directive))

6.3.1.1 Detection field

Detection maps for each system were constructed from the data collected during the test trials. These maps present the test grid area with a square on each node where the target was placed. In each square, information relating to the assessors findings for that particular system and for that particular location are collated. For ease of reading, this section only presents simplified versions of the maps, presenting a detection map and a recognition map for each visual system and a detection map only for the audio system.

For each target location the detection map presents the following information:

1. Whether the target was detected or not:
    i. Target not seen via direct vision or via the system (White)
    ii. Target seen from direct vision (Green square)
    iii. Target seen via the system (Blue square)
2. The number of assessors that detected the target (N= ? out of 3)
3. How much of the target object was visible to the assessors (an approximate percentage value of the total target visible to each assessor). This is expressed in each target location as the range of percentage values reported by the three assessors i.e 50-80%

For each target location the recognition map presents the following information:

1. Whether the target was detected or not:
   i. Target not seen via direct vision or via the system (White)
   ii. Target seen from direct vision (Green square)
   iii. Target seen via the system (Blue square)
2. The mean recognition score.

(Please note recognition data has not been collected for the front camera system. However, a review of the limited number of photographic images was conducted and these results are discussed with the results for Class VI mirror recognition scores).

For the audio system:

1. Whether the target was detected or not:
   i. Target not seen via direct vision or via the system (White)
   ii. Target seen from direct vision (Green square)
   iii. Target seen via the system (Blue square)
2. Whether this was a 'Correct' detection i.e. the detection of the target was provided using the appropriate warning signal for the distance zone in which the target had been presented.

6.3.1.2 Accuracy of detection for each system

6.3.1.2.1 Standard Class VI mirror

Figure 558 depicts the detection map of the Class VI mirror. The map shows that the area of coverage provided by the Class VI mirror far exceeded the region specified in the 2003/97/EC Directive (approximately marked out in yellow), extending two metres further to the left of the specified area and a further two metres to the right and one metre forwards. The mirror (setup in the position used in the test trials) provided more coverage to the right hand side of the vehicle compared to the camera system (setup in the position used in these test trials).

6.3.1.2.2 Camera

The camera system provided extensive coverage ranging far beyond the test area. The total area covered by the camera extended forwards in excess of 100m and in excess of 75m to either side of the central point of the camera. However the area of interest is the area that cannot be seen via direct vision and this is mapped out in the grid test area. Figure 559 depicts the detection map of the front camera system.

Results show that the camera system offered the most extensive field of view of all the systems tested. The area of coverage provided by the camera system far exceeded the region specified in the 2003/97/EC Directive. The camera system (setup in the position used in the test trials) provided more coverage to the left hand side of the vehicle.

6.3.1.2.3 Sensor

During the trials it became apparent that the sensors were having difficulty detecting the child manikin target, failing to detect almost all presentations. It was unclear why this was happening. For this reason a different target was used, a male volunteer 1791mm in height, which was capable of reliable detection by the sensors. Figure 560 depicts the detection map of the front sensor system. Results show that the sensor range was focussed on the prescribed area for Class VI mirrors in 2003/97/EC Directive, as required. However, within this area it failed to detect the target at three locations (Row 0, Column -1), (Row 0, Column 0), and (Row 0, Column 1). The system gave one false response at Row 1, Column 1 reporting the target to be closer than it actually was by presenting a continuous warning signal.

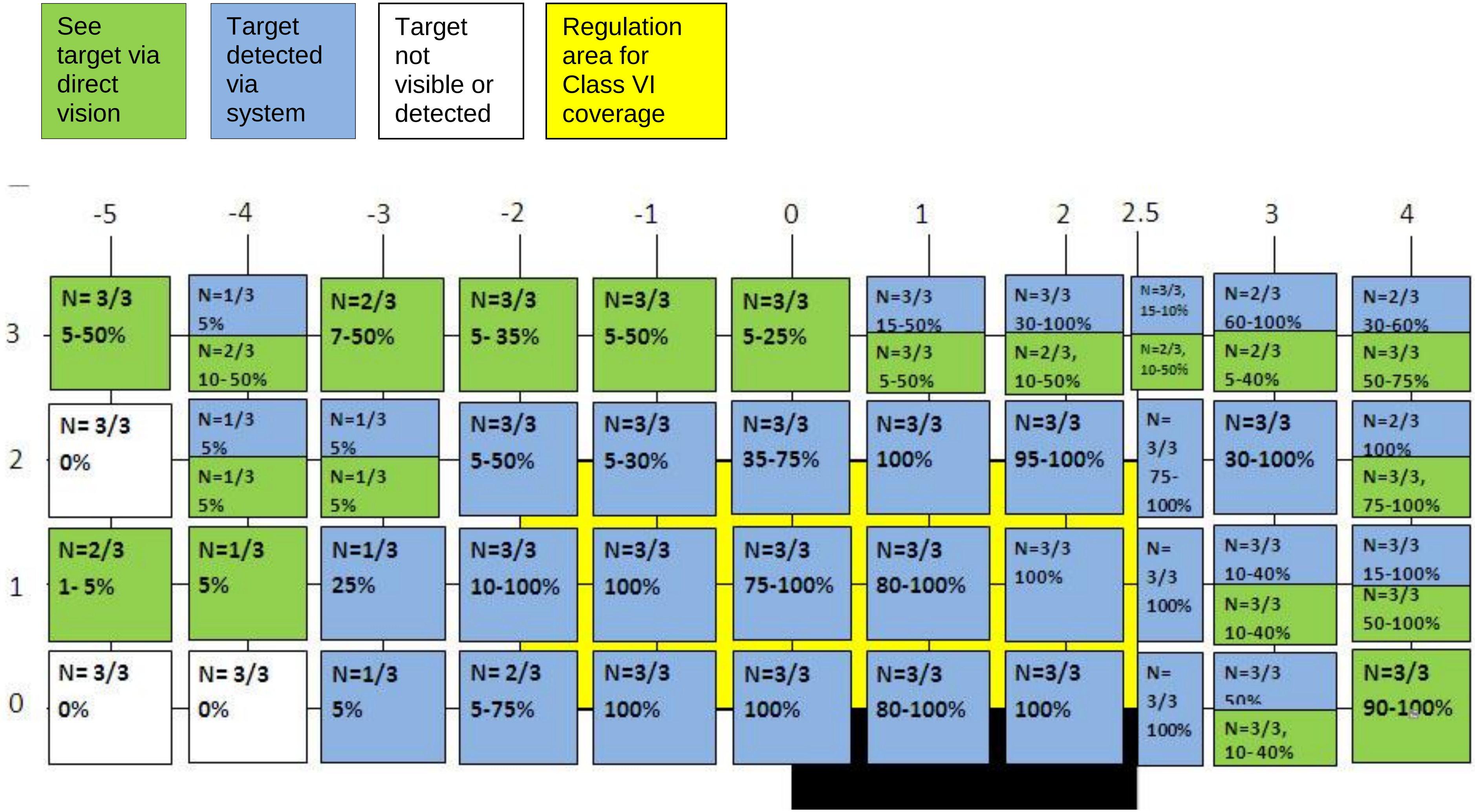

Figure 558. Class VI mirror detection map

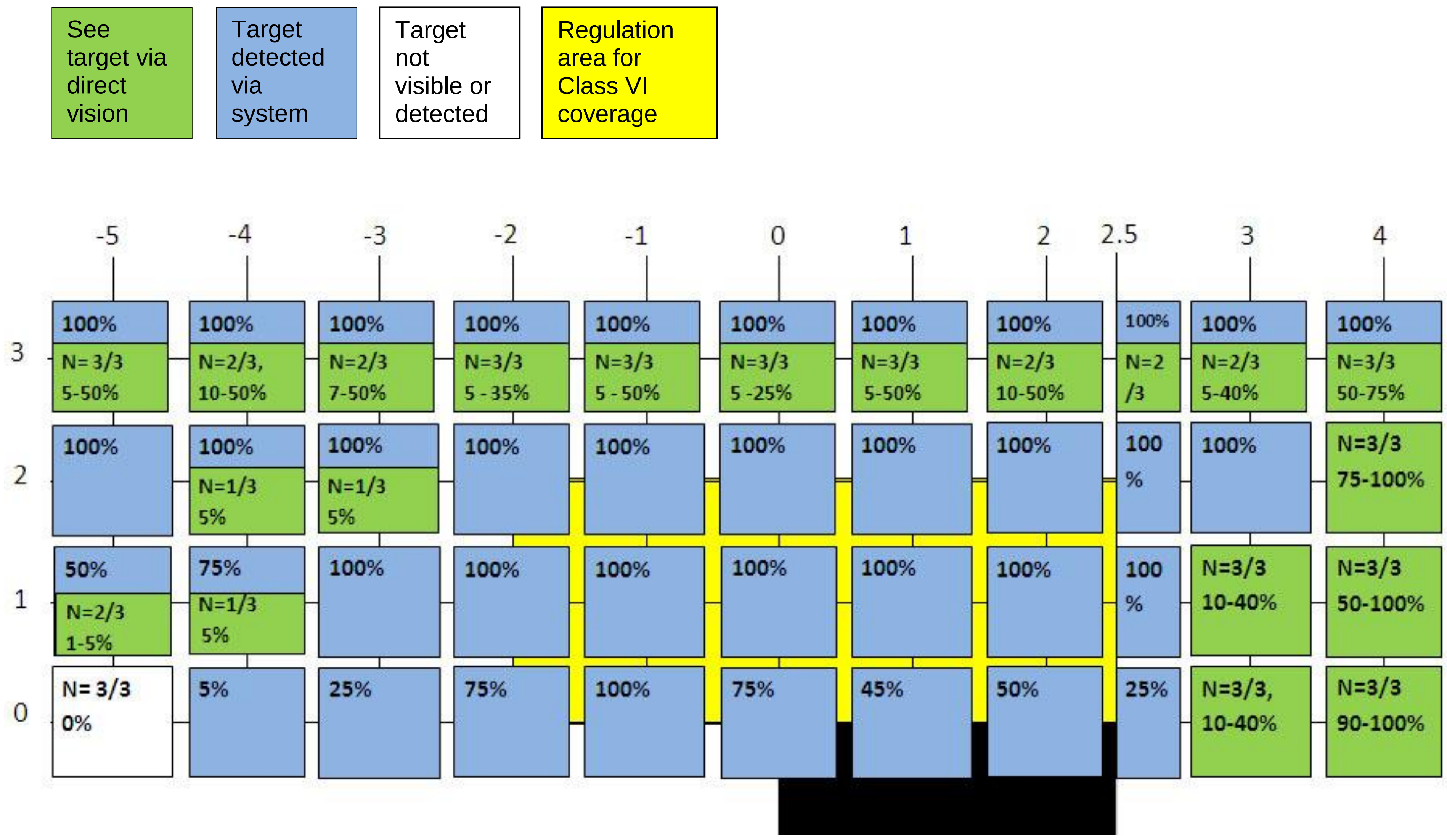

Figure 559. Front camera detection map

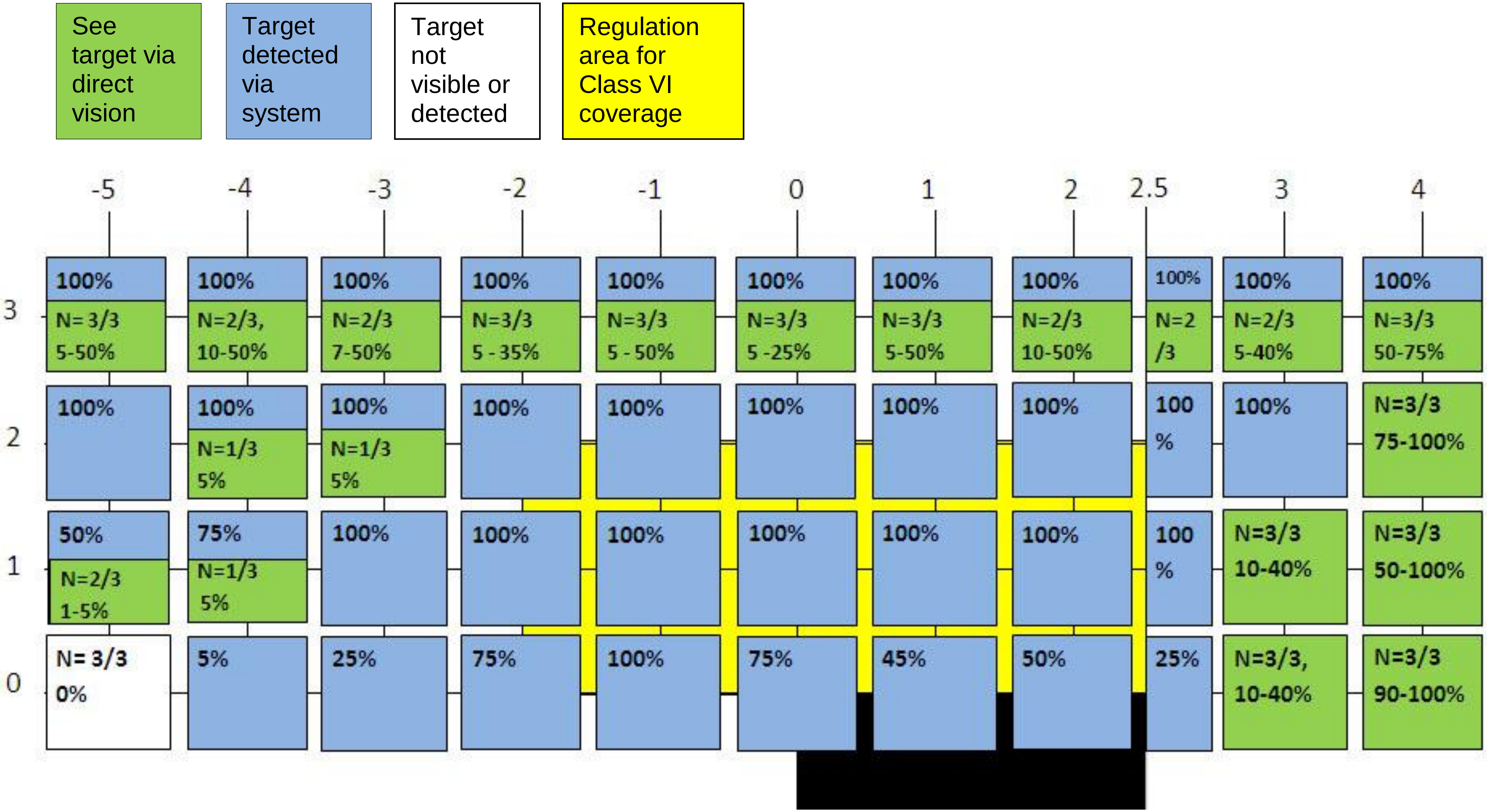

Figure 560. Front sensor system detection map

6.3.1.3 A comparison of frontal detection fields

The camera system provided the most extensive cover of the test area, only failing to detect the target in six out of the 44 test locations (13.6%) compared to 11 out of 44 (25%) for the Class VI mirror and 29 out of 44 (66%) for the sensor system (Table 48). Furthermore of the six locations not detected by the camera system only one was not able to be seen via direct vision, therefore resulting in only one blind spot in the test area, whereas the Class VI standard mirror had three comparable blind spots. The sensor system's functionality was specifically restricted to the Class VI prescribed area, therefore performing within its stated specification but not reliably beyond this area. However, the sensor system did fail to detect in six target locations within the Class VI 2003/97/EC prescribed area (Table 48). Therefore providing the least effective performance in these trials.

Technology	Number of nodes where the target was NOT detected by the system in the Directive prescribed area for Class VI	Number of nodes where the target was NOT detected by the system in the test area	Number of blind spots within the test area
Standard Class VI mirror	0	11	3
Camera	0	6	1
Sensor	6	29	12

Table 48. Number of locations where system did not detect the target

6.3.2 Visual systems - recognition

Table 49 shows a count of the number of target locations where the target was presented such that all of the target (100%) was made visible via the system. Of the two visual systems, the camera system provided a greater number of images presenting the full target image (29 out of 44). Whereas the Class VI mirror presented 20 complete images of the target. The degree to which the images were distorted varied for each location, for each of the devices. The most distortion occurred at the extremes (on the edges of the mirror and camera monitor screen). However, due to the test target's dimensions (i.e. not being particularly wide) the main effect of the distortion manifested itself in changes in the orientation of the target image. The mirror system provided a greater range of changes in orientation with the target being rotated from -170 to +160 degrees with a mode of +45 degrees across locations (Table 49), whereas the camera system had a smaller range from -45 to +20 degrees, with the majority of target locations being presented at -45 degrees. Orientation of the presented image in the Class VI mirror was most extreme between column 0 to column -3 of the grid, from row 0 to 3. In these areas the image tended to be presented between -90 and -180 degrees from the upright (0 degrees) position. Therefore at some points the image was presented upside down. Figure 561 shows the recognition map for the Class VI mirror. It is not clear whether it was the effect of orientation or the percentage of visable area of the target presented that had the main effect on recognition scores, as low recognition scores were associated with locations where the percentage area of the target presented was below 100% and also orientation of the target was not in an upright position. Figure 562 provides three example pictures depicting a range of recognition scores and target orientations for the Class VI mirror.

	Visible area of target	**Orientation**		**Mean recognition scores**	
	Number of nodes where 100% of target object visible via the system	Range	Mode	Range	Mean value across all locations where the target was detected
Standard Class VI mirror	20	-180 to +160	45	1 to 6	3.3
Camera	29	-45 to +20	-45	Missing data	Missing data
Sensor	N/A	N/A	N/A	N/A	N/A

Table 49. Summary table of visible target area, orientation and mean recognition scores

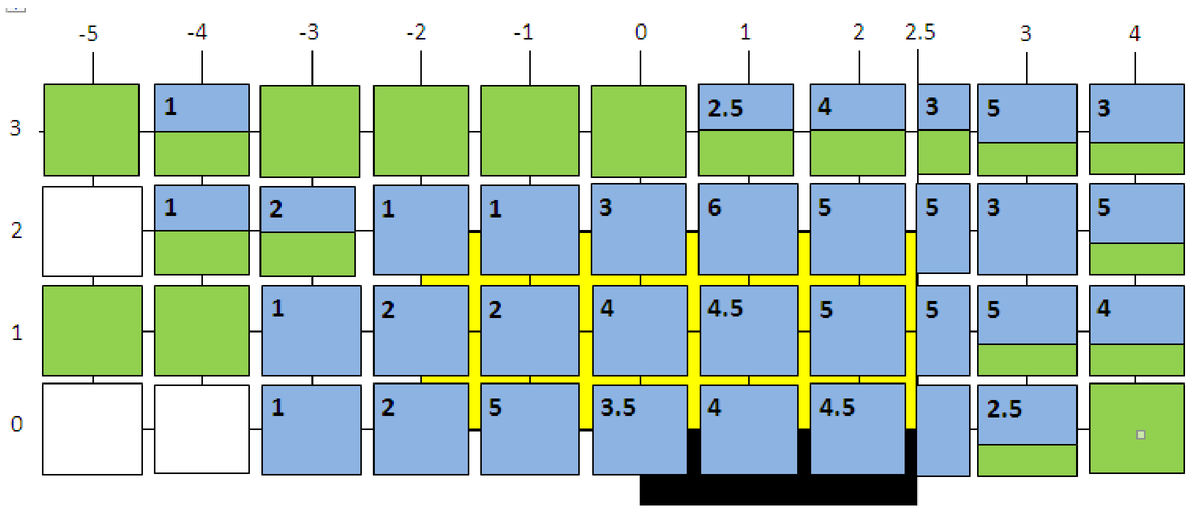

Figure 561. Class VI mirror recognition map

		
Location Column -2, Row 2 Example of mean recognition score 1. Orientation reported by assessors was 180 (upside down)	**Location Column -1, Row 0** Example of mean recognition score 5. Orientation reported by assessors was -130 and -150	**Location Column 1, Row 2** Example of mean recognition score 6. Orientation reported by assessors was +50 and +75
Class VI mirror		

Figure 562. Example of images and the type of orientation and recognition scores for Class VI mirror

6.3.3 Night time assessment

6.3.3.1 Class VI

6.3.3.1.1 Forward lighting

To the front of the vehicle the integral headlamps provided greater illumination of the surrounding area than the side marker lamps provided to the side of the vehicle. The pattern produced at the road surface from the headlamps is shown in Figure 563. This photo clearly depicts to the two headlamp beams and the non-illuminated area between them at close proximity to the cab front.

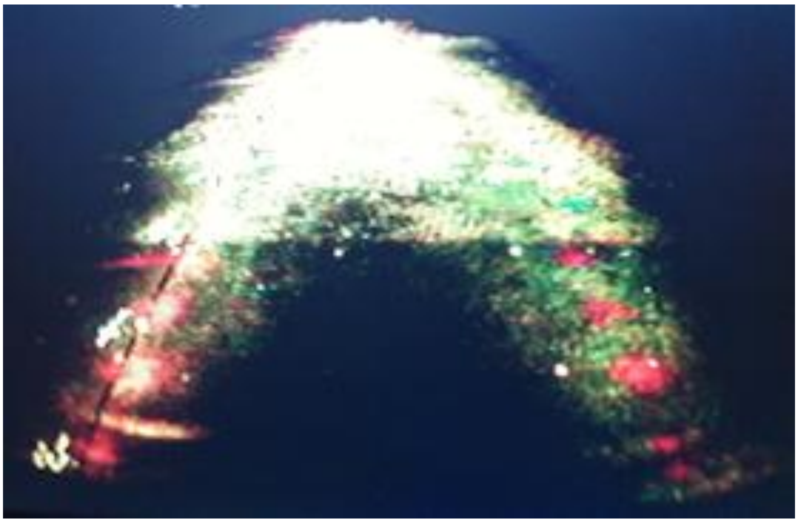

Figure 563. Area to front of cab illuminated by headlamps

6.3.3.1.2 Mirror

When the child pedestrian was positioned in the non-illuminated area between the vehicle headlamps, the target was only very faintly discernable in the Class VI mirror. Refer to Figure 564.

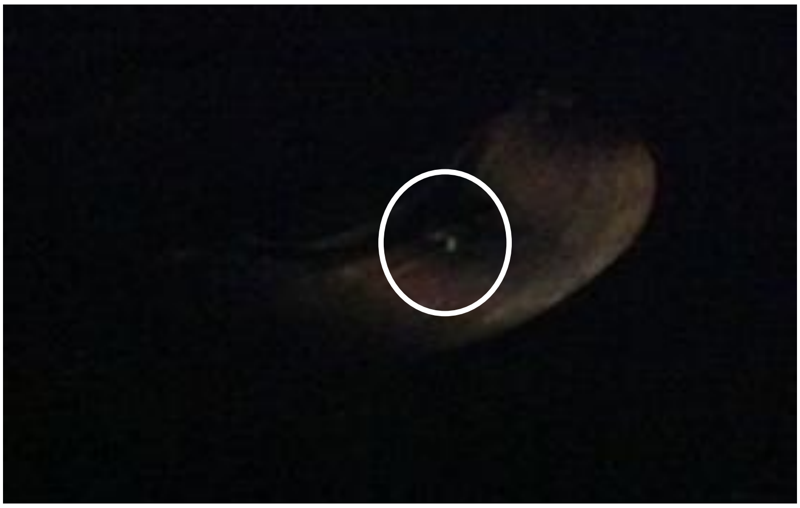

Figure 564. Child pedestrian target in non-illuminated area between vehicle headlamps

When the child pedestrian was positioned in the direct beam of one of the headlamps the visibility of the target improved in the Class VI mirror. Refer to Figure 565.

Figure 565. Child pedestrian target in the direct beam of a headlamp

The cyclist, when located in a similar area as the child pedestrian, was more visible in the Class VI mirror. The higher contrast of the cyclist against the background compared to the child pedestrian is due to the higher reflectivity of this target which acted to improve its visibility. Refer to Figure 566.

Figure 566. Cyclist target in the direct beam of a headlamp

6.3.3.1.3 Camera

When the child pedestrian was positioned close to the cab front in the non-illuminated area between the headlamps, this target could not be seen. When the cyclist was positioned in this area, the greater size of the cyclist target and its closer proximity to the camera resulted in a large image which could be detected as a shadow against the illuminated road surface. Refer to Figure 567.

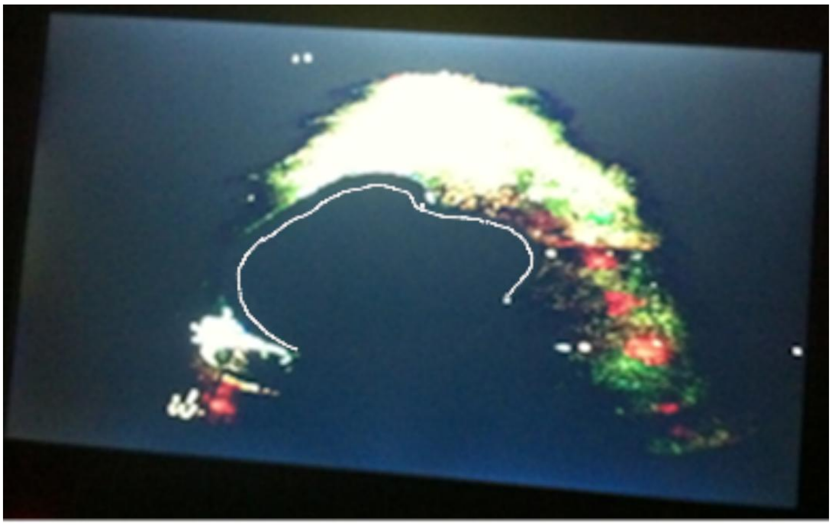

Figure 567. Cyclist target in non-illuminated area to front of vehicle

When the child pedestrian was located further forward in an area illuminated by one of the headlamps, this target was clearly visible in the screen. Refer to Figure 568.

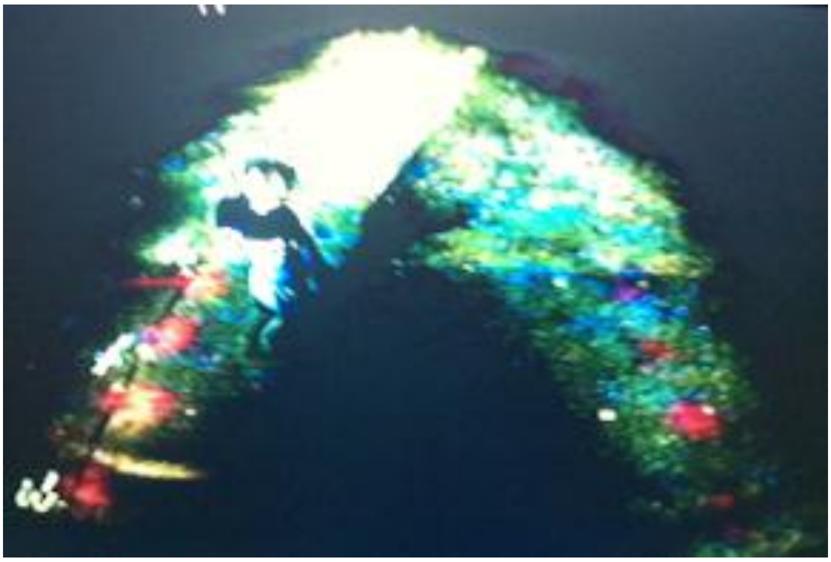

Figure 568. Child pedestrian target in the direct beam on one of the vehicle's headlamps

When the cyclist was similarly located, this target was also clearly visible in the screen. Refer to Figure 569.

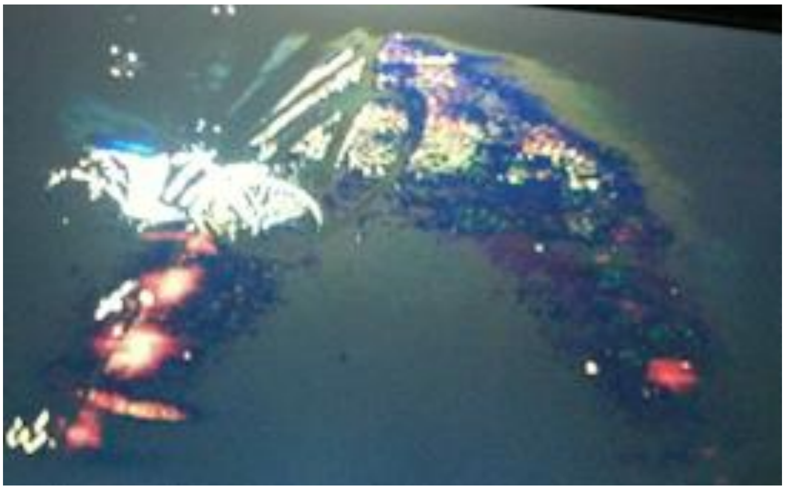

Figure 569. Cyclist target in the direct beam on one of the vehicle's headlamps

6.3.3.1.4 Sensors

Targets in close proximity to the sensors were detected to the front of the vehicle cab and the alerting display activated. Refer to Figure 570.

Figure 570. Class VI area sensor detecting target not visible on screen

6.3.4 Side area (Including area specified for Class V mirrors (2003/97/EC Directive))

6.3.4.1 Detection field

For each target location the following detection maps presents the following information:

1. Whether the target was detected or not:
    - i. Target not seen via direct vision or via the system (White)
    - ii. Target seen from direct vision (Green square)
    - iii. Target seen via the system (Blue square)
2. The number of assessors that detected the target (N= ? out of 3)
3. How much of the target object was visible to the assessors (an approximate percentage value of the total target visible to each assessor). This is expressed in each target location as the range of percentage values reported by the three assessors i.e. 50-80%.

For the audio system:

1. Whether the target was detected or not:
    - i. Target not seen via direct vision or via the system (White)
    - ii. Target seen from direct vision (Green square)
    - iii. Target seen via the system (Blue square)
2. Whether this was a 'Correct' detection i.e. the detection of the target was provided using the appropriate warning signal for the distance zone in which the target had been presented.

6.3.4.2 Accuracy of detection for each system

6.3.4.2.1 Class V mirror

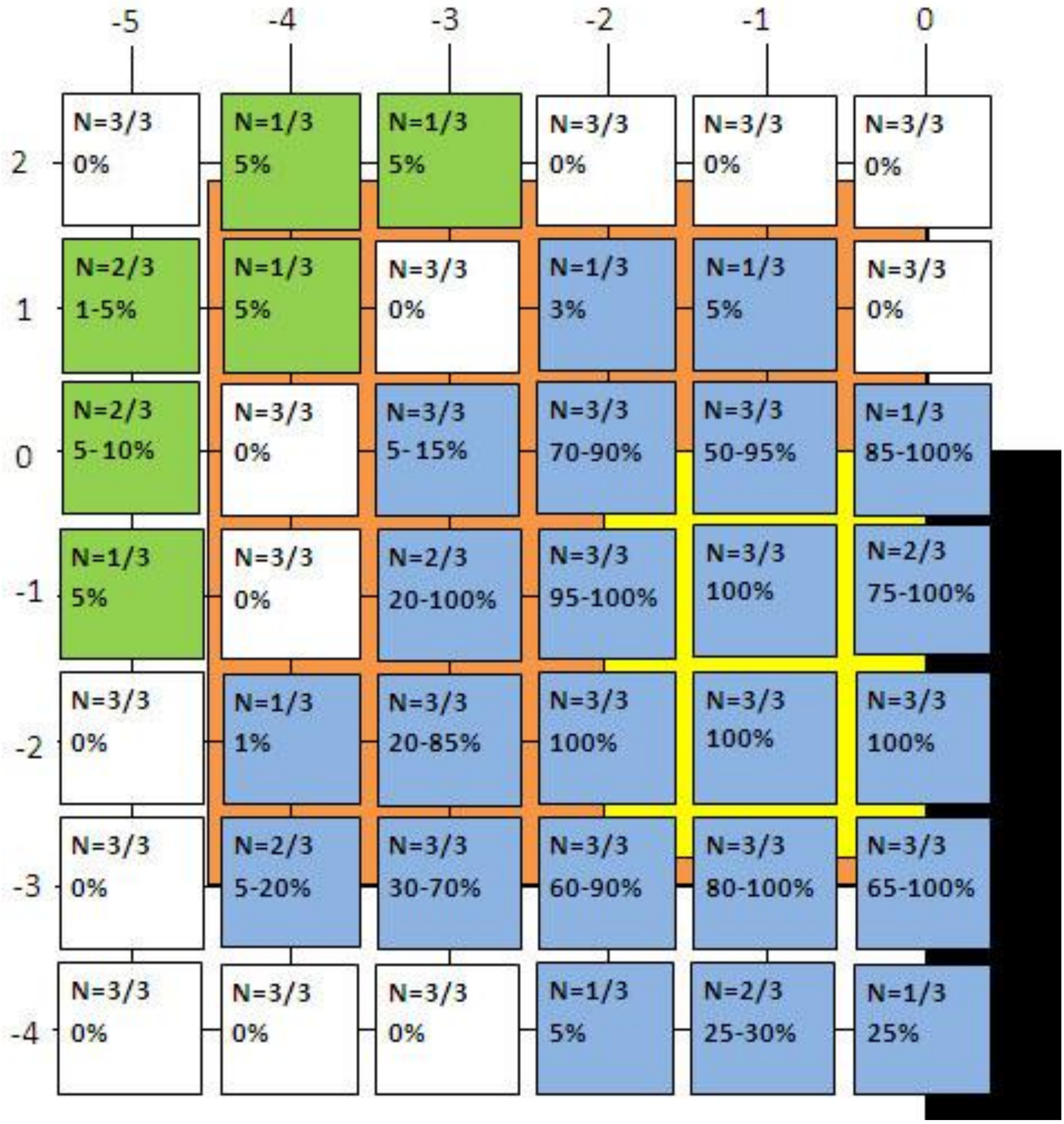

Figure 571 depicts the detection map of the Class V mirror tested. The map shows that the area of coverage provided by the Class V mirror far exceeded the region specified in the 2003/97/EC Directive (Approximately marked out in yellow), extending one to two metres further to the left of the specified area and a further metre to the fore and aft of the prescribed area. The mirror provides approximately ¾ coverage of the GRSG proposed area (approximately marked out in orange), only failing to provide coverage of the top left quarter.

6.3.4.2.2 Extended view mirror (Spafax)

Figure 572 depicts the detection map of the Spafax mirror. The map shows that the area of coverage provided by the Spafax mirror far exceeded the region specified in 2003/97/EC Directive (Approximately marked out in yellow), extending three metres further to the left of the prescribed area and a further one to two metres to the fore and aft of the prescribed area. In comparison to the GRSG recommended area (Approximately marked out in orange) the Spafax mirror nearly covers the whole area, only failing to provide coverage of very top left nodes (Column -4, Row 2 and Column -4, Row 1).

6.3.4.2.3 Side camera

Figure 573 depicts the detection map of the side camera system. Data was not collected for regions extending beyond the front of the LGV cab. However, from the data collected for the Class VI camera system, the region specified in 2003/97/EC Directive (Approximately marked out in yellow) is exceeded and extends to cover the GRSG recommended area (Approximately marked out in orange), to the point at which data was not collected.

6.3.4.2.4 Side sensors

Figure 574 depicts the detection map of the side sensors. The map shows that the area of coverage provided by the side sensors covers the region specified in the 2003/97/EC Directive which was the requested focus for their set up, extending one to two metres fore and aft of the prescribed area. These particular sensors do not extend fully into the GRSG recommended area. The sensor system provided extended coverage to the fore and aft into the GRSG area but lacked width of coverage, not extending beyond column -2. Whilst a different configuration of the sensors may have achieved this, this was not tested.

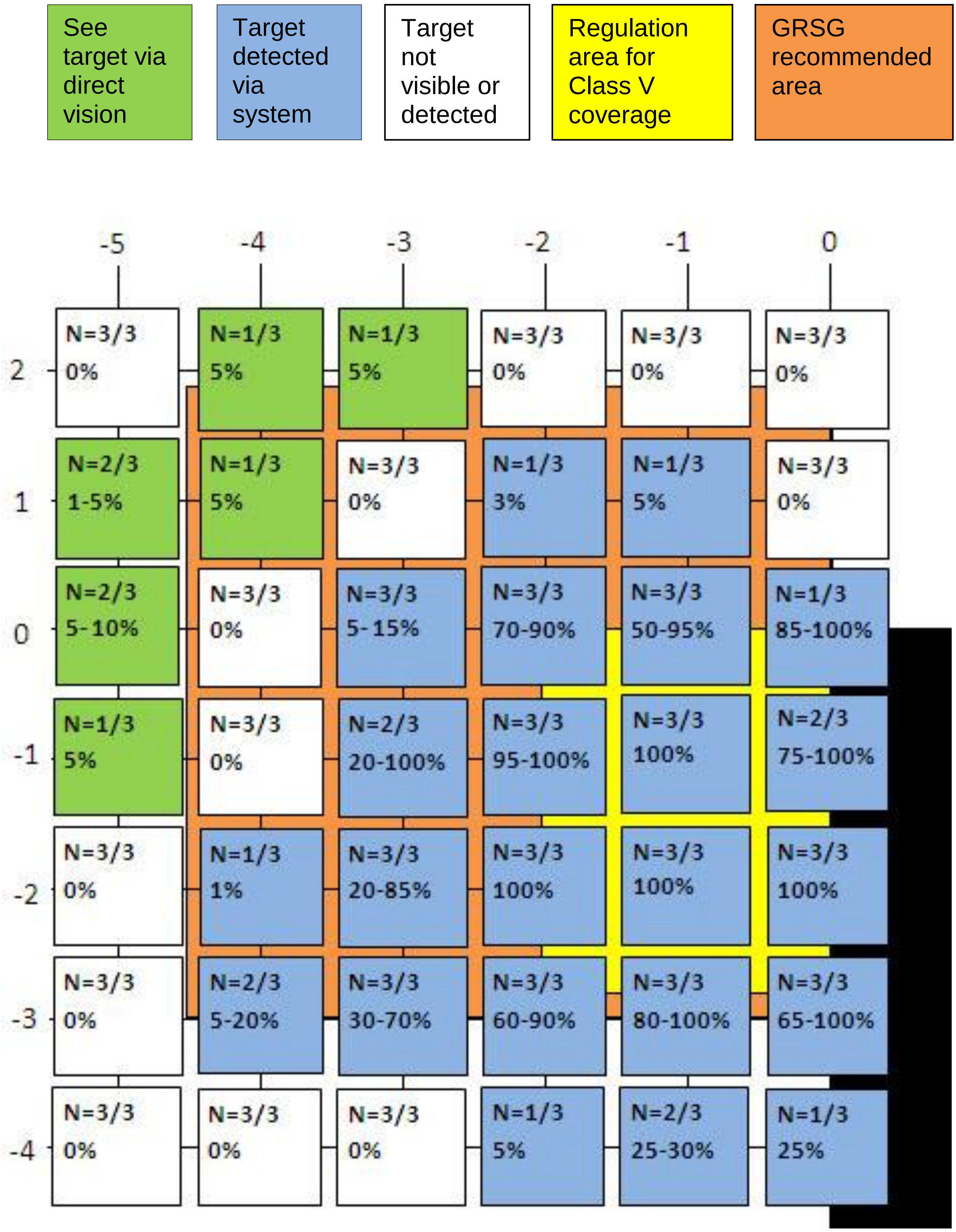

Figure 571. Standard Class V mirror detection map

Figure 572. Spafax detection map

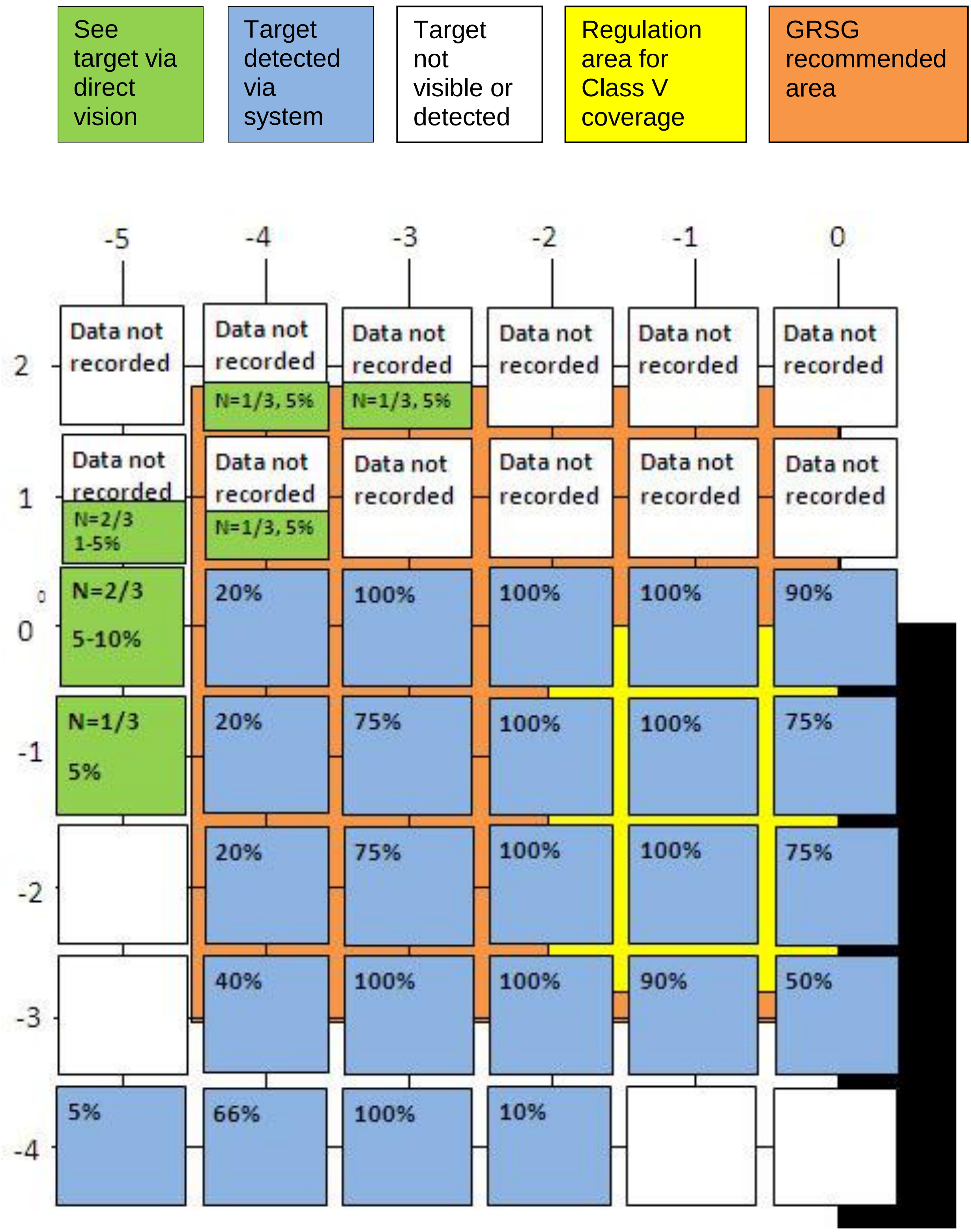

Figure 573. Side camera detection map

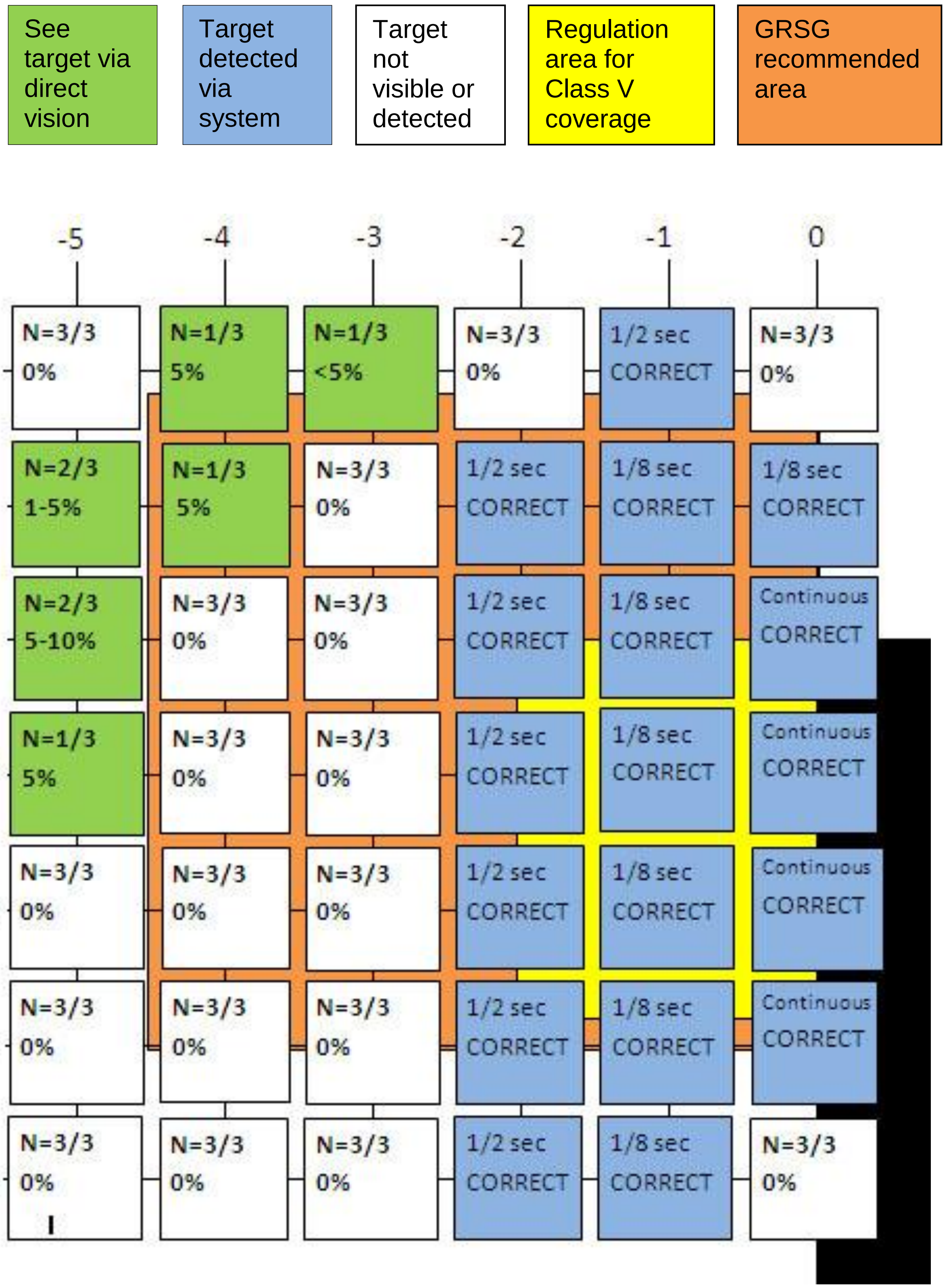

Figure 574. Side sensor system detection map

6.3.4.3 A comparison of detection fields of the side area

All the systems provided full view of the Directive 2003/97/EC prescribed area. However, the Class V mirror, Spafax mirror and camera system provided the most extensive cover of the entire test area. In particular, the Spafax mirror provided the least number of nodes where the target was **NOT** detected by the system (2 out of 42) and none of these resulted in a blind spot (Table 50).

Technology	Number of nodes where the target was NOT detected by the system in the Directive prescribed area for Class VI	Number of nodes where the target was NOT detected by the system in the GRSG prescribed area.	Number of nodes where the target was NOT detected by the system in the test area	Number of blind spots within the test area
Standard Class V mirror	0	5	19 out of 42 locations	13 out of 42 locations
Spafax	0	1	2 out of 42 locations	0 out of 42 locations
Camera	0	0 (however, please note - no data was collected for five target locations within the GRSG prescribed area)	6 out of 30 locations (There were 12 location where no data was recorded)	4 out of 30 locations (There were 12 locations where no data was recorded)
Sensor	0	10	24 out of 42	18 out of 42 locations

Table 50. Number of locations where system did not detect the target

6.3.5 Visual systems - recognition

Table 51 shows a count of the number of target locations where the target was presented such that the entire target (100%) was made visible via the system. Of the three visual systems the Spafax provided a greater number of images presenting the full target image (23 out of 44). However, it should be noted that due to complications resulting from heavy snowfall, the camera system was not assessed over the area extending out in front of the LGV cab.

The degree to which the images were distorted varied for each location for each of the devices (Table 51). However, due to the test target's dimensions (i.e. not being particularly wide) the main effect of the distortion manifested itself in changes in the orientation of the target image. The Spafax mirror system provided a greater range of changes in orientation with the target being rotated from -180 to 170 degrees with the most number of locations resulting in an image being presented at -80 and -180 degrees from the upright position. Therefore at some locations the target was presented upside down.

The camera system provides the least changes in orientation across all locations, ranging from -85 to 85 degrees. The most regularly presented orientation of the target was at -10 and 10 degrees from the upright position. Therefore in the majority of locations the target was presented more or less upright, providing the driver with a target orientation consistent with the real-world. The greatest changes in orientation occurred for target locations close to the side of the vehicle.

For all systems, it is not clear whether it was the orientation or the percentage of visbale area of the target presented that had the main effect on recognition scores, as low recognition scores were associated with locations where the percentage area of the target presented were below 100% and also orientation of the target was not in an upright position.

Figure 576, Figure 577 and Figure 578 depict the recognition maps for each of the detection devices.

For each target location the following recognition maps present:

1. Whether the target was detected or not:
    i. Target not seen via direct vision or via the system (White)
    ii. Target seen from direct vision (Green square)
    iii. Target seen via the system (Blue square)
2. The mean recognition score.

The Class V and the camera system gained the mean highest recognition scores 2.4 and 3.6 respectively. The Class V and the Spafax mirror gained their highest mean recognition scores within the Directive 2003/97/EC prescribed area, whereas the camera system gained highest scores in the Directive 2003/97/EC prescribed area and just beyond, spreading out into the orange, GRSG proposed area. Figure 575 shows an image from all three visual systems for the same presentation location of the target. It illustrates the differences in recognition scores and orientation across the three types of system.

	Visible area of target	**Orientation**		**Mean recognition scores**	
	Number of nodes where 100% of target object visible via the system	Range	Mode	Range	Mean value across all locations where the target was detected
Standard Class V mirror	9 out of 42 (21%)	-150 to 180	180 (followed equally by -80 and -90 and 80 and 85)	0 to 5.7	2.4
Spafax	23 out of 42 (55%)	-180 to 170	-80 and -180	0 to 4.7	2.1
Camera	10 out of 30 (33%)	-85 to 85	-10 and 10	1 to 6	3.6
Sensor	N/A	N/A	N/A	N/A	N/A

Table 51. Summary table of visible target area, orientation and mean recognition scores

		
Location Column -1, Row -1 Example of mean recognition score 2.7. Orientation reported by assessors was 180 (upside down)	**Location Column -1, Row -1** Example of mean recognition score 3.3. Orientation reported by assessors was 180 (upside down)	**Location Column -1, Row -1** Example of mean recognition score 4. Orientation reported by assessors was +45
Class V mirror	**Spafax mirror**	**Side camera**

Figure 575. Example of images and the type of orientation and recognition scores for each of the visual systems

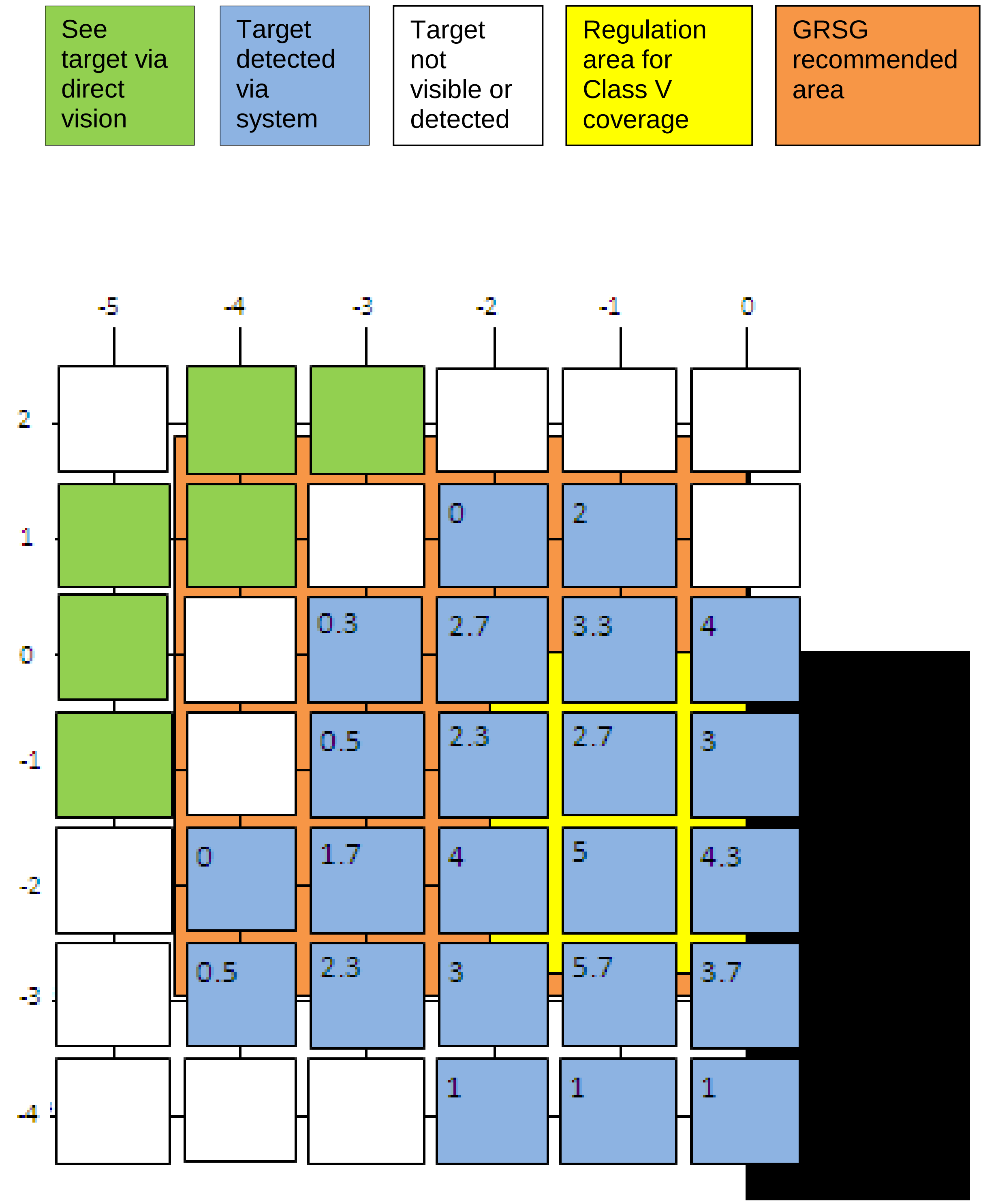

Figure 576. Standard Class V mirror recognition map

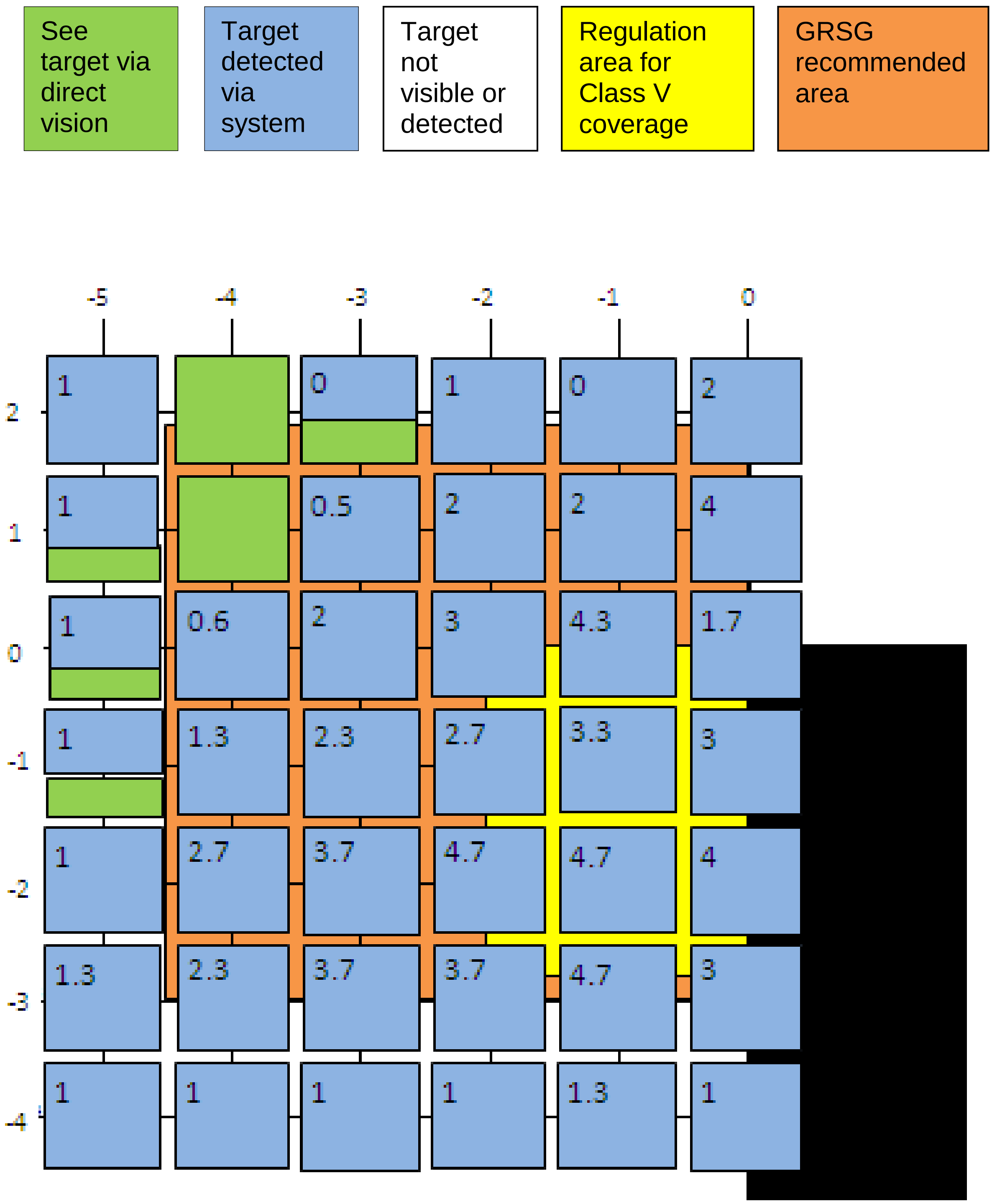

Figure 577. Spafax mirror recognition map

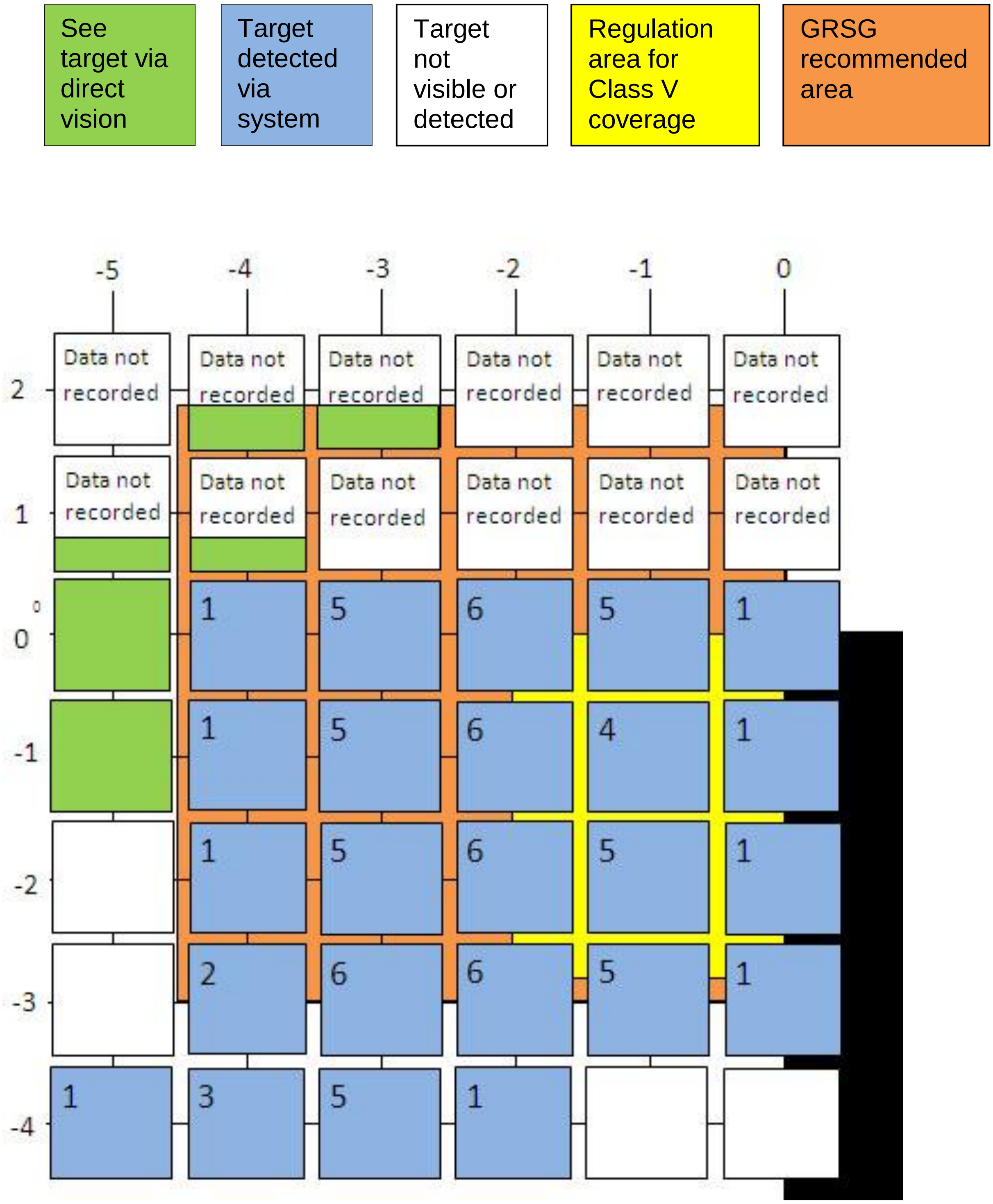

Figure 578. Side camera recognition map

6.3.6 Night time assessment

6.3.6.1 Class V

6.3.6.1.1 Mirror

Reduced vehicle lighting to the side of the vehicle was insufficient to illuminate the child pedestrian and the cyclist and thus these were not discernible in the Class V mirror. Additional external lighting such as street lighting may have improved their visibility but this was not possible to investigate within the confines of the test site. Lighting sources integral to the target such as the car's headlamps improved this target's visibility within the Class V mirror. Refer to Figure 579.

Figure 579. Approaching car in Class V mirror

Although the car target was only visible in the Class V mirror for a short period of time, warning of its approach was clearly obtained through the Class V mirror. Refer Figure 580.

Figure 580. Car approaching in Class IV mirror

6.3.6.1.2 Camera

The child pedestrian was similarly insufficiently illuminated to be viewable within the Class V area camera. The cyclist was only viewable when using its own lights where both the front and rear lights showed in the display image. Refer to Figure 581.

Figure 581. Cyclist in Class V area camera

The car was also visible primarily due to the high contrast provided by the vehicle's headlamps against the background. Refer to Figure 582. Interestingly, the illumination of the road surface ahead of the vehicle provided by the vehicle's own headlamps provided a strong visual cue in the camera screen of the approaching car. Refer to Figure 583.

Figure 582. Car in Class V area mirror

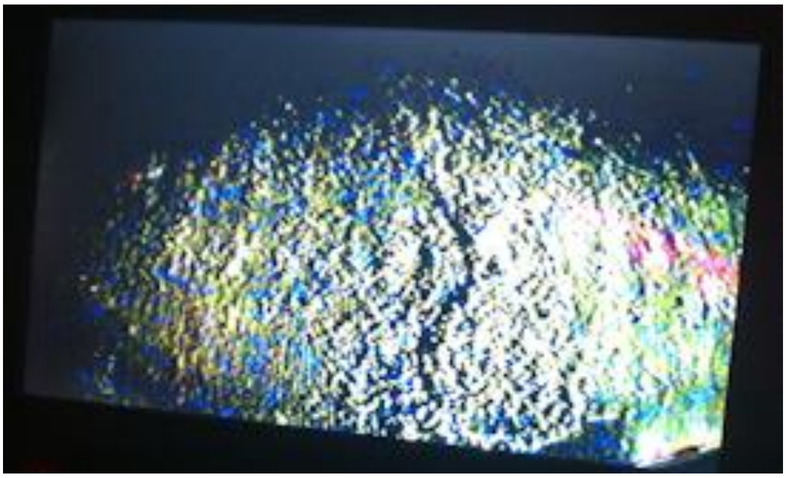

Figure 583. Approaching car headlamps on road surface in Class V area camera

6.3.6.1.3 Sensors

Targets in close proximity to the sensors were detected to the side of the vehicle cab and the alerting display activated. Refer to Figure 584.

Figure 584. Class V area sensor detecting passing car

6.3.7 A comparison of Class V mirror to Spafax mirror in side swipe scenario

6.3.7.1 Assessment 1

A car was used as a target to provide a comparison between the Class V mirror and a Spafax mirror for a side swipe scenario and also to investigate the effect of distortion on a wider, larger object than the child target used in the previous assessments. The target was positioned with the middle of the car two metres out from the side of the LGV and with the front of the car in line with the front of the LGV cab, as depicted in Figure 585. Photographs of the images of the car in this positioned as presented in the Class V mirror and the Spafax were then taken.

Figure 585. Target car at 2 metre off-set from LGV

Figure 586A, shows the image of the target car as presented in the Class V mirror. Figure 586B, shows the image of the target car as presented in the Spafax mirror. From these two images it can be seen that the effect of the distortion is similar for both mirrors causing the image of the passing car to become elongated. However, the image presented in the Spafax mirror shows the car relatively positioned nearer to the centre of the mirror due to its greater field of coverage.

	
Figure A. Class V	Figure B. Spafax

Figure 586 (A & B). Mirror images of target car at 2 metre offset from the LGV

6.3.7.2 Assessment 2

The target was then repositioned such that it was on the boundary of the GRSG proposal with its nearside wheels at 4.5 metres from the side of the LGV. The car was positioned in row 0, with the front of the car in line with the front of the LGV cab.

Compared to the view gained when the car was positioned at the two metre boundary of the Class V area, Figure 587 shows that the level of disotortion is more pronounced in the Spafax mirror due to its greater curvature (The target was not detectable in the Class V mirror).

The target was then re-positioned such that it was on the boundary of the GRSG proposal with its nearside wheels at 4.5 metres from the side of the LGV. It was positioned in row 0, with the front of the car in line with the front of the LGV cab. The target whilst distorted is visible in the Spafax mirror as shown; however it was not visible in the Class V mirror.

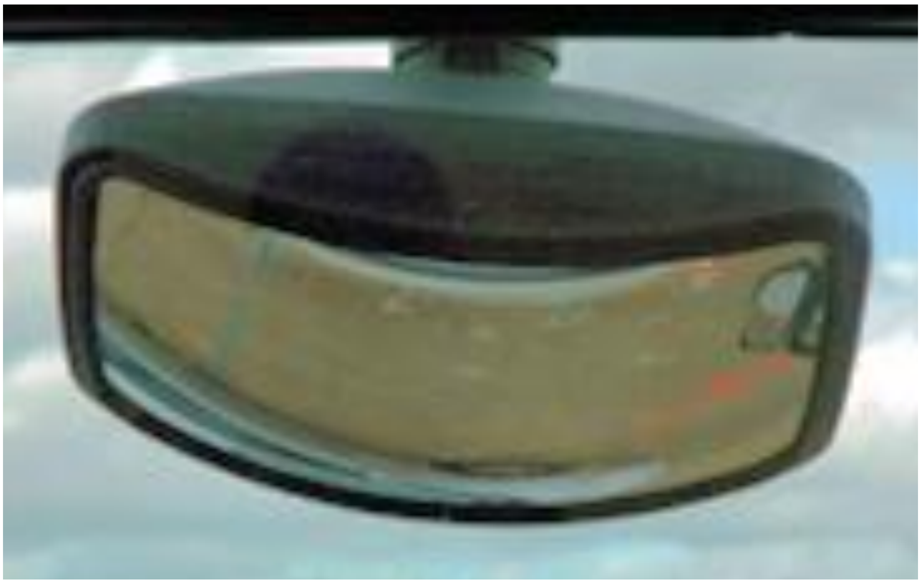

Figure 587. Image of car at the edge of the GRSG proposal areas

6.3.7.3 Assessment 3

With the car remaining 4.5 metres out from the side of the LGV it was then moved forward five metres in one metre intervals, corresponding to Rows 0, 1, 2 and 3 with additional markers placed at 4 and 5 metres forward of the front of the LGV. Figure 588, A to E show how the image of the car, in the Spafax mirror, changed through its progression along the nearside of the LGV.

4.5m out from the side of the LGV cab, front of car in line with front of the LGV cab.	
4.5m out from the side of the LGV cab, Front of car 1m in front of LGV cab.	
4.5m out from the side of the LGV cab, Front of car 2m in front of LGV cab.	
4.5m out from the side of the LGV cab, Front of car 3m in front of LGV cab.	

4.5m out from the side of the LGV cab, Front of car 4m in front of LGV cab.	
4.5m out from the side of the LGV cab, Front of car 5m in front of LGV cab.	

Figure 588 (A – E). Progression of car images in Spafax mirror

6.3.8 Summary

6.3.8.1 Detection

6.3.8.1.1 Front

- Within the Class VI prescribed area, the Class VI mirror and the camera system provided complete detection over the Directive 2003/97/EC prescribed area. The sensor system showed detection failures at the nearside edge and along the front of the vehicle
- Within the extended area of the grid, the camera system provided the most extensive coverage (38/44 test locations) followed by the Class VI mirror (33/44 test locations). The poorer performance of the sensor system may in part be accounted for by its set up being focussed to the prescribed area
- The greater overlap between direct and indirect vision provided by the camera system permits greater redundancy in the forward visual field. This means that drivers whose anthropometry and/or seating preferences necessitate extreme locations in cab which may reduce their forward visual field will be affected by blindspots
- In addition the camera system helps to overcome the nearside blindspots suffered by the Class VI mirror.

6.3.8.1.2 Side

- Within the Class V prescribed area, all systems provided complete detection over the Directive 2003/97/EC prescribed area
- Within the GRSG proposed area, the Spafax mirror outperformed the Class V mirror achieving almost total coverage (one detection failure, compared to five). For environmental reasons, it was not possible to collect data from the GRSG area forward of the front of the vehicle for the camera system; however for the region of the GRSG area where data was collected there were no detection failures
- Within the extended area of the grid, the Spafax mirror outperformed the Class V mirror achieving almost total coverage (two detection failures, compared to 13).
- The poorer performance of the camera and sensor system over the GRSG and extended area of the grid may in part be accounted for by their set up being focussed to the prescribed area
- There was less redundancy in the systems with respect to the overlap between direct and indirect vision compared to the Class VI area indicating a greater potential for blindspots. Again an alternative set up for the Class V camera and sensor system may have improved this.

6.3.8.2 Recognition

Ease of recognition of the target is an important consideration. Correct identification enables the driver to quickly interpret the visual scene, assess the potential risks within it and determine an appropriate course of action which is then enacted via the vehicle controls. If a driver is supported in correctly identifying an object, then they are more likely to be able to infer, for example, what the object is likely to be doing, the speeds it is travelling at, its direction of motion, etc. Factors related to mirror design which may influence recognition will be affected by factors such as the perceived distortion of the target, its orientation and the quality of image.

6.3.8.2.1 Orientation

As previously stated in Section 6.3, the following results are dependent on the systems' mounting position and the position of the viewer's eye point' used specifically in these assessment trials and therefore should be viewed within this context.

- The mirror based systems presented the most extreme changes in orientation of the target, often presenting the target in positions ranging from on its side to upside down. It can be inferred that this will have an impact on ease of recognition of the target. This may be further confounded by the bird's eye view perspective of the image

- The camera systems provided images with more constrained changes in orientation. For the front camera system this was constrained to -45 to 20 degrees therefore always presenting an upright image. For the side camera a slightly more extensive range of orientation was presented, ranging from -85 to 85 degrees, but with over half of the locations resulting in orientation of between +30 and -10 degrees. Therefore typically presenting an upright target. The camera system also benefited from providing less of a bird's eye view than the mirror systems
- The superior performance of the camera system was reflected in the recognition ratings which had a mean value of 3.6 for the camera system, 2.4 for the Class V mirror and 2.1 for the Spafax mirror.

6.3.8.2.2 Amount of target visible

- The camera system displayed a greater proportion of the target area compared to the standard mirrors. It was considered that the greater the proportion of the target available for viewing, the easier for the driver to recognise it, subject to confounding issues such as orientation.

6.3.8.2.3 Quality of image

- Mirrors are affected by rain and dirt more so than camera systems. The mirror surface and windscreen are both vulnerable whilst the camera lens may enjoy considerable protection from being mounted vertically and having a hood
- However, the image from camera systems is reliant on the quality of the camera lens and the internal viewing screen. Viewing of the screen can also be compromised by the effects of glare and sudden changes in contrast, Figure 589.

Figure 589. Internal screen of the camera system with the sun light shining onto the screen

6.3.8.2.4 Distortion

- Distortion of the child target presented itself more as changes in orientation rather than bending of the image. For larger objects such as the car the distortion resulted in a more pronounced effect, bending the image significantly
- Distortions of the car image in the Class V mirror and Spafax mirror were most pronounced at the edges of the mirrors. Again orientation was also significant, with the images being presented not only bent but also upside down. Although the camera system was not assessed using the car target it can be inferred from the child target results that the distortion would be less and the image would not be flipped upside down.

6.3.8.2.5 Interpretation of direction of motion

- The camera system, being subject to fewer changes in orientation and distortion, provided the most intuitive system in that the image provided on the screen provided a truer reflection of what was happening externally. This is best illustrated through example. Below are two examples illustrating the effect of orientation and predicting what that target will do (Figure 590 and Figure 591).

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>Class VI Mirror</td><td>Camera system</td><td>External view</td></tr>
<tr><td colspan="3">Location Column +1, Row 2</td></tr>
<tr><td colspan="3">The camera system is more intuitive in terms of the location of the target in relation to the LGV. The position of the target on the screen better reflects the real location outside, whereas the mirror in less clear. On the mirror the child target appears further away and more offset than it actually is.

Notice the child appears to be facing left in mirror. Whereas the child appears to be facing right in camera view, which reflects its real position.</td></tr>
</table>

Figure 590. Example 1

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>Class VI Mirror</td><td>Camera system</td><td>External view</td></tr>
<tr><td colspan="3">Location Column +2, Row +2</td></tr>
<tr><td colspan="3">Note: On the camera system the child is facing right whereas on the mirror the child is facing left. The mirror gives a greater view to the right of the driver but the orientation of the target impairs prediction of the child's likely movement.</td></tr>
</table>

Figure 591. Example 2

6.3.9 Driver opinions of the systems

6.3.9.1 Rationale

The driver interviews undertaken in Work Package 1, Task 2 found that the vast majority of the drivers had not had experience of camera and sensor systems. An additional task to the agreed work programme was therefore undertaken to probe this area further. This comprised a questionnaire which was distributed via an organisation with such systems fitted to their vehicles. The questionnaire was of necessity kept brief to align with the project timescales and as a means for increasing the self-completion response rate. For this reason, the questionnaire focussed specifically on obtaining the drivers' views on mirrors, cameras and sensors; data relating to the drivers themselves or their vehicles was not collected. Seventeen responses were received. Due to the voluntary nature of completion of the questionnaire, there is a potential for a negative bias in the responses i.e. drivers dissatisfied with one or more of the systems may have taken advantage of this opportunity to express this whereas those who are generally satisfied may have felt less inclined to respond. A copy of the questionnaire is available in Appendix 4.

6.3.9.2 Mirrors

- 16 drivers expressed satisfaction with the number of mirrors, with their responses ranging from 'Enough' and 'OK' to 'Very good'
- 12 drivers expressed satisfaction with the coverage of the mirrors of blind spots; one mentioned coverage issues for the Class V mirror (Class V does not cover rear of front nearside wheel or far enough out) and one mentioned adjustment issues for the Class V and Class VI mirrors. It should be noted that these findings are dependent upon the drivers having a clear understanding of how mirrors should be set up. In addition, whilst drivers may consider the vision provided by their mirrors to be sufficient, it is not possible to confirm if they have been set to maximal effect
- 14 drivers expressed satisfaction with the mirror image quality with their responses ranging from 'Reasonable' to 'Very clear'. One driver stated that the image was bad when wet and two drivers mentioned the need for the mirrors to be clean.

6.3.9.3 Cameras

- Camera systems had been used by 12 drivers, mainly to the rear of the vehicle
- All the views were positive ranging from 'Useful' to 'Very good'. One driver stated that they would still get out to check on occasions and one stated that the cameras were good once they had got used to them.

6.3.9.4 Sensors

- Sensor systems had been used by 14 drivers; ten to the nearside.
- Seven drivers disliked the sensor system stating that they found it 'Annoying', 'Distracting', 'Beep too loud', Sensors too sensitive and the visual display not being conveniently sited
- One driver thought the system was OK
- Two drivers thought the system was good / very good – One driver was happy with it, one driver had become used to it
- Four drivers favoured the system but three disliked the beeping and two stated the need for more reliability.

6.4 Discussion

6.4.1 Mirrors

- The findings of this Work Package support those of Work Package 4: mirror image quality, concerning the mirror edges being the area of greatest distortion
- However whilst the assessments within this Work Package indicate that the mirrors pose a greater challenge to recognition over camera systems, the findings of Work Package 4 found that recognition of the images afforded by regulated mirrors is not problematic unless at the edges. Whilst this might be taken to imply that current mirror designs, although offering poorer visual representation than camera systems, are sufficient it should be noted that the quality of vision trials were conducted under favourable conditions. Rain, dirty mirrors, complex driving scenarios, fatigued and / or stressed drivers, etc, have the potential to degrade driving performance including reliable and efficient use of the mirrors. The extent of the contribution of these factors to accident scenarios is not known neither is the extent to which improvements to vision could mitigate against these.

6.4.2 Cameras

- With respect to the camera system, the findings from the expert appraisal within this Work Package regarding their generally favourable performance were extended by the drivers whom gave positive responses regarding their use.

6.4.3 Sensor systems

- The expert appraisal of the sensor systems showed some failings in the prescribed area compared to the mirror and camera systems
- The majority of the drivers recounted unfavourable experiences in their use of the system; these related to annoyance / distraction of the audio feedback (9/14 drivers who had used sensors) and unreliability / over sensitivity of the system giving rise to false alarms (5/14).

6.4.4 Conclusion

The results of the driver questionnaire found that blind spots were reported as being more problematic in relation to changing lanes, using roundabouts, negotiating junctions and reversing which could be compounded by the poor practices of other road users such as undertaking and not using indicators. Anecdotal comments from those contacted in the course of the project suggested that drivers may check their mirrors then attend to another element of the driving task e.g. final check to confirm the junction is clear, and then move off. However in the interim another road user has positioned themselves relative to the vehicle creating a hazardous situation which the driver is unaware of thereby raising the potential for an accident. These examples indicate the potentially valuable contribution which could be made to the driving task by sensors which support the driver by acting as an extra pair of eyes but without adding more to the drivers visual task i.e. the drivers attention is alerted by an auditory source to a hazard only if there is something which needs their attention. Sensors also have the potential to make a significant contribution to hazard detection under night-time conditions. However more work is needed to determine sensor accuracy over a larger area and issues relating to false alarms and the Human-Machine Interface relating to the auditory output also need to be considered.

The camera systems have the potential to improve the indirect viewing area beyond that achievable with conventional mirrors and to portray the viewed image in a manner which is more intuitive to the driver which may better aid drivers when dealing with a high mental workload. However, the amount of this effect is not known and the camera still suffers the same limitations as the mirror regarding the need for the driver to be looking in them at the appropriate time.

In conclusion, of the three technologies reviewed: mirrors, cameras and sensors, there was no single technology which performed best. Both the camera and the sensor systems complemented the performance of the mirrors. The camera displays had the ability to provide larger, more identifiable images than the mirrors whilst the sensors had the ability to support the driver by 'looking' when they are not able.

7 WORK PACKAGE 6: IMPACT ASSESSMENT

7.1 Introduction

In the description of work for Phase 2 of the project, the team undertook to complete an impact assessment for solutions to each of the issues studied in Work Packages 1 to 4, that is:

- WP1: N_2 and N_3 Blind Spot Determination
- WP2: M_1 Forward Field of View, A/B Pillar Obscuration
- WP3: M_1 and M_2 Rear Field of View, Visibility of Rear Obstacle
- WP4: Mirror Image Quality.

The proposal had this to say about the impact assessment that would be conducted:

> "Where the research determines that there is a real problem in terms of risk of accidents, the most cost-effective solution will be identified. Where this solution calls for changes to be made to existing legislative standards, an impact assessment will be carried out. This sets out a range of possible measures that the responsible minister can adopt, and provides guidance for him in choosing which of these, if any, to approve. The assessment evaluates as precisely as possible the cost and benefit of the courses of action on society in general and specific stakeholders. The procedure for carrying out the Impact Assessment has been standardised across government and is set out by the Department for Business, Innovation and Skills on its website".

Solutions have been proposed for Work Packages 1 and 3, and impact assessments carried out for a variety of options to these. However, in the case of Work Package 2, although A- and B-pillars on cars can be shown to impair forward and side vision, there is no solution in the area of vehicle legislation that could benefit this impairment without having a serious effect on other safety aspects of the vehicle. In the case of Work Package 4, a number of recommendations have been made, including a firm proposal to require all new N_2 and N_3 vehicles to be fitted with all mirrors (including Class II, IV, V and VI) that are capable of being adjusted from the driver's seat. The cost of installing such mirrors in the current vehicle fleet was estimated. However, the project did not provide the data needed to estimate the benefits that would result, so it was not possible to determine the magnitude of the benefit that might accrue from this measure.

7.2 Methodology

The first step in the impact assessment was to define the range of practical measures that were identified as solutions to the problem in each of the work packages. The range of measures was limited to those actions that the Department for Transport might be able to undertake, either on its own or in collaboration with other stakeholders. Where changes in vehicle engineering standards were required, these can generally only be made on the basis of the internationally-agreed standards that govern vehicle type approval.

The second step was to identify the engineering changes that would be necessary to vehicles or operating procedures in order to conform to the changes in legislation. In most cases, these comprised additional systems that must be added to the vehicle, or changes to its existing systems. In other cases, there may be changes in the operators' procedures. The project carefully evaluated the options available to a stakeholder.

The third step was to evaluate the costs and benefits to the stakeholders resulting from implementing the measures identified above. In most cost-benefit studies the total costs and benefits are evaluated separately and compared against each other. In this case, however, a slightly different technique was employed. This starts by evaluating the total benefits that will accrue in one year once the measures are fully in place, using the accident data. Once each improved vehicle has been put into service, these annual benefits will continue to accumulate each year for as long as the system remains active. For the purposes of this assessment, it has been assumed that the system will operate for a period of 5 years before requiring replacement or major overhaul. Therefore, the annual benefits are multiplied by 5 to give the total benefits, and these can be balanced against the additional vehicle cost. This total value is then divided by the number of vehicles per year that are affected by the engineering changes, to give a value for the benefit that will arise from each vehicle. This represents in effect a budget cost per vehicle for implementing these changes, if the measure is to have a positive benefit. The range of engineering solutions that might achieve these benefits are then evaluated and reviewed. There are several advantages to this approach, compared with the conventional technique:

The numbers are much more comprehensible than the tens or even hundreds of millions of pounds of total benefit and cost that might be involved in the case of an effective measure that requires changes across a large number of vehicles.
The market for engineering solutions can be assessed in a more comprehensive way. For example, where a range of systems that could alleviate a problem is on the market, the assessment is no longer limited to the "cheapest" or "average" price, but can examine in detail that portion of the market that meets the necessary budgetary constraints.

In the market review for solutions, allowance has been made for:

- The retail cost of devices.
- The labour for installing them.
- Where this can be estimated, any changes in operating costs of the vehicle, such as fuel consumption, loss of productivity etc.

The benefits that accrue from making the proposed change in most cases correspond to the value of the deaths and injuries that will be prevented by adopting the proposed measure. This is done on the basis of expert judgement as to the number of injuries that are potentially preventable by the measure, and an estimate of the effectiveness of the measure in achieving this. In the UK, there are accepted monetary values than are assigned to each fatal, serious and slight injury, and for each fatal, serious and slight injury accident. These figures are published by the Department for Transport, in the annual Recorded Road Casualties for Great Britain document. They are based on "willingness to pay" studies conducted by the Department and updated at regular intervals. Using these standard values, we are able to compare the value of the costs and benefits for each single measure.
As mentioned above, most of the legislative changes that are proposed can only be implemented on an EU-wide basis. However, evaluating costs and benefits over the EU as a whole is not practical within the scope of the project. The reason for this is that comparable accident and vehicle fleet figures are not always available for the whole of the EU, and other member states adopt widely differing values for the cost of injury. Therefore the costs and benefits have been evaluated for the United Kingdom alone. Broadly, it could be assumed that the balance of costs and benefits would be similar across the Union, but it would be for the other national representatives at the ECE working groups to estimate these for their own territories.

A full evaluation of costs and benefits needs to take account of the fact that these arise at different times, insofar as the costs occur when the vehicle is manufactured, but the benefits accumulate gradually during the time it is in service. Current UK statistics show an average age of just over 7 years for the UK LGV fleet, so it is likely to take well in excess of 10 years before this transition period is complete. For the purposes of the assessment, the comparison is made on the basis that the benefits of a fully compliant vehicle fleet exist; in other words the situation that will occur once the changes have spread over the full vehicle fleet.

7.3 Solutions and cost-benefit analysis

7.3.1 Blind-Spot prevention for N_2 and N_3 vehicles

7.3.1.1 Proposed measures

Work Package 1 showed that there was a deficiency in the driver's vision to the front nearside on N_2 and N_3 vehicles, and that this was largely responsible for many injuries, typically those in Clusters 1, 2 and 7 of the accident analysis. These corresponded to three different collision scenarios as follows:

- Cluster 1: Side-swipe collision of a left-hand drive LGV with a car during a lane change manoeuvre to the right (in other words, the side opposite the driver).
- Cluster 2: Side-swipe collision of a right-hand drive LGV with a car, during a lane change manoeuvre to the left, or collision with vehicle merging from the left (essentially, a mirror image of Cluster 1).
- Cluster 7: Collision of the LGV with a vulnerable road user, during a left-turn manoeuvre.

It identified two measures that need to be made in order to reduce injuries in these types of collision. One of these was judged to have the potential to eliminate collisions where the driver looked but was unable to see the hazard, and the other the potential to eliminate all of the collisions, including those where the driver failed to look.

These two measures were, respectively:

- To introduce legislation to require the extension of the driver's field of view on the passenger side of all new N_2 and N_3 class vehicles (using the Class V mirror) in the lateral dimension, from the current 2m minimum distance from the vehicle side (specified in Directive 2003/97/EC and Regulation ECE46.02) to 4.5m from the vehicle side, and in the longitudinal direction from the current 1m forwards of the driver's ocular points to 3m forwards. The current longitudinal dimension to the rearmost edge of the zone of 1.75m behind the driver's ocular points remains unchanged.
- To introduce legislation to require the installation on all new N_2 and N_3 category vehicles of an automated system capable of detecting a pedestrian or cyclist close to the nearside of the LGV, and to alert the driver when this occurs as they are about to make an abrupt left turn.

7.3.1.2 Engineering changes proposed

For the first measure, it was concluded that it is practical to extend the field of view to the necessary extent by simply fitting a larger Class V mirror. Alternatively, a vehicle manufacturer may choose to comply with the proposed change to the legislation by installing a camera-monitor system to view the nearside of the LGV.

The project examined an extended view mirror by a leading manufacturer that will meet the proposed requirements. It also examined the range of camera-monitor systems currently on the market and concluded that systems suitable for meeting the proposed change already exist. Both of these have been demonstrated to work effectively on demonstrator and concept vehicles, and are already fitted to a small number of LGVs in service. It is therefore concluded that there are no technical problems that will prevent manufacturers from installing either of these on most conventional designs of LGV. It should be noted that ECE46.02 already allows camera systems to be fitted in place of Class V mirrors, so there is already a legal basis for using either type of system.

For the automated alert systems proposed as the second measure, there are a number of technologies that can be used as the basis of such a system; for example, ultrasound, radar, infra-red or machine vision. Some of these technologies are mature, have been demonstrated on safety concept vehicles and are already on the market. An important question that has been raised in relation to such systems is the effectiveness of the Human-Machine Interface (HMI) that delivers the warning to the driver. This is whether it can deliver the warning effectively, but without annoying the driver or overloading them with unnecessary alerts to the extent that they begin to ignore them completely. Discussions with manufacturers suggest that a good form of HMI is the combination of a small LED positioned next to or within in the Class IV mirror that illuminates when the system detects a person close to the side of the LGV, supplemented with an audible or haptic warning to the driver whenever the left-turn indicator is activated.

It is believed that the benefits of such types of system justify the establishment of an EU-wide requirement to fit them on all new LGVs. However, there is currently no standard for assessing how effectively they are capable of detecting a Vulnerable Road User in the appropriate zone, and this must be established before a European standard can be put in place. The technical requirements of this standard have not yet been established and are outside the scope of this project. However, most of the requirements will apply to the component approval of the system and not its installation on the vehicle. This means that the majority of the cost of developing and approving the system will be spread over the full sales of the system, rather than for its installation in a specific vehicle type.

7.3.1.3 Benefits

Both of the measures proposed have the potential to prevent a large proportion of the injuries that fall into Cluster 7 of the accident analysis, that is, the collision of left-turning LGVs with vulnerable road users. The accidents in this cluster comprised the following numbers for year 2008:

- Slight 27, Serious 5, Fatal 3.

These were accidents involving LGVs, where there was some indication that driver blind spot might have been a contributory factor. However, the numbers include all types of LGV, including light goods vehicles in the N_1 class. Since the proposal is only to require N_2 and N_3 vehicles to adopt the changes, then those accidents to N_1 vehicles will not be affected. Cluster 7 contains 18 N_1 vehicles, within a total of 35. Since no evidence can be found to evaluate the involvement of the different categories according to severity, it is assumed that this is equal for all categories.

Therefore, the above figures have been reduced in the ratio of 18/35 or 0.514 to eliminate the N_1 vehicles. With these eliminated the totals are:

- Slight 13.11, Serious 2.43, Fatal 1.46.

7.3.1.4 Benefits of first two measures (larger mirror or camera system)

"Failed to look properly" was the most common contributory factor in STATS 19 reports and was noted in 39% of slight accidents, 32% of serious accidents, and 24% of fatal accidents that occurred in 2009. For this measure, it was assumed that giving the driver a better field of view would make no difference in these cases, so the above figures were multiplied by 0.61, 0.68 and 0.76 respectively to account for this. The resulting figures were multiplied by the standard costs per accident for each class of injury noted in Reported Road Casualties Great Britain 2009, to give the following annual benefits value for the UK.

Injury Class	Number of accidents prevented	Value of preventing each accident £	Prevention value (rounded to nearest £)
Slight	8.00	1880	15 039
Serious	1.65	21 370	35 291
Fatal	1.11	1 790 200	1 982 519
All	10.76		2 032 849

Table 52 Annual Benefits from Eliminating Cluster 7 Accidents to N_2 and N_3 Vehicles where "Driver Failed to Look Properly"

Please note that whilst the 'Number of accidents prevented' are reported to two decimal places, their actual values have been used in the calculation of the 'Prevention value'. Therefore differences which may arise when comparing the 'Prevention value' with the result of multiplying the second and third column of each table are due to rounding.

As well as preventing some of the injuries in Cluster 7, the same measures if implemented on the overseas LGVs associated with this cluster would also reduce the number of side-swipes in Cluster 1 and the injuries associated with them, so these can also be counted in the benefits. The accidents in this cluster comprise

- Slight 168, Serious, 7, Fatal 1.

According to the accident data, all of these accidents involved N_2 or N_3 category vehicles, so all of them will be affected by the measure. As for the Cluster 7 results, these are scaled to eliminate the failed to look properly cases, using the same factors. The resulting number of accidents and benefits value is given below.

Injury Class	Number of accidents prevented	Value of preventing each accident £	Prevention value (rounded to nearest £)
Slight	102.48	1880	192 662
Serious	4.76	21 370	101 721
Fatal	0.76	1 790 200	1 360 552
All	108.00		1 654 936

Table 53 Annual Benefits from Eliminating Cluster 1 Accidents to N_2 and N_3 Vehicles where "Driver Failed to Look Properly"

Please note that whilst the 'Number of accidents prevented' are reported to two decimal places, their actual values have been used in the calculation of the 'Prevention value'. Therefore differences which may arise when comparing the 'Prevention value' with the result of multiplying the second and third column of each table are due to rounding.

Again, we can count the benefits from preventing some of the Cluster 2 accidents as above. The accidents in this cluster comprise

- Slight 161, Serious 7, Fatal 1

In this case, there were 2 light goods vehicles that would not be affected out of a total of 169, so these figures have been multiplied by 167/169, or 0.988. Discounting the number who failed to look properly, this gives the following numbers and values.

Injury Class	Number of accidents prevented	Value of preventing each accident £	Prevention value (rounded to nearest £)
Slight	97.05	1880	182 450
Serious	4.70	21 370	100 517
Fatal	0.75	1 790 200	1 344 451
All	102.50		1 627 418

Table 54 Annual Benefits from Eliminating Cluster 2 Accidents to N_2 and N_3 Vehicles where "Driver Failed to Look Properly"

Please note that whilst the 'Number of accidents prevented' are reported to two decimal places, their actual values have been used in the calculation of the 'Prevention value'. Therefore differences which may arise when comparing the 'Prevention value' with the result of multiplying the second and third column of each table are due to rounding.

Adding the benefits for Cluster 7, Cluster 1 and Cluster 2 accident figures, the total annual value of benefits per year resulting from the measures is £5 315 203. Over the assumed 5 year life of the system, the total benefits come to £26 576 013 (allowing for rounding errors). If the measure is to prove economic, the average budget for parts and installation per affected vehicle will be the total 5 year benefits, divided by the number of vehicles affected. For the purpose of this assessment, it is assumed that the measure will apply to all new N_2 and N_3 LGVs in the UK. Currently, very few LGVs are fitted with systems of this type, so it is assumed that all of these vehicles will be affected. Using figures from SMMT for new vehicle registrations, the number of N_2 and N_3 LGVs registered in the UK in 2010 was 30200. Dividing the total benefits by this figure, this represents a budget of £880 per vehicle for the purchase and installation of a suitable system, if a positive benefit is to be achieved by this measure.

7.3.1.5 Benefits of the third measure (driver alert)

Unlike the camera system, which is not likely to affect those accidents in which the driver failed to look properly, the driver alert has the potential to eliminate all of the accidents in Clusters 1, 2 and 7. Therefore, the estimation of benefits for this measure counts all of these accidents.

The resulting reduction in accidents and associated values for the Cluster 7, Cluster 1 and Cluster 2 accidents are given in the following tables.

Injury Class	Number of accidents prevented	Value of preventing each accident £	Prevention value (rounded to nearest £)
Slight	13.11	1880	24 655
Serious	2.43	21 370	51 899
Fatal	1.46	1 790 200	2 608 577
All	17.00		2 685 131

Table 55 Annual Benefits from Eliminating All Cluster 7 Accidents to N_2 and N_3 Vehicles

Please note that whilst the 'Number of accidents prevented' are reported to two decimal places, their actual values have been used in the calculation of the 'Prevention value'. Therefore differences which may arise when comparing the 'Prevention value' with the result of multiplying the second and third column of each table are due to rounding.

Injury Class	Number of accidents prevented	Value of preventing each accident £	Prevention value (rounded to nearest £)
Slight	168.00	1880	315 840
Serious	7.00	21 370	149 590
Fatal	1.00	1 790 200	1 790 200
All	176.00		2 255 630

Table 56 Annual Benefits from Eliminating All Cluster 1 Accidents to N_2 and N_3 Vehicles

Injury Class	Number of accidents prevented	Value of preventing each accident £	Prevention value (rounded to nearest £)
Slight	159.09	1880	299 098
Serious	6.92	21 370	147 820
Fatal	0.99	1 790 200	1 769 014
All	167.00		2 215 932

Table 57 Annual Benefits from Eliminating All Cluster 2 Accidents to N_2 and N_3 Vehicles

Please note that whilst the 'Number of accidents prevented' are reported to two decimal places, their actual values have been used in the calculation of the 'Prevention value'. Therefore differences which may arise when comparing the 'Prevention value' with the result of multiplying the second and third column of each table are due to rounding.

Adding the benefits for Cluster 7, Cluster 1 and Cluster 2 accident figures, the total annual value of benefits per year resulting from the measures is £7 156 692 (allowing for rounding errors). Over the assumed 5 year life of the system, the total benefits come to £35 783 462 (allowing for rounding errors). If the measure is to prove economic the average budget for parts and installation per affected vehicle will be the total benefits, divided by the number of vehicles affected. For the purpose of this assessment, it is assumed that the measure will apply to all new N_2 and N_3 vehicles in the UK. Currently, very few LGVs are fitted with systems of this type, so it is assumed that all of these vehicles will be affected. Using figures from SMMT for new vehicle registrations, the number of N_2 and N_3 LGVs registered in the UK in 2010 is 30200. Dividing the total benefits by this figure, this represents a budget of £1185 per vehicle for the purchase and installation of a suitable system, if a positive benefit is to be achieved by this measure.

7.3.1.6 Costs

Consultations with system suppliers were carried out to evaluate the cost of purchasing a system that would just meet the requirements of the proposed measure, if this were part of a deal with a vehicle manufacturer to fit to all their vehicles. They were also asked for the time that one of their skilled fitters might take to install the system, which was multiplied by a figure of £35 per hour for current labour costs in the automotive industry.

For the mirror system, it was not possible to undertake a full market survey because only one suitable mirror is known to exist at the present time. However, the manufacturer of this mirror estimated a retail price of £40 for their product. This falls within the range of prices for existing Class V mirrors. Fitting is the same as the current Class V mirror, so it is assumed that there is no additional labour associated with installation. The cost represents less than 5% of the budget figure of £880, so this represents a strong balance of benefit over cost.

For the camera system, the average purchase price quoted was £420, with a typical installation time of 2 hours, representing £70, making a total of £490. Since the system would replace a Class V mirror (average cost £40) this represents a net additional cost of £450. This represents 51% of the budget figure of £880, so this also represents a strong balance of benefit over cost, although not quite as strong as the mirror. Since camera-monitor systems are already covered by the legislation, mandatory installation will not require the manufacturer to undertake any additional testing for type-approval, so there will be no additional costs associated with approval that would be imposed on either the system or vehicle manufacturer.

The costs for mandatory installation of a driver alert system have been derived in a similar way, by costing systems incorporating ultrasound sensors, activating a flashing LED and an audible alarm when reverse gear is selected. The average purchase price for such a system is £360, with an estimated £70 cost for installation, making £430 in all. This represents 36% of the budget price of £1185 per vehicle for a system of this type. Again, this represents a balance of benefit over cost.

7.3.1.7 Other considerations

All of the measures proposed here have been assessed for their effect on Government targets for CO2 emissions and other environmental considerations.
In the case of the larger mirror, its overall dimensions are only marginally greater than a conventional Class V mirror, and in any case the contribution of the Class V to the overall aerodynamic drag generated by all of the mirrors is small. Therefore, it is assumed that any increase in fuel consumption and CO2 emissions due to changes in drag will be negligible.

In the case of the camera-monitor systems, these normally house the camera inside a streamlined housing mounted flush with the surface of the cab, so the aerodynamic drag is quite low. If an operator chooses to fit a camera system, then they may have the option of dispensing with the Class V mirror, in which case there may be a small saving in fuel costs due to the reduction in aerodynamic drag. However, it is not known whether the operator would prefer to do this, or whether they would prefer to retain the Class V mirror as a back-up.

Considering the power required to operate the system, this is estimated to be less than 100w on average. This is negligible, compared with the motive power of a typical LGV.

The alerting system would have an even smaller effect on CO2 emissions, since the external sensors would project at most a few millimetres from the vehicle bodywork, and the power consumption would be less than the camera-monitor.

7.3.1.8 Conclusions

Considering the UK alone, if the regulations for driver vision required an extension of the area visible to the nearside from 2m to 4.5m from the side of the vehicle, this could be accommodated by fitting either a slightly larger Class V mirror, or by installing a suitable camera-monitor system. For the larger Class V mirror, there would be a negligible additional cost to the manufacturer or operator, but the measure has the potential to save 2.6 fatal, 11.1 serious and 207.5 slight injuries per year on UK roads, representing a saving of £5 315 203 per year, or £26 576 013 over an assumed 5 year life for the mirror (allowing for rounding errors). This represents a significant saving for negligible additional cost.

If manufacturers chose to meet the requirements by installing a camera-monitor system, it is assumed that the same number of injuries would be saved so the total value of the benefits would be the same. Dividing this total by the 30 200 heavy LGVs registered in the UK per year represents a budget of £880 per vehicle, if it is to achieve a positive balance of benefit over cost. MIRA has surveyed the market for camera-monitor systems and there are many systems that could meet the requirements for less than this budget. Overall, the average price is £490 per vehicle, including installation, giving a total cost of £14 798 000 per year for all N_2 and N_3 vehicles registered in the UK. Therefore, the camera-monitor system represents a positive balance of benefit over cost.

If all LGVs in the UK were required to install driver alert systems, this would have the potential to save 3.4 fatal, 16.3 serious and 340.2 slight injuries per year, representing £7 156 692 per year, or £35 783 462 (allowing for rounding errors) over the 5 year life assumed for the system. Spread over the 30 200 LGVs registered per year in the UK, this represents a budget of £1185 per vehicle, if it is to achieve a positive balance of benefits over cost. From a market survey of alert systems suitable for meeting the requirements, it is apparent that there is a range of systems available within the budget price. Overall, the average price per vehicle for such systems, including installation, amounts to £430. This represents a positive balance of benefit over cost in the ratio of 2.76.

Measure	Larger Class V Mirror	Camera / Monitor	Driver Alert
Total benefits over 5 years	£26.5 m	£26.5m	£35.7m
No of vehicles affected	30200		
Target unit cost	£880	£880	£1185
Average net cost per vehicle	£40	£490	£430
Benefit / cost	22.5	1.80	2.76

Table 58 Cost-benefit summary for potential solutions to blind-spot prevention for N_2 and N_3 vehicles

On this basis, it appears that the engineering changes to accommodate both of the proposed measures would prove economic, insofar as the benefits of reducing injuries over the working life of the systems exceed the additional cost of purchasing and installing the system.

This conclusion should be weighed against the assumptions that have been made in this assessment. These are detailed elsewhere but may be summarised as follows:

- That the measure is introduced throughout Europe, and that the overall costs and benefits in the other member states will be commensurate with the UK figures quoted here.
- That all N_2 and N_3 vehicles in service are fitted with a compliant system.
- That the enlarged mirror or camera systems will prevent all of the N_2 / N_3 collisions identified in Clusters 1, 2 and 7 of the accident analysis, except those in which "failed to look properly" is identified as a contributory factor.
- That the rate of involvement of N_1 in the collisions identified in the clusters is the same as for N_2 and N_3 vehicles.
- That the driver alert system will prevent all of the N_2 / N_3 collisions identified in Clusters 1, 2 and 7, including those where "failed to look properly" is identified as a contributory factor.
- That the benefits will be realised over a 5-year service life of the system.
- That there will be no additional running costs for the vehicles over this period.

7.3.2 Visibility of rear obstacle

7.3.2.1 Proposed measures

The project has demonstrated that there is a deficiency in the rear vision from certain M_1 and M_2 vehicles, and that this is largely responsible for many injuries associated with vehicles that are reversing.

From the research and testing carried out in Work Package 3, the following engineering changes to vehicles are proposed, in order to reduce the number of injuries that occur when these vehicle types are reversing:

- To mandate the installation of a camera-monitor system on all M_1 and M_2 category vehicles, to allow the driver to view the area to the rear while reversing.
- To mandate the installation of a driver alert system on all M_1 and M_2 vehicles, to warn the driver of persons close to the rear of the vehicle while reversing.

7.3.2.2 Engineering changes proposed

In the case of the camera-monitor system, the minimum equipment level would be a single camera mounted in a position that gives the field of view specified. Although some cameras offer a "night vision" capability, this is not considered to be a necessary part of the minimum fitment, since the reversing lamp will provide sufficient illumination at the range required. A basic monochrome monitor would be sufficient. No minimum screen size needs to be specified. The most basic systems currently offered for sale incorporate a 2.5inch colour monitor.

In the case of the driver alert system, the minimum equipment level would be a single sensor with an audible alarm. However, the most basic systems currently on sale offer 2 sensors with a multi-tone buzzer. Many suitable systems are already on the market as reversing aids.

7.3.2.3 Costs for the camera-monitor system

The camera-monitor and driver alert systems proposed as reversing aids for M_1 and M_2 vehicles are different from the systems proposed for N_2 / N_3 blind spot. The latter are of much more rugged design to withstand the working environment of a LGV, and are designed for a 24volt electrical system. The devices proposed for this application do not require these qualities and are therefore generally cheaper.

The partners have reviewed 8 reversing camera-monitor systems currently on sale as retrofit devices and also the systems offered by manufacturers as factory-fitted accessories in 2 popular mid-range saloon cars. All of these meet the minimum specification detailed above. The retrofit systems cover a range of prices from £40 to £205 with an average price of £130; some of the higher priced systems offer features that are not necessary for the basic functionality envisaged such as combined sensor alerts and night vision. On this basis, the typical price for a basic system is considered to be £125, which covers the 5 cheapest systems. Installation of these systems (some of which use wireless connectivity for the monitor unit) is judged to require less than 1 hour's labour, representing an additional cost of £35, making a total cost of £160 per car. The additional cost charged by car manufacturers for their original equipment reversing camera systems varies between £200 and £400 and is therefore consistent with the above costs.

Currently, reversing cameras are classed as surveillance cameras and are therefore not subject to mandatory performance standards. If their fitment was made obligatory, then it might be appropriate to introduce some form of minimum performance requirements for them, and these could be incorporated into ECE46.02, since this already addresses camera-monitor systems as alternatives for some mirror types. This could impose an additional cost on manufacturers, which could increase unit costs by a small amount, depending on sales volumes.

Although some new cars are already fitted with reversing cameras as standard, these are believed to form a very small proportion of the total number produced. If all of the 1 996 300 new cars registered in the UK in 2010 were required to be fitted with reversing camera-monitor systems, therefore, the total cost would be approximately £319 408 000. However, this only considers M_1 vehicles and not M_2.

7.3.2.4 Benefits for the camera-monitor system

The cluster analysis referred to in the previous section was confined to category N vehicles only, and did not include accidents to category M vehicles, as per the agreed project plan. Hence it is not possible to examine the benefits of preventing reversing accidents in the same way. To overcome this difficulty, access was granted by DfT to some earlier unpublished data for reversing accidents. This data was only available for M_1 vehicles in 2007, where vehicle blind spot was judged to be a contributory factor. Due to the lack of data availability for M_2 vehicles, the following sections therefore only consider benefits with respect to M_1 vehicles. The data contained the following classes of injury:

- Slight 118, Serious 41, Fatal 0.

For the purposes of benefits calculation, it was assumed that all of these accidents could potentially have been prevented by the provision of a reversing camera or a driver alert on the affected vehicle. The benefits for the two measures were assumed to be the same.

The value of these benefits is given in the table below:

Injury class	Number of accidents prevented	Value per accident, £	Benefits, £
Slight	118	1880	221 840
Serious	41	21 370	876 170
Fatal	0	1 790 200	0
All	159		1 098 010

Table 59 Annual Benefits from Eliminating Reversing Accidents to M_1 Vehicles where Blind Spot was a Contributory Factor

As with the blind-spot camera and alert systems in the previous section, it is assumed that these systems will have a life of 5 years before requiring replacement of major overhaul. Therefore, we can count that the total benefits will be 5 times the annual benefits given above. This represents a total benefit of £5 490 050, if the measures are effective.

According to SMMT figures, the number of new cars registered in the UK in 2010 was 1 996 300. Very few of these were fitted with a reversing camera, so in the case of the camera system, it is assumed that this is the number of affected vehicles. Dividing the total benefits by this number of vehicles gives £2.75 per vehicle, which is effectively the budget for a suitable system, if a positive benefit is to be achieved.
In the case of reversing alarms, a survey by MIRA showed that approximately 20% of vehicles are already equipped with systems of this type. Therefore, the number of affected vehicles is approximately 1 597 040. Using a similar calculation as the above, the total benefits require a system cost of less than £3.43 per vehicle.

7.3.2.5 Costs for the driver alert system

MIRA reviewed 18 parking sensors currently on sale as retrofit devices, and also the systems offered as factory fitted accessories on 5 mid-range saloon cars. All of these meet the minimum specification detailed above. The retrofit devices range in price between £30 and £110, with an average price of £62. In general, the more expensive systems do not offer more features, so it is assumed that the difference in price is determined by quality. Installation of these systems is judged to require 1 hours labour, representing an additional cost of £35, making a typical total cost per vehicle of £97.

It is difficult to identify an accurate price for factory-fitted systems since most of these are offered as a package together with other features. However, two of the manufacturers reviewed offer 2-sensor "parking systems" for £130 and £199, and one offers a 4-sensor system for £249.

Unlike the reversing camera system, a significant proportion of new cars are already fitted with parking sensors as standard. No statistics could be found for this. However, MIRA conducted a small survey of current vehicles and estimates that 20% of 2007-2011 cars have such systems already fitted. Therefore, the additional number of systems that will be needed if all cars are to be fitted is estimated as 1 597 040. Therefore, the estimated total cost for installing these across the fleet in the UK is £154 912 880.

Measure	Reversing camera / monitor	Driver alert
Total benefits over 5 years	£5.5m	£5.5m
No of vehicles affected	2.0m	1.6m
Target unit cost	£2.75	£3.43
Average net cost per vehicle	£160	£97
Benefit / cost	0.02	0.04

Table 60 Cost-benefit summary for potential solutions to rear visibility for M_1 vehicles

7.3.2.6 Other considerations

Currently, camera systems are permitted as an alternative to certain classes of mirrors by ECE46.02. Therefore, this regulation would form the regulatory basis for the performance of reversing camera systems. On the other hand, there is currently no mandatory standard for the performance of reversing alarms, and it might be necessary to draft such a standard if these are to be made mandatory. Approval of systems to this standard could impose a cost burden on manufacturers, with a consequent additional cost per component passed on.

Calling for the mandatory installation of camera-monitor or driver alert systems for the most numerous sector of the motor industry (even in the UK, let alone Europe) would call for a significant increase in the production of such devices, even on a world-wide basis. It is not known whether the industry is capable of responding to this increase in demand, or what the effect on raw material resources would be, or what effect this might have on the price structure.

Both of the measures proposed here have been assessed for their effect on Government targets for CO2 emissions and other environmental considerations. External cameras and sensors of this type do not significantly alter the external profile of the car and their power consumption is negligible in comparison with the motive power of the vehicle. They would therefore not be expected to affect the fuel consumption or CO2 emissions of cars. However, the change in CO2 emissions associated with the increased production of these devices is not known.

7.3.2.7 Conclusions

On the basis of these figures, it is estimated that requiring all M_1 vehicles in the UK to install reversing cameras or driver alerts could prevent 0 fatal, 41 serious, and 118 slight injuries per year on UK roads, representing a saving of £1 098 010. Since very few cars are currently fitted with reversing cameras, this represents a per-vehicle benefit of £2.75. On the other hand, since an estimated 20% of new cars are already fitted with a reversing alert system, the average benefit from equipping the remaining cars with one of these is higher, at £3.43 per vehicle. Against this, a survey of the market for these systems indicates that the average price for a reversing camera system is approximately £160 per vehicle, while the average price for a reversing alert system is £97 per vehicle. None of the systems surveyed was available for less than the budget price. On balance therefore, the cost of equipping the entire UK car fleet with either type of system would be more than the benefits arising from the reduction in injuries.

Instead, it is recommended that a further review should be carried out in 5 to 10 years time, when it seems likely that the majority of cars will be equipped with reversing cameras or alerts as standard. If this happens, the costs of implementing the measures will have reduced significantly, making their adoption across the whole of the M_1 fleet more attractive economically.

7.3.3 Mirror image quality

7.3.3.1 Proposed measure

From the research undertaken, it appears that drivers of N_3 vehicles may not adjust their mirrors correctly, although no quantitative data appears to be available on this. Thus, even though the vehicle mirrors could potentially allow the driver to see the minimum areas prescribed in the regulation, the full extent of these areas may not be seen from the driver's seat. It is believed that the main reason for this is that the driver is too busy to check or adjust the mirrors at the start of shift or does not know how to do so correctly. However, there may also be cases where the driver is using the mirror for a purpose other than that for which it is intended e.g. close manoeuvring.

Difficulties in adjusting the mirrors may be problematic for drivers. For many LGVs the mirrors are located too far above the ground to be reached without steps. Class II and IV mirrors are often located too far forwards to be reached easily through the driver's window. Even where access is possible, the nearside mirrors require the driver to leave their seat to make the adjustment, and this may require some backward and forward movement while the position of the mirror is checked and re-adjusted.

There is a widely-held belief that the wide angle view of Class V and VI mirrors makes it less important to set them correctly, and that once set they will offer an adequate view for a wide range of driver sizes and driving positions. Simulation work in WP1 has shown that this is not so.

The technology for adjusting mirrors remotely is now quite common on M_1 vehicles, and is being offered as standard equipment on some N_2 / N_3 vehicles for the Class II mirrors. However, the number of Class IV, V and VI mirrors incorporating electric adjustment is currently very small.

The measure proposed is that all new N_2 and N_3 LGVs in the UK should be required to be fitted with mirrors, including Class IV, Class V and Class VI, that are adjustable from the driver's seat. In the case of Class II mirrors, most manufacturers already have such mirrors available so it will only be necessary to offer them as standard, rather than an option. However, they would face a greater obstacle in fitting Class V and VI mirrors that are electrically adjustable. A market survey failed to find any manufacturers who currently offer such mirrors so it would be necessary for them to develop new products to meet this demand, even though the necessary actuators already exist.

7.3.3.2 Costs

MIRA has conducted a survey of parts prices to estimate the additional cost of electric Class V and VI mirrors over the equivalent manually adjustable mirrors, and this would be approximately £50 per mirror to include switches, actuators and wiring. Thus, for a LGV that currently has electrically adjustable Class II mirrors only, the cost of full electrical adjustment would be £200, for two Class IV's, one Class V and one Class VI.

7.3.3.3 Benefits

It is not possible at this stage to evaluate the benefits of the measure, because it was not practical for the project to survey the proportion of vehicles on the road where the mirrors are mal-adjusted to a dangerous extent, or to judge to what extent a particular degree of mal-adjustment affects the accident risk. Furthermore, even if such mirrors make adjustment easier, it is not known whether this will encourage drivers to adjust them more frequently, without other measures such as publicity campaigns being put in place. Therefore, it is not possible to make a case for whether the proposed measure would be economic or not.

7.3.3.4 Conclusion

Although it seems likely that there would be a reduction in the injuries arising in vision-related accidents by requiring all mirrors on N_2 and N_3 vehicles to be adjustable from the driver's seat, it is not possible to estimate how many injuries would be saved by this measure. In addition, it is critical that drivers understand the rationale for the defined visible area and are capable of adjusting mirrors to meet that specification. The average cost of installing these on a LGV would be approximately £200, but it is not known whether this would result in a positive overall balance of benefit over cost.

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APPENDICES

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APPENDIX 1: DRIVER INTERVIEW DATA COLLECTION SHEET

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<table>
<tr><td colspan="4">INTERVIEW DETAILS (version 6)</td></tr>
<tr><td>Date:</td><td></td><td>Interview number:</td><td></td></tr>
<tr><td>Organisation:</td><td></td><td>Location:</td><td></td></tr>
<tr><td>Interviewer:</td><td></td><td></td><td></td></tr>
<tr><td>Vehicle make:</td><td></td><td>Vehicle model:</td><td></td></tr>
<tr><td>Vehicle registration year:</td><td></td><td></td><td></td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">PARTICIPANT INFORMATION</td></tr>
<tr><td colspan="4">See separate document to be retained by the participant</td></tr>
<tr><td colspan="4">AGREEMENT</td></tr>
<tr><td colspan="4">The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethical Advisory Committee.

• I have read and understood the information sheet and this consent form.
• I have had an opportunity to ask questions about my participation.
• I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.
I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others.

I agree to participate in this study.

I agree to having photographs taken and for these to be used public dissemination such as reports, websites.
Request to have face obscured (yes/no)</td></tr>
<tr><td>Signature:</td><td></td><td>Print name:</td><td></td></tr>
<tr><td>Interviewer signature:</td><td></td><td></td><td></td></tr>
</table>

Vehicle details

Make and model:...

Category: N2 / N3

Age of Vehicle: ....

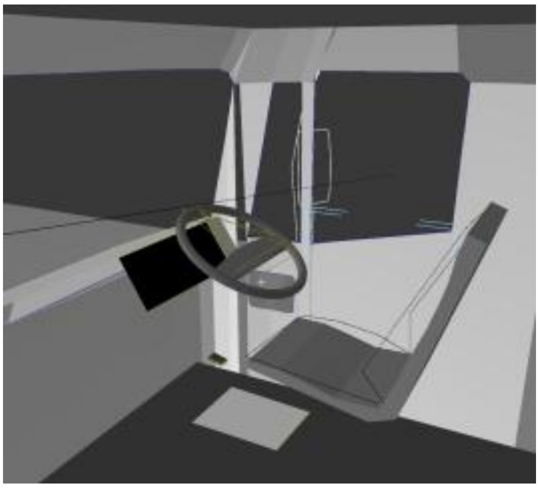
Mirrors Fitted: Class 5 6

1. Driver anthropometry will be captured

i. Stature………………………………………………= mm
ii. Sitting height …………………………………….. = mm
iii. Buttock knee length ………………………….. = mm
iv. Knee height……………………………………... = mm
v. Arm length……………………………………….= mm
vi. Sitting shoulder height ………………………. = mm
vii. Hand length……………………………………... = mm
viii. Shoulder Breadth………………………………. = mm

2. Seat adjustability range will be captured

Notes: Assumes steering wheel has height and angle adjust. Assumes seat has height/fore-aft/backrest and seat base angle adjust



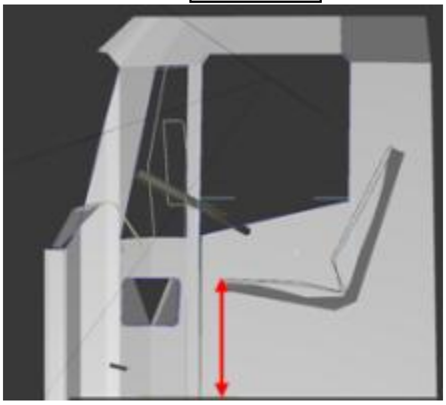
Cab illustration

3. In cab adjustability available

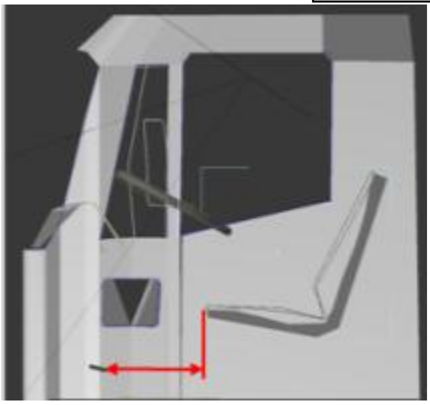
Adjustment	YES	No
Seat Fore/aft	❑	❑
Seat base angle	❑	❑
Seat Back rest angle	❑	❑
Seat height	❑	❑
Steering wheel angle	❑	❑
Steering wheel protrusion	❑	❑
Seat base length adjust	❑	❑

4. Capture Driver selected seat position

Seat height=



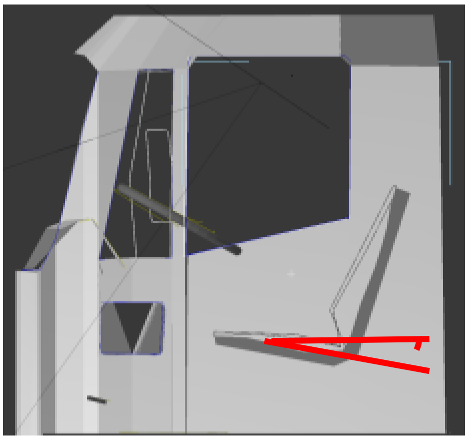
Fore aft adjustment position =



horizontally from front edge of accelerator pedal

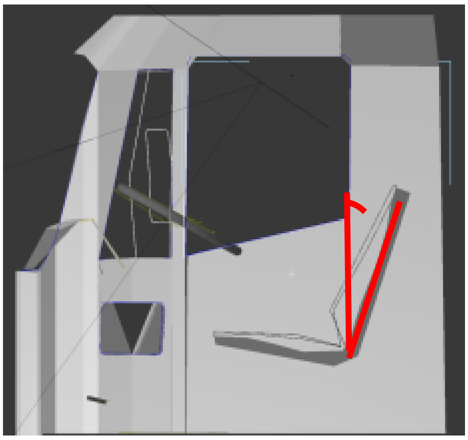
Seat base angle=

Using inclinometer (take photo of Location)

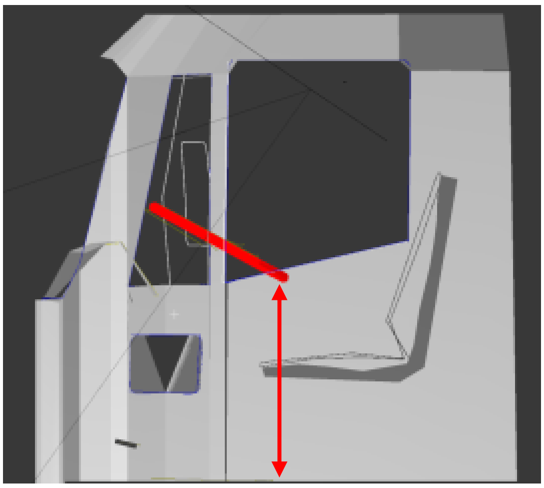


Seat back angle=

Using inclinometer (take photo of Location)

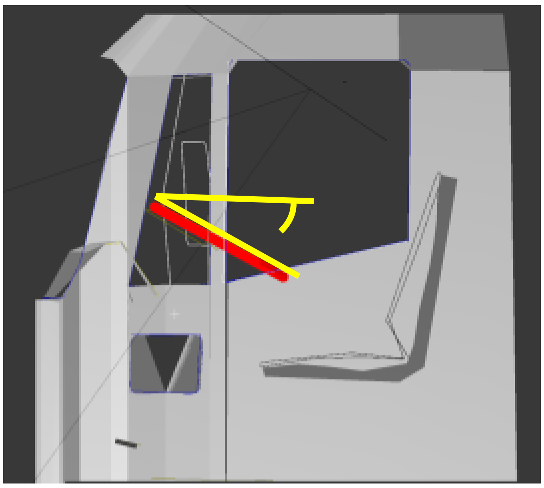


Steering wheel height =



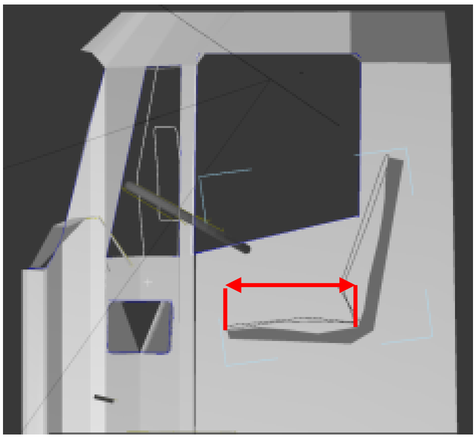
Steering wheel angle =

Using inclinometer



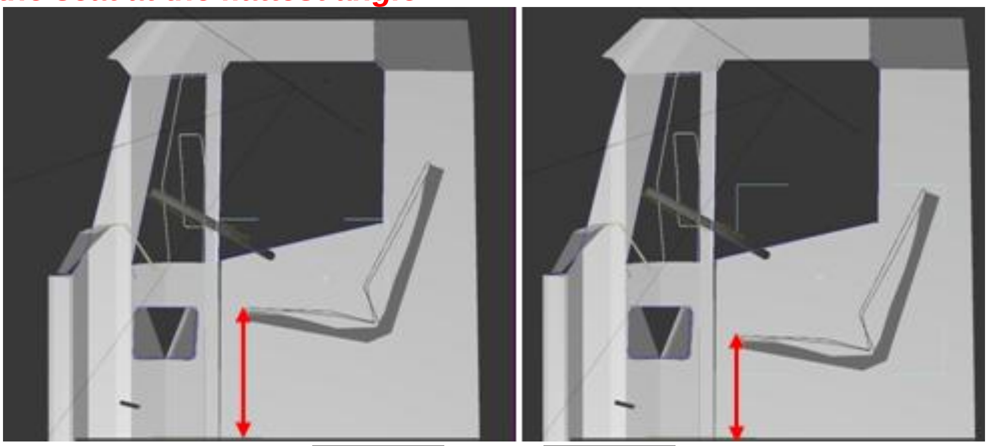
Measure on the two edges of the rim

Seat base length adjusted = [ ]



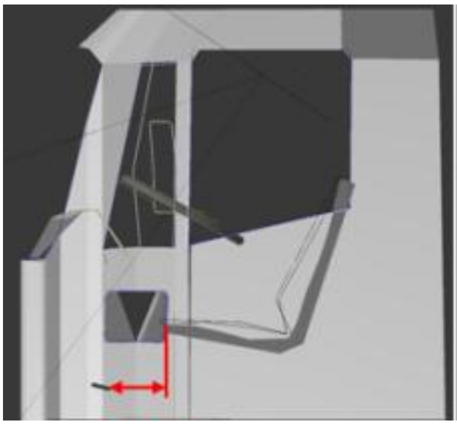
5. Capture adjustability ranges from the vehicle

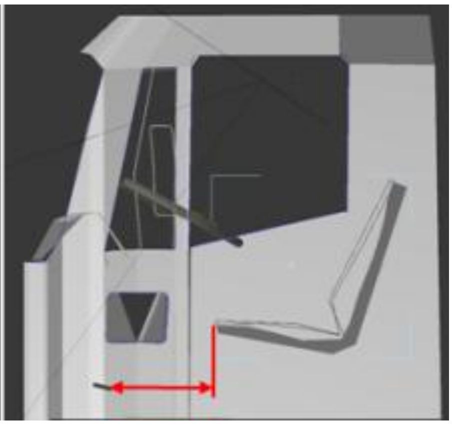
Max/Min seat height ***If seat angle is base adjustable take this measure with the seat at the flattest angle***



Max = [ ] Min = [ ] (mm)

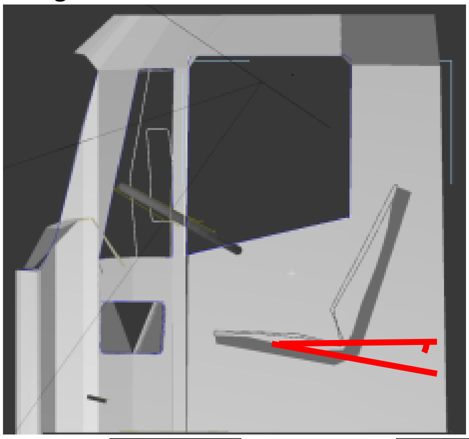
Fore aft adjustment possible (horizontally from front edge of accelerator pedal)

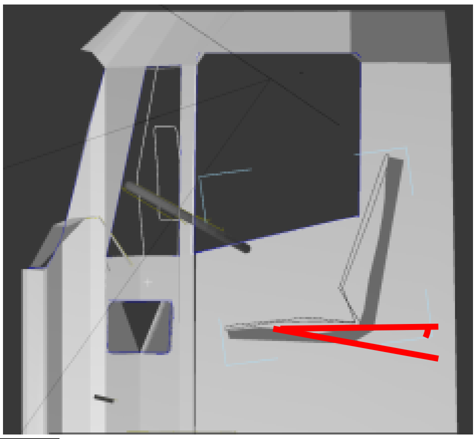




Max = [ ] (mm) Min = [ ] (mm)

Seat base angle

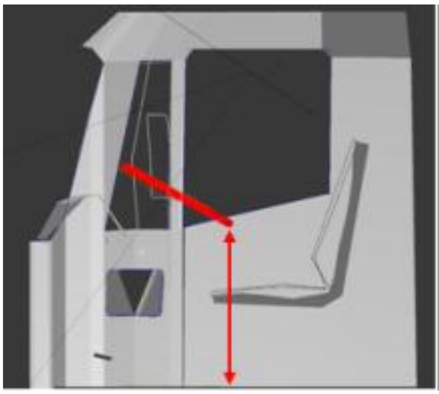


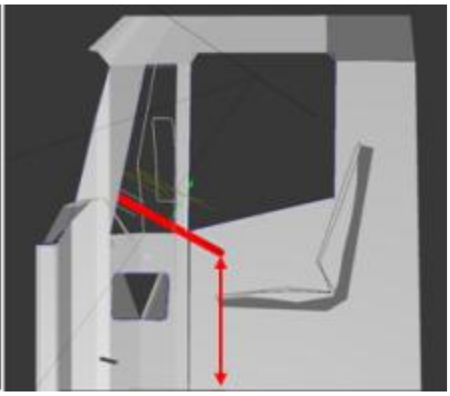


Flattest= [ ] Steepest = [ ] (Degrees using inclinometer)

Take photo of inclinometer position on seat base cushion

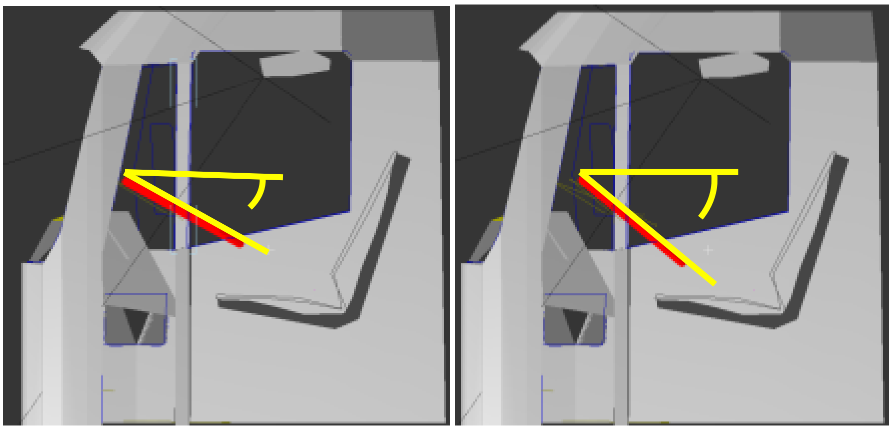
Height adjust of steering wheel (If angle adjust is present take measurement at flattest angle)





Highest= [ ] Lowest = [ ]

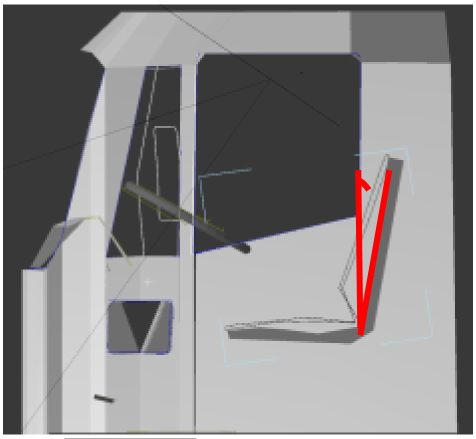
Steering wheel angle adjust



Flattest= [ ] Steepest = [ ] (Degrees using inclinometer)

Take photo of inclinometer position on seat base cushion

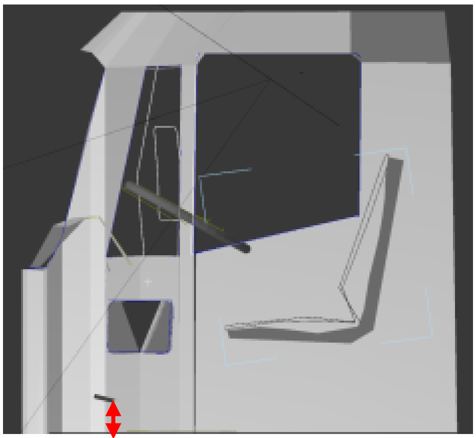
Maximum rearwards backrest angle if limited by cab structure (e.g. Not a sleeper cab)



Steepest = ____ (Degrees using inclinometer)

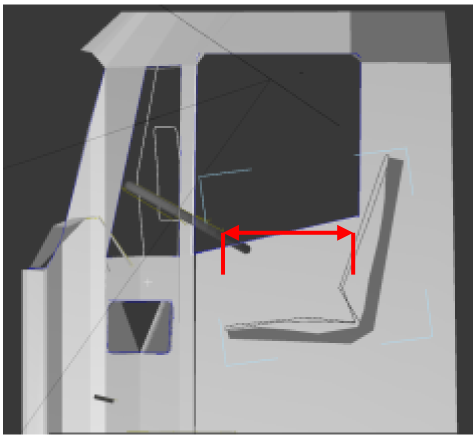
Take photo of inclinometer position on seat back cushion

Height of accelerator pedal above the floor



Height = ____

Seat base length minimum= ____ Seat base length maximum= ____



Driver and interior photographs required

Capturing posture joint angles

Side view of driving posture ***(hand on steering wheel, Right foot on accelerator pedal)***
e.g. MUST BE AS PERPENDICULAR AS POSSIBLE TO THE DRIVER TO ALLOW JOINT ANGLE CAPTURE

Photo taken YES/NO

Capturing interior

Take multiple overlapping images (we can combine these to create panoramic images) e.g.

Capture driver posture when reaching to furthest reachable control on the dash

Capture from each side (through both doors)

Capture the control that is used in 3 above so that it can be located in photo 2 above.

Interview questionnaire

Aim: To provide information on scenarios that cause either near misses, or accidents in terms of mirror use and their ability to support the situational awareness of the driver

Driver details

1. How many years have you been driving LGVs?

2. On average how many hours do you drive a LGV per week?

3. Do you regularly drive a LGV in cities and Towns?

4. Do you regularly drive a LGV on the motorway?

5. Do you regularly drive in left hand drive countries?

LGV blind spots

6. In general, to what extent are LGV drivers aware of problems that can be caused by poor vision e.g. mirror 'blind spots'?

7. Please indicate the areas around the vehicle that are difficult to view using the mirrors (Separate sheet contains the image below).

Plan view of a LGV

Situations where blind spots are critical

8. Can you tell me of any particular situations where the blind spots that you indicated cause potential problems? (e.g. changing lanes on a motorway)

9. Do weather conditions make these blinds spots worse?

10. Can you tell me how the actions of other vehicles, cyclists and pedestrians have the potential to cause accidents?

11. Are there any methods that you use to compensate for poor vision from the LGV cab? (e.g. vehicle position at junctions)

12. If you drive in Europe, can you describe situations where vision issues are worsened?

Vehicle design

13. In your experience are some vehicle designs better than others in terms of visibility of the exterior environment from the driving position?

14. List good and poor vehicle makes and models if provided

15. What might be done to improve driver vision with respect to the structure of the vehicle? (e.g. a-pillar design)

16. Are you aware of or have used after market vehicle modifications that help to solve mirror blind spots? (e.g. camera systems, Fresnel lenses)

17. Are any of these devices or systems fitted to this vehicle?

18. Do you always need to adjust your seat after another driver has used it?

Thank you for your time

APPENDIX 2: TRAINER INTERVIEW DATA COLLECTION SHEET

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<table>
<tr><td colspan="4">INTERVIEW DETAILS (version 1)</td></tr>
<tr><td>Date:</td><td></td><td>Interview number:</td><td></td></tr>
<tr><td>Organisation:</td><td></td><td>Location:</td><td></td></tr>
<tr><td>Interviewer:</td><td></td><td></td><td></td></tr>
<tr><td>Vehicle make:</td><td></td><td>Vehicle model:</td><td></td></tr>
<tr><td>Vehicle registration year:</td><td></td><td></td><td></td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">PARTICIPANT INFORMATION</td></tr>
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• I have had an opportunity to ask questions about my participation.
• I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.
I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others.

I agree to participate in this study.

I agree to having photographs taken and for these to be used public dissemination such as reports, websites.
Request to have face obscured (yes/no)</td></tr>
<tr><td>Signature:</td><td></td><td>Print name:</td><td></td></tr>
<tr><td>Interviewer signature:</td><td></td><td></td><td></td></tr>
</table>

Driver posture photographs required

Capturing posture joint angles

Ask trainer to demonstrate any recommended driving postures.

Take side view photo of driving posture

e.g. MUST BE AS PERPENDICULAR AS POSSIBLE TO THE DRIVER TO ALLOW JOINT ANGLE CAPTURE

Photo taken YES/NO

Note here any specific instructions given/ comments made, etc.

____

How do you instruct drivers to adjust their mirrors for general driving?

____

Interview questionnaire

Aim: To provide information on scenarios that cause either near misses, or accidents in terms of mirror use and their ability to support the situational awareness of the driver

Driver details

1. How many years have you been an LGV training instructor?

2. How many years have you been driving LGVs?

3. On average how many hours do you drive a LGV per week?

4. Do you regularly drive a LGV in cities and Towns?

5. Do you regularly drive a LGV on the motorway?

6. Do /Did you regularly drive in left hand drive countries?

LGV blind spots

7. In general, to what extent are LGV drivers aware of problems that can be caused by poor vision e.g. mirror 'blind spots'?

8. What guidance do you provide regarding this in your training? What do you provide as 'best practice'?

9. Please indicate the areas around the vehicle that are difficult to view using the mirrors (Separate sheet contains the image below).

Plan view of a LGV

Situations where blind spots are critical

10. Can you tell me of any particular situations where the blind spots that you indicated can cause potential problems for LGV drivers? (e.g. changing lanes on a motorway)

11. Do weather conditions make these blinds spots worse?

12. Can you tell me how the actions of other vehicles, cyclists and pedestrians have the potential to cause accidents?

13. Are there any methods that you recommend should be used to compensate for poor vision from the LGV cab? (e.g. vehicle position at junctions)

14. With respect to driving in Europe, can you describe situations where vision issues are worsened?

Vehicle design

15. In your experience are some vehicle designs better than others in terms of visibility of the exterior environment from the driving position?

16. List good and poor vehicle makes and models if provided

17. What might be done to improve driver vision with respect to the structure of the vehicle? (e.g. a-pillar design)

18. Are you aware of or have used after market vehicle modifications that help to solve mirror blind spots? (e.g. camera systems, Fresnel lenses)

19. Are any of these devices or systems fitted to this vehicle?

Thank you for your time

APPENDIX 3: DETECTION TIMES - SUMMARY DATA

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Class IV Nearside

	Car		Bike	
Detection response	Incorrect detection	Correct detection	Incorrect detection	Correct detection
Number of responses	1	77	N/A	80
Detection time Minimum	2	0.87	N/A	1.74
Detection time Maximum	2	2.89	N/A	0.96
Detection time Mean	2	1.58	N/A	3.12
Detection time Std. Deviation	N/A	0.42	N/A	0.46
Detection time Variance	N/A	0.18	N/A	0.212

Class IV Offside

	Car		Bike	
Detection response	Incorrect detection	Correct detection	Incorrect detection	Correct detection
Number of responses	N/A	80	N/A	79
Detection time Minimum	N/A	0.26	N/A	0.69
Detection time Maximum	N/A	2.63	N/A	3.27
Detection time Mean	N/A	1.44	N/A	1.45
Detection time Std. Deviation	N/A	0.38	N/A	0.41
Detection time Variance	N/A	0.15	N/A	0.172

Class V

	Car		Bike	
Detection response	Incorrect detection	Correct detection	Incorrect detection	Correct detection
Number of responses	10	10	9	130
Detection time Minimum	1.91	1.62	1.13	0.75
Detection time Maximum	4.44	4.81	6.0	4.44
Detection time Mean	3.36	2.96	2.53	1.8
Detection time Std. Deviation	0.97	0.36	1.4	0.55
Detection time Variance	0.94	1.28	1.97	0.30

	Child		Bag	
Detection response	Incorrect detection	Correct detection	Incorrect detection	Correct detection
Number of responses	9	70	2	57
Detection time Minimum	1.5	0.76	1.81	0.75
Detection time Maximum	4.87	5.69	2.12	6.81
Detection time Mean	2.23	2.14	1.97	1.97
Detection time Std. Deviation	1.07	0.83	0.22	0.8
Detection time Variance	1.14	0.69	0.05	0.64

Class VI

	F/F Bike		L/R Bike	
Detection response	Incorrect detection	Correct detection	Incorrect detection	Correct detection
Number of responses	3	96	1	98
Detection time Minimum	2.53	1.12	3	0.24
Detection time Maximum	3.07	5.15	3	4.22
Detection time Mean	2.84	1.87	3	1.69
Detection time Std. Deviation	0.28	0.6	3	0.578
Detection time Variance	0.08	0.35	3	0.33

	Child		Bag	
Detection response	Incorrect detection	Correct detection	Incorrect detection	Correct detection
Number of responses	9	111	9	111
Detection time Minimum	1.53	0.96	0.40	1.16
Detection time Maximum	3.63	3.28	1.44	4.48
Detection time Mean	2.60	1.93	2.47	2.12
Detection time Std. Deviation	0.71	0.50	0.63	0.68
Detection time Variance	0.50	0.25	0.40	0.47

APPENDIX 4: DRIVERS OPINIONS OF INDIRECT VISION SYSTEMS

Intentionally Blank

Indirect vision technologies
Driver questionnaire

Mirrors

1. What are your thoughts regarding . . .
   Number of mirrors?

   Blindspot coverage by the mirrors? *(Good or are there any gaps – Where?)*

   Quality of image in the mirror *(e.g. blurred/distorted or clear)*

   Any further comments regarding mirrors?

Cameras

2. Have you driven a truck which has a camera system for detecting objects in the blind spots around the vehicle? Yes No

   If yes, what areas did it cover and what did you think of it?

Sensors

3. Have you driven a truck which has a sensor system for detecting objects in the blind spots around the vehicle? Yes No

If yes, what areas did it cover and what did you think of it?

If an object was detected, how was the information presented?

Cameras and/or sensor systems

(Please note if you are talking about cameras or sensors or both)

4. How did you find using the system(s) when you first started using them?

5. Did this change over time? Yes No

   If yes, how?

6. What do you like most about the system(s)

7. What do you dislike about the system(s)