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# DEFINING THE REQUIREMENT FOR A DIRECT VISION STANDARD FOR TRUCKS USING A DHM BASED BLIND SPOT ANALYSIS

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## Abstract

The aim of the study was to understand the nature of blindspots in the vision of drivers of trucks caused by vehicle design variables such as cab design. The paper is the second of two submitted to ICED17. This paper focuses upon the results for the quantification of blindspots and the first paper presents the methodology (Marshall & Summerskill, 2017). In order to establish the cause and nature of blind spots 19 top selling trucks were scanned and imported into the SAMMIE DHM system. A CAD based vision projection technique allowed multiple mirror and window aperture projections to be created. By determining where simulated VRUs could be positioned without being visible in the direct vision of a driver, the vehicles were compared. By comparing the drivers eye height and the obscuration distance of VRUs a correlation was identified. By exploring the design features of outliers in this correlation, it was determined that direct vision blind spots are affected by various design variables. This led to the definition of a requirement for a direct vision standard for trucks, with a standard now being defined by the authors in a project funded by Transport for London.

**Keywords**: Product modelling / models, Evaluation, Design engineering, Case study

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# 1 INTRODUCTION

The paper presents the development and application of a method to assess the size of blind spots in driver's vision created by the design, structure and height of truck cabs. The paper is the second of two papers submitted to ICED17: the 21st International Conference on Engineering Design. The first paper focuses upon the methodology for the quantification of blind spots in trucks in the UK and Europe (Marshall and Summerskill, 2017) and this paper presents the results from the research and outlines the need for a direct vision standard to address the current issues. The paper explores the results of this process and how the results were used to identify design features which contribute to blind spot size. The research was sponsored by Transport for London (TfL, 2016) due to concerns associated with the increase in accidents between vulnerable road users (VRUs) such as cyclists and pedestrians, and Heavy Good Vehicles (HGVs). The evidence for this concern is provided by accident data that is gathered in the UK. For example, the UK STATS 19 database shows that there has been a general improvement in road safety in the UK with fatal casualties being reduced by 49% between the years 2000 and 2012. However, over the same time period the number of killed or seriously injured cyclists increased by 21%. A similar situation exists in the UK capital, where the number of cyclists' journeys have increased over the past 15 years, with 51% increase in killed or seriously injured cases between the 2000 and 2012 (Talbot, R. 2014). This increase has resulted in a number of initiatives to improve safety in the UK capital sponsored by Transport for London. A key issue that has been identified is the over representation of HGVs in accidents with VRUs where 'blind spots' were identified as contributing factor in the STATS 19 accident database (Summerskill, 2014). This led to the issue of blind spots in the vision of HGV drivers being explored in a research project performed by the authors. The authors have experience in a range of projects which have been defined to explore the design and analysis of HGVs to identify blind spots (Cook et al, 2011, Marshall et al 2013, Summerskill 2015a, Summerskill 2016), and how to improve these blind spots (Summerskill, 2014 and Summerskill 2015b). These projects and the project described in this paper use a virtual methodology in the Digital Human Modelling (DHM) system SAMMIE (Case et al, 2016). This research body has included results which led to the amendment of UNECE Regulation 46 in terms of the coverage of Class V mirrors (Summerskill, S. 2016). The aim of the project being described in this paper was to determine the size and location of volumes of space, around a representative sample of HGVs, which are visible directly to a driver, visible through the use of indirect vision (mirrors) and not visible to a driver. Blind spots could then be identified and quantified for each truck model in the sample, allowing a comparison between the truck designs. The basic premise was that by quantifying the blind spot issue vehicle operators would be able to select trucks with the best possible combination of direct and indirect vision for drivers, and vehicle designers could see how design features can reduce the size of blind spots. In addition to this, the work led to the recommendation for the definition of a direct vision standard for trucks.

# 2 METHODOLOGY FOR BLIND SPOT ANANYSIS

The project focused upon the use of DHM for the analysis of blind spot size and location. The technique that was used has been established over a number of projects as discussed above. The key elements of a virtual approach using DHM which is explores the size of blind spots are described in Marshall & Summerskill (2017) in detail and outlined below.

## 2.1 Modelling a representative sample of vehicles in CAD

With a project aim of 'understanding direct and indirect vision for HGVs in the UK' a key element was the selection of the vehicle sample. The sample was defined to include 19 vehicles including Euro 6 category N3 (new HGVs above 7.5 tonnes), Euro 6 N3G (new HGVs above 7.5 tonnes with features defined for off road use) and low entry cab vehicles, with over 95% of new vehicle registrations being covered by these models (Summerskill, 2015b). This was done as a method of exploring the potential of these vehicles to have reduced blind spot size. These vehicle models were sourced and 3D scanned using techniques described in Summerskill (2015b). Please see (Marshall and Summerskill, 2017) for more detail on the methodology. Figure 1 shows an example of the DHM techniques that were used in the project to quality blind spot size.

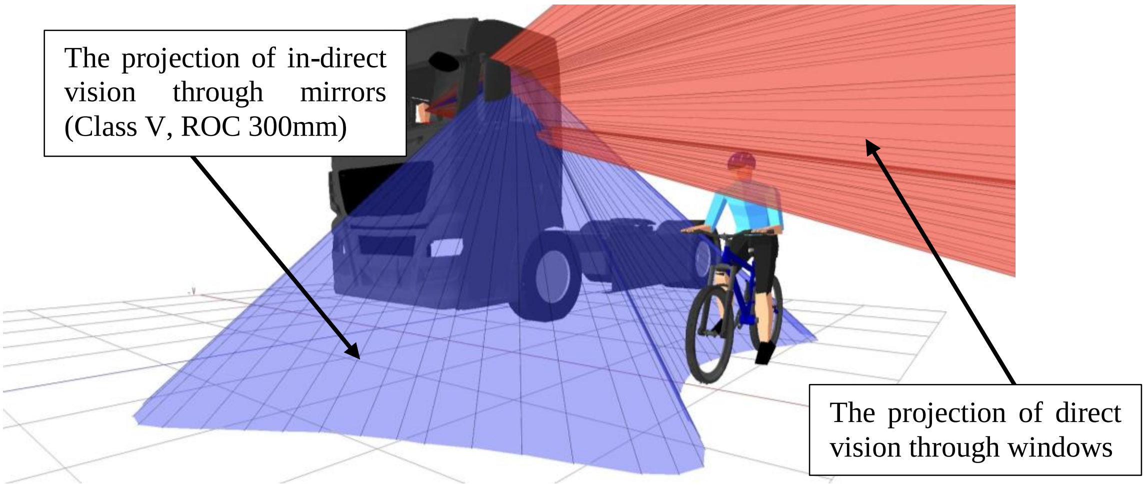


*Figure 1. The use of SAMMIE DHM software to visualise the volumes of space visible to a driver through direct and indirect vision*

A review of accident in the UK established the key areas where collisions occur with VRUs and from these statistics a number of scenarios were defined as shown in Figure 2.

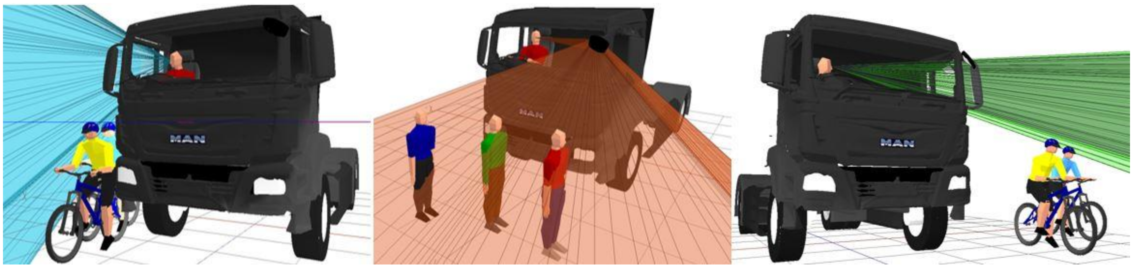

*Figure 2. The scenarios, from left to right, the distance from the driver's door that cyclists can be hidden, the distance from the front of the truck that pedestrians can be hidden, and the distance from the passenger door at which cyclists can be hidden*

The cyclists that were adjacent to the cab doors shown in Figure 2 were positioned with the rear cyclist having the top of the head in line with the driver's eye point, and the front cyclist being 1m forward of this. The results from the analysis of the three tests shown in Figure 2 included the distances away that each simulated VRU could be positioned from the cab without being seen through direct vision through the windows and indirect vision through the mirrors, from a predefined driver's eye point

### 2.2 The analysis of the results

Following the production of the results an analysis was performed to explore the design features of the different cab designs which have an effect on the distances at which vulnerable road users can be obscured from the driver’s vision. This involved performing comparisons and statistical tests between the data associated with the following design features; the height of the driver’s eye point above the ground for each vehicle, the distance at which the passenger side rear most cyclist can be hidden from the driver using direct vision, and the distance at which the middle pedestrian in front of the cab can be hidden from the driver using direct vision.

## 3 RESULTS: THE DESIGN FEATURES OF AN HGV CAB WHICH AFFECT BLIND SPOT SIZE AND LOCATION

### 3.1 Vehicle design features highlighted by the obscuration distance for cyclists adjacent to the passenger door

The first comparison made was the driver’s eye height (50th%ile UK male driver) above the ground and the distance away from the vehicle that the rear near side cyclist could be obscured. Figure 3 shows these two variables plotted in a graph for the standard vehicle designs, the low entry cabs were excluded as their designs are generally different to the standard cab designs. The graph shows that generally there is a trend of increasing driver eye height with increasing distance away from the cab at which the near side rear cyclist can be obscured. In order to explore this further and to see if there is any statistical significance in this trend, a Spearman's Rho (single tailed) correlation test was performed. This demonstrated a strong correlation coefficient of 0.6 ($r_s = .6$, $p < 0.009$) where values between 0.5 and 1 are considered to be strong. This means that there is a link between the eye height of the driver above the floor and the maximum distance that a cyclist can be hidden to the near side of the cab. There were however some anomalies in this trend when comparing the results between vehicles in the same category.

The identified cases were;

- Case 1. The eye height of the driver for the Mercedes Arocs is considerably higher than the Scania P N3G, and yet the cyclist is hidden from view at approximately the same distance away from both vehicles as highlighted by the dotted circles in Figure 3.
- Case 2. DAF CF has a lower driver eye height above the ground than the Volvo FM, but the cyclist is fully hidden further away from the vehicle when compared to the Volvo FM, as highlighted by the dotted circles in Figure 3.
- Case 3. MAN TGX has a lower driver eye height above the ground than the Scania R, but the cyclist is fully hidden further away from the vehicle when compared to the Scania R as highlighted by the dotted circles in Figure 3

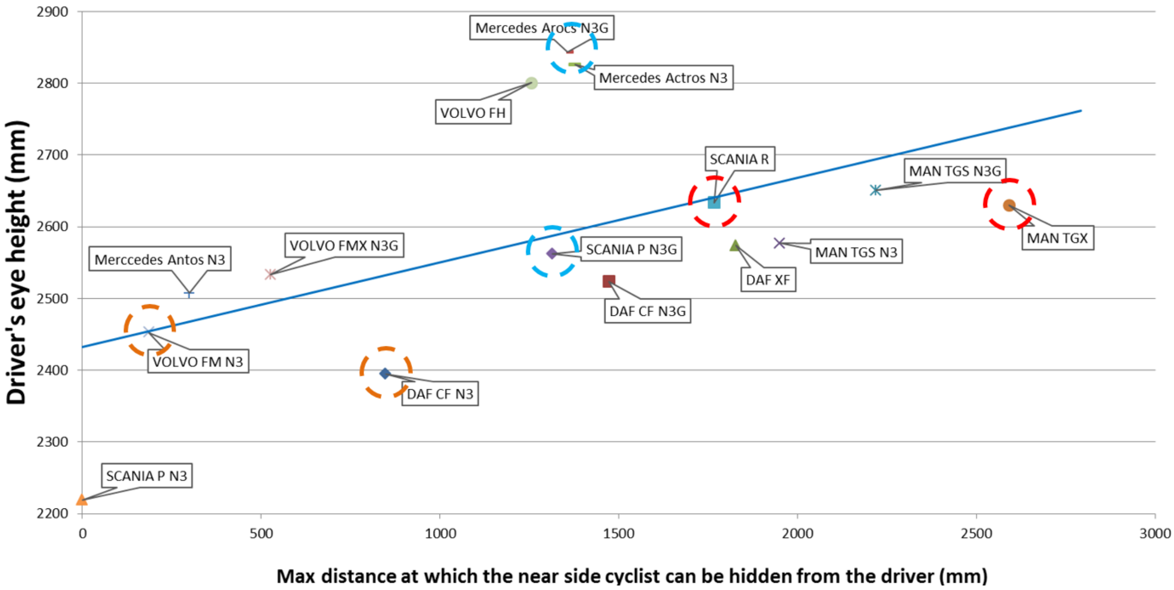


*Figure 3. Driver's eye height plotted against the maximum distance away from the vehicle that the rear near side cyclist can be hidden from the driver*

These anomalies were considered to be important because a comparison of design features associated with the three anomalies has the potential to highlight design features which are associated with improving direct vision.

### 3.1.1 Case 1. Comparing the Mercedes Arocs N3G to the Scania P N3G

In the case of the comparison between the Mercedes Arocs N3G and the Scania P N3G, the eye height of the driver for the Mercedes Arocs N3G is considerably higher (281mm) than the Scania P N3G, and yet the cyclist is hidden from view at approximately the same distance away from both vehicles. A comparison of the vehicle design variables shows that this can attributed to the width of the cab, where the Mercedes Arocs N3G is narrower than the Scania P N3G combined with the design of the window. The Mercedes Arocs has a lower window bottom edge in relation to the eye position in the cab. In effect, when the looking through the eyes of the driver, the bottom edge of the window would appear lower in the Mercedes Arocs N3G than in the Scania P N3G, allowing the driver to see more. This is shown in Figure 4.

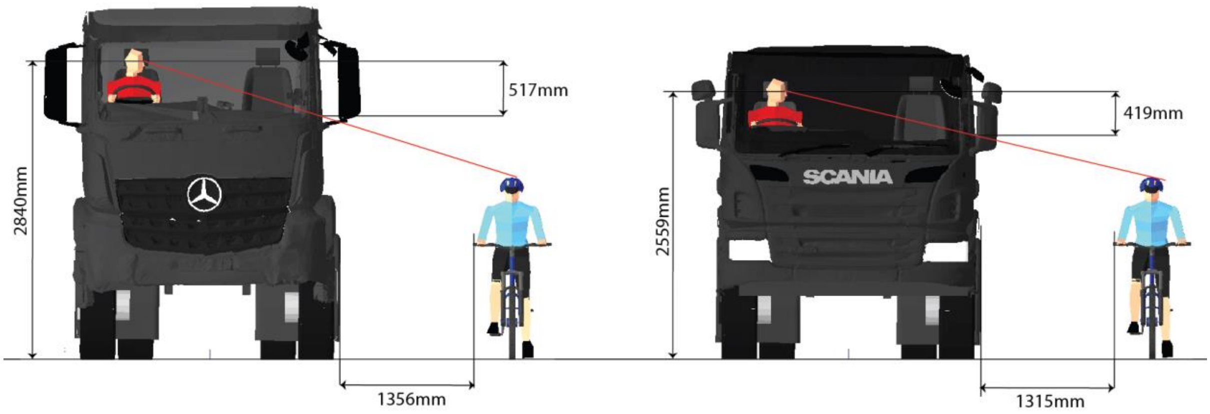


*Figure 4. Illustrations of the comparison between the Mercedes Arocs N3G and the Scania P N3G where the driver eye height is considerably higher for the Mercedes but the cyclists are hidden at similar distances*

#### 3.1.2 Case 2. Comparing the DAF CF N3 to the Volvo FM N3

In the case of the comparison between the DAF CF N3 and Volvo FM N3, the DAF CF has a lower driver eye height above the ground than the Volvo FM, but the cyclist is fully hidden further away from the vehicle when compared to the Volvo FM. A comparison of the design variables shows that this can be attributed to the window design, where the Volvo FM has a lower window bottom edge in relation to the eye position of the driver in the cab. In effect, when the looking through the eyes of the driver, the bottom edge of the window would appear lower in the Volvo FM than in the DAF CF, allowing the driver to see more. The width of the Volvo FM and DAF CF cabs are both reported as being 2490mm by the manufacturers. Therefore, the cab width does not affect the performance in this case. See Figure 5.

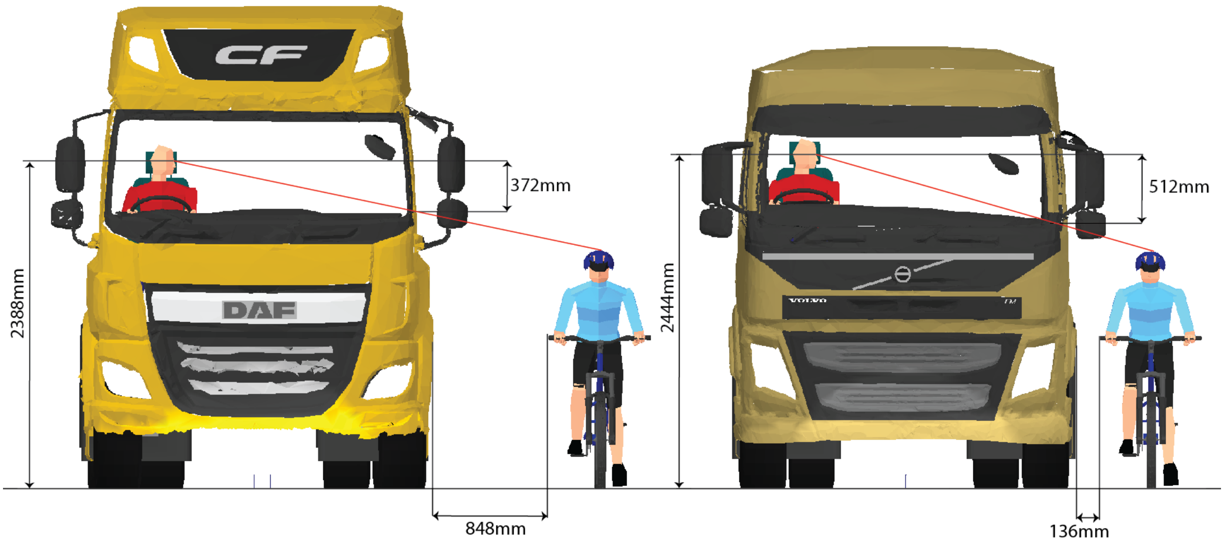


*Figure 5. Illustrations of the comparison between the DAF CF N3 and the Volvo FM N3 where the driver eye height of the DAF is lower than that of the Volvo, but the cyclist is hidden further away for the DAF*

#### 3.1.3 Case 3. Comparing the Scania R N3 to the MAN TGX N3

In the case of the comparison between the Scania R N3 and the MAN TGX N3, the MAN TGX has a lower driver eye height above the ground than the Scania R, but the cyclist is fully hidden further away from the vehicle when compared to the Scania R. See Figure 6. A comparison of the design variables shows that this can be attributed to the window design, where the Scania R has a lower window bottom edge in relation to the eye position in the cab. In effect, when the looking through the eyes of the driver, the bottom edge of the window would appear lower in the Scania R due to differences in the profile of the window bottom edge as shown in Figure 7 which shows the driver's eye view of the passenger window for both vehicles.

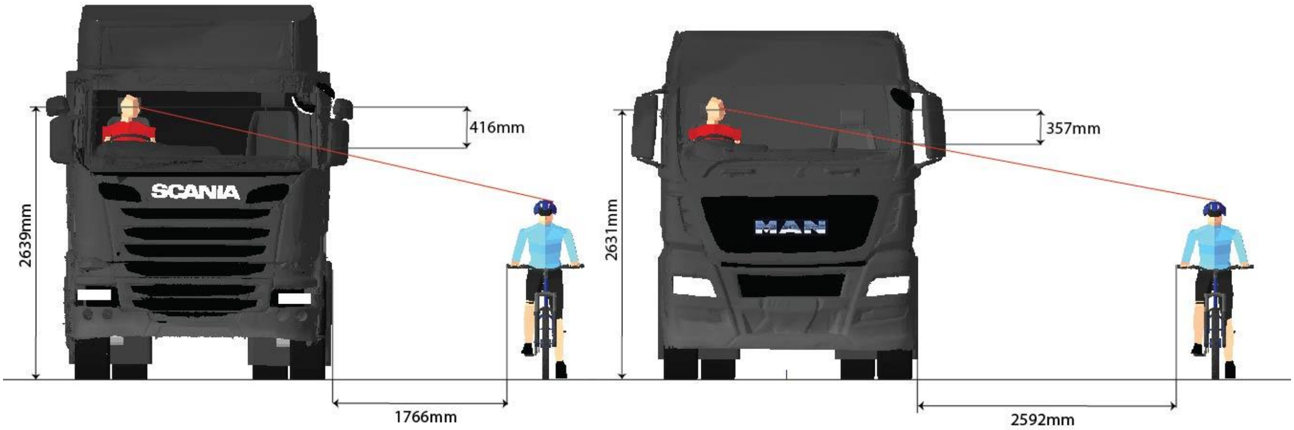


*Figure 6. Illustrations of the comparison between the Scania R N3 and the MAN TGX N3 where the eye heights of the drivers are similar, but the cyclist can be hidden further away from the vehicle cab*

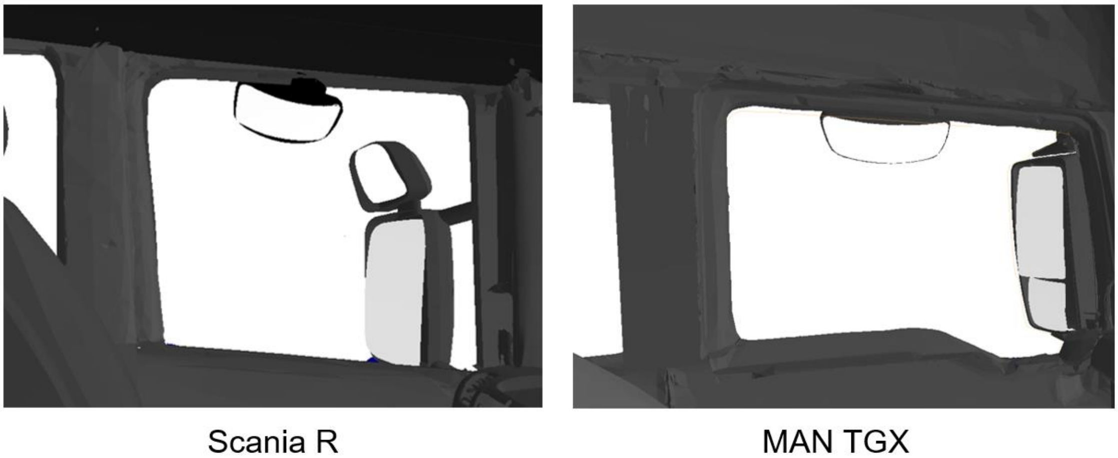


*Figure 7. The drivers eye view of the passenger window for the Scania R and the MAN TGX*

### 3.2 Summary for the comparison between driver eye height and the obscuration distance of the near side cyclist

The correlation between eye height of the driver and the distance at which the rear near side cyclist can be obscured from the driver has shown that, in general, an increase in driver height produces an increased distance away from the cab at which the cyclist can be obscured. The low entry cabs showed a much-improved ability for the driver to directly see vulnerable road users when compared to 'standard' vehicle designs. The further analysis of the situation for the 'standard' cab designs has shown that the variability in the design of window apertures can produce results which 'buck the trend' that is established by the graph in Figure 3, and the statistical testing of correlation. This is shown in Cases 2 and 3 where the vehicles with the larger vertical distance between the eye point and the lower edge of the window glass outperformed the other vehicles which were being compared. Case 1 illustrated that width of the vehicle can also be a factor, with the narrow cab of the Mercedes Arocs combined with a lower window edge with respect to the eye position, allowing the Mercedes Arocs to outperform the Scania P N3G. On the basis of these analysis the following recommendations can be made with regard to cab design

- Recommendation 1: The ability of a driver to directly see vulnerable road users to the nearside of the vehicle can be maximised by designing window apertures with a bottom edge that is as low as possible with respect to the eye position of the driver.
- Recommendation 2: The ability of a driver to directly see vulnerable road users to the near side of the vehicle can be maximised by designing a cab to have the minimum possible width between the side windows

### 3.3 Vehicle design features highlighted by the obscuration distance of pedestrians to the front of the vehicle

The second comparison made was the driver's eye height (50th%ile UK male driver) above the ground and the distance away from the vehicle that the central pedestrian object to the front of the cab could be obscured from the driver. Figure 8 shows these two variables plotted in a graph for the standard vehicle designs, the low entry cabs were excluded as their designs are generally different to the standard cab designs.

In order to explore this further and to see if there is any statistical significance in this trend, a Spearman's Rho (single tailed) correlation test was performed. This demonstrated a very strong correlation coefficient of 0.846 ($r_s = .846$, $p < 0.00004$) where values between 0.5 and 1 are considered to be strong. This means that there is a link between the eye height of the driver above the floor and the maximum distance that a pedestrian to the front of the cab can be hidden from the driver's view. There were however some anomalies in this trend when comparing the results between vehicles in the same category.

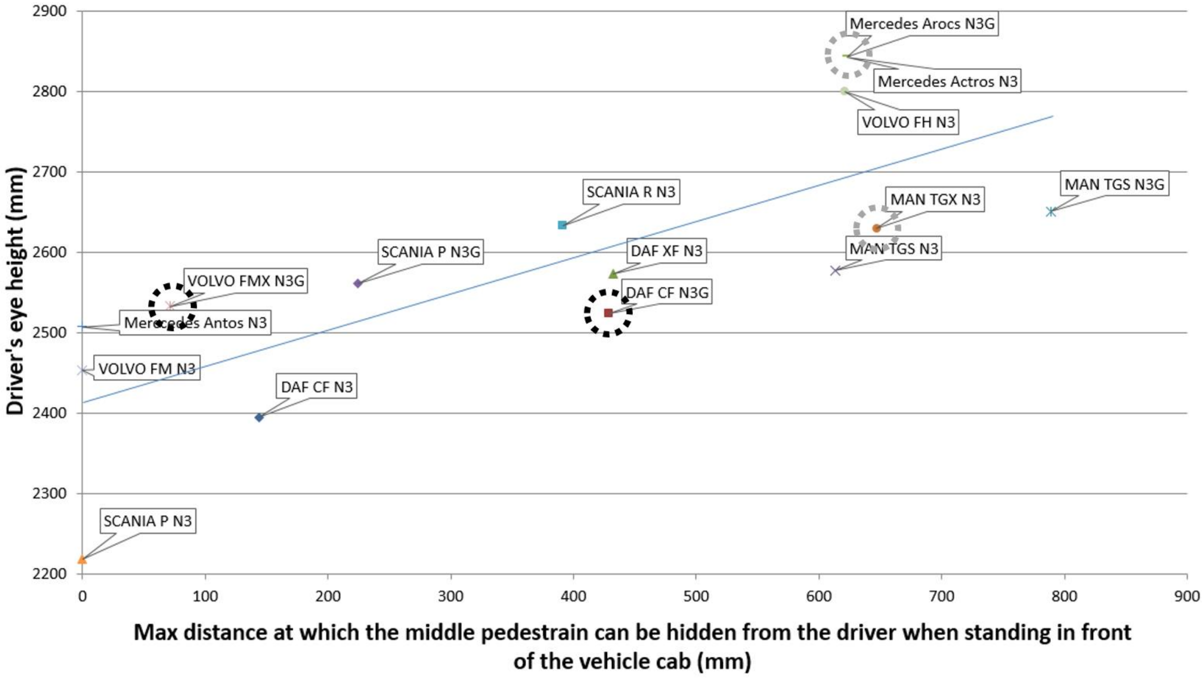


*Figure 8. Plotting the Driver's eye height against the maximum distance away from the vehicle that the middle pedestrian can be hidden from the driver*

The identified cases were;

- Case 4. The eye height of the driver for the Mercedes Actros N3 is considerably higher than the MAN TGX N3, and yet the pedestrian is hidden from view at approximately the same distance away from both vehicles as highlighted by the black dotted circles in Figure 8.
- Case 5. The DAF CF N3G and the Volvo FMX N3G have a similar eye height above the ground, and yet the pedestrian is fully hidden further away from the vehicle for the DAF CF N3G, as highlighted by the grey dotted circles in Figure 8.

### 3.3.1 Case 4. Comparing the DAF CF N3G to the VOLVO FMx N3G

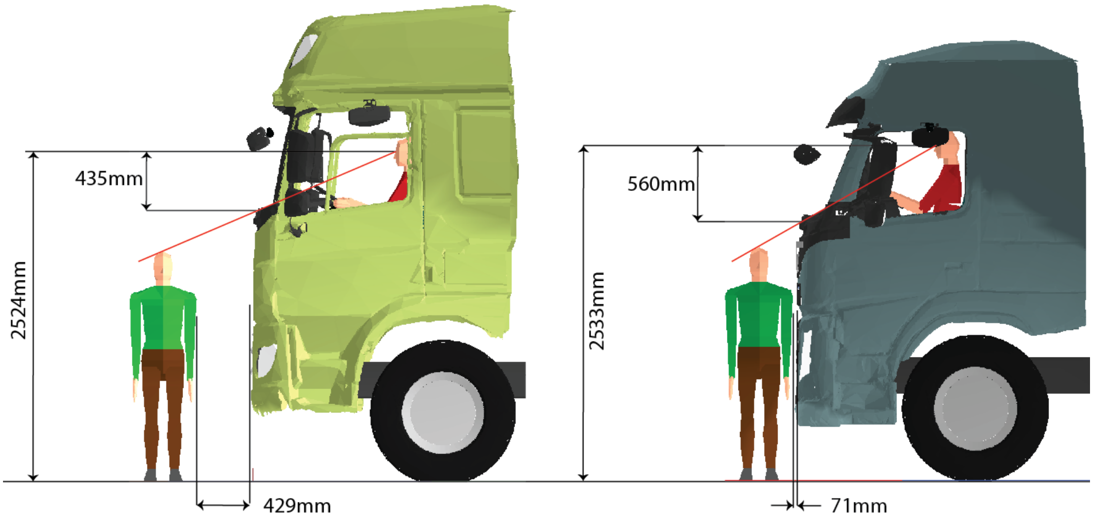


*Figure 9. Illustrations of the comparison between the DAF CF N3G and the Volvo FMX N3G where the eye heights of the drivers are similar, but the pedestrian can be hidden further away from the vehicle cab for the DAF*

In the case of the comparison between the DAF CF N3G and Volvo FMX N3G, the DAF CF N3G has a similar driver eye height above the ground (9mm lower) than the Volvo FM, but the pedestrian is fully hidden further away from the vehicle when compared to the Volvo FMX N3G. A comparison of the design variables shows that this can be attributed to the window design, where the Volvo FMX N3G has a lower windscreen bottom edge in relation to the eye position of the driver in the cab. In effect, when the looking through the eyes of the driver, the bottom edge of the windscreen would appear lower in the Volvo FMX N3G than in the DAF CF N3G, allowing the driver to see more as shown in Figure 9.

### 3.3.2 Case 5. Comparing the Mercedes Actros N3 to the MAN TGX N3

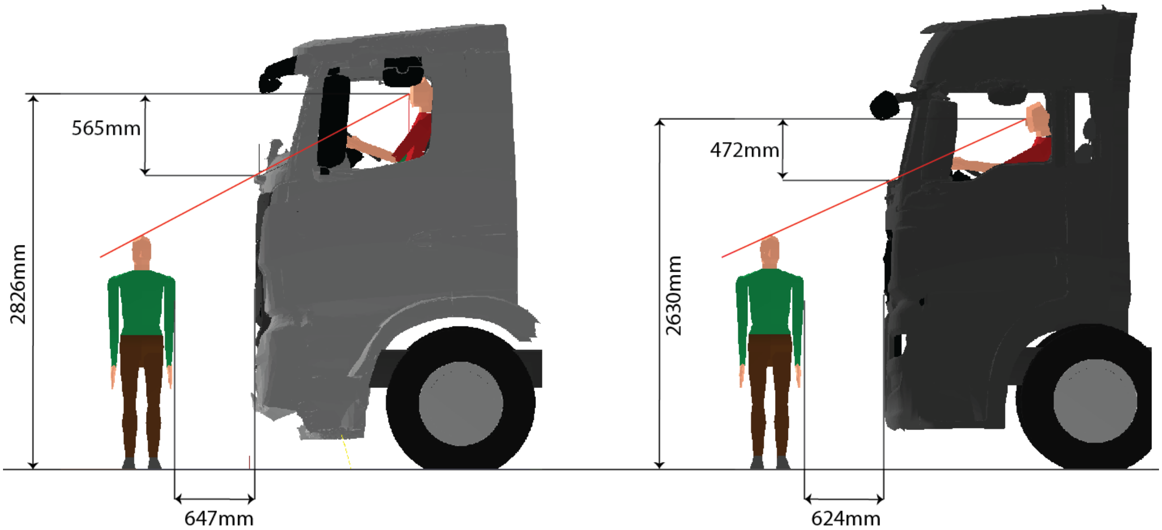


*Figure 10. Illustrations of the comparison between the Mercedes Actros N3 and the Volvo MAN TGX N3 where the eye heights of the drivers are similar, but the pedestrian can be hidden further away from the vehicle cab for the DAF*

In the case of the comparison between the Mercedes Actros N3 and MAN TGX N3, (see Figure 10) the Mercedes Actros N3 has a higher driver's eye height than the MAN TGX N3 (196mm higher) but there is only 23mm difference between the two vehicles in terms of the distance away that the pedestrian can be hidden. A comparison of the design variables shows that this can be attributed to the windscreen design, where the Mercedes Actros N3 has a lower windscreen bottom edge in relation to the eye position of the driver in the cab (93mm lower). In effect, when the looking through the eyes of the driver, the bottom edge of the windscreen would appear lower in the Mercedes Actros N3 than in the MAN TGX N3, allowing the driver to see more.

### 3.4 Summary for the comparison between driver eye height and the obscuration distance of the central pedestrian

The correlation between eye height of the driver and the distance at which the central pedestrian can be obscured from the driver has shown that, in general, an increase in driver height produces an increased distance away from the cab at which the pedestrian can be obscured. The variation in this measure is less than that shown in Figure 3, and the strength of the correlation is stronger than in the analysis of the lateral visibility of the cyclist. The low entry cabs showed a much improved ability for the driver to directly see vulnerable road users when compared to ‘standard’ vehicle designs, the further analysis of the situation for the ‘standard’ cab designs has shown that the design of the windscreen lower edge, and the design of the dash board which was used to modify the projection of windscreen visibility, can affect the performance of a vehicle in the test being described. On the basis of the analysis the following recommendation can be made with regard to cab design:

Recommendation 1: The ability of a driver to directly see vulnerable road users to the front of the vehicle can be maximised by designing windscreen apertures with a bottom edge that is as low as possible with respect to the eye position of the driver, whilst carefully considering the design of the dash board to not impinge upon the windscreen view.

Consultation with vehicle manufacturers during the project has highlighted that the size of glazed areas is a factor which must be balanced with the strength of the cab which is tested during the type approval process.

## 4 DISCUSSION

The results from the analysis of blind spot size illustrated that in general, the ability of a vehicle to obscure a VRU from the direct vison of a driver is directly correlated to the height of the driver's eye point, and therefore the height of the cab above the ground. However, there were a number of cases where specific design features of cab models were highlighted due to the results of the correlation exercise which highlighted outliers.

The specific design of the driver's location in the cab with reference to the bottom edges of the windows, and the design of those window profiles, can have considerable effects on the direct vision performance of a vehicle. The LDS team concluded that this is due to a lack of standardisation of what a driver should be able to directly see through windows. The United Nations Economic Commission for Europe (UNECE) Regulation 46 is a standard which regulates what a driver must be able to see through mirrors, and so all vehicles comply with this standard through a process called type approval, which is a certification process in Europe.  Therefore, a key recommendation from the project performed was that a 'Direct Vision' standard should be defined for HGVs which follows the same certification process for new vehicles being brought into the market. UNECE regulation 125 covers the standardisation of direct vision for passenger cars, and so there is precedent.

TfL have subsequently commissioned a project with the LDS team that will define and test a Direct Vision standard for London, with potential adoption in Europe through the mechanism of UNECE regulation. This standard will follow a process that uses the projections of the volume of visible space that can be seen by the driver being intersected with an assessment zone volume that is placed around the vehicle, following a process that was defined by TRL (TRL, 2016).

By defining and applying a Direct Vision standard TfL have the option the ban the worst performing HGVs from the streets of London, and the London Mayor stated this as an aim of the project in press release in September of 2016 (Mayor, 2016). The project reported here established the need for a direct vision standard and has therefore added to the debate on blind spots in HGVs and supported an agenda that has the potential to improve vehicle design, and remove trucks with large blind spots from the streets of London.

## 5 CONCLUSIONS

The research explored the direct vision performance of a range of HGV designs that cover over 95% of new vehicle registrations in the UK. The virtual techniques that were used defined a direct link between the size of direct vision blind spots and the height of HGV cabs above the ground. A detailed analysis of the correlation graphs highlighted outliers which were explored in more detail. These highlighted specific features which have the potential to affect direct vision performance. The variability in the design features of cabs that affect direct vision performance fostered a recommendation for the definition of a direct vision standard for HGVs. This work is currently being performed by the LDS team with adoption in London by the year 2020, and the envisaged wider adoption in Europe through the mechanism of UNECE standards.

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