The use of DHM to quantify a measure of direct vision performance in trucks

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Abstract

Accidents between vulnerable road users and trucks have been linked to the inability of drivers to directly see the areas in close proximity to the front and sides of the vehicle cab. The lack of direct vision is mitigated through the use of mirrors. The coverage requirements of mirrors are standardized in a UNECE standard. Direct Vision for trucks is not currently standardized in any way. Research by the authors identified key requirements for a Direct Vision Standard (DVS) which was subsequently designed. The method used to quantify direct vison measures the volume of space that is visible, of an assessment volume around the vehicle cab, from a driver's eye point. The result is a volumetric score in m^3. This standard is now being applied in London, England, and a UNECE version is in development. This paper describes how DHM was used to provide a measure of real-world performance which correlates to a high level with the volumetric score, and an automated version of this process that is being used in the UNECE version.

Keywords: Blind spot, collision, regulation, safety.

Introduction

This paper reports the development of methods for quantifying direct vision from heavy good vehicles. Whilst there has been general improvement in road safety the UK, there has been an increase in collisions between Vulnerable Road Users (VRUs) and Heavy Goods Vehicles (HGV, category N3, with a gross weight in access of 12 tonnes.). Research has identified that the number of accidents occurring is disproportionate to the number of HGVs on the road and identified specific scenarios in which accidents are most likely to occur (Talbot 2014, Cook 2011, Summerskill 2019a). In Europe over 4000 VRUs are killed or seriously injured in collisions with HGVs each year. The size and location of blind spots in direct vision of the HGV driver caused by the height and structure of the vehicle has been the focus of multiple research projects and papers. The height of the HGV driver's eye point above the ground plane can be in excess of 3m for European vehicle designs. Therefore, direct vision is not possible for large areas in close proximity to the cab. Figure 1 shows a typical long haul design which can obscure the direct vision of the a large number of cyclists from a single eye point. The inset image shows the view from the driver's eye point that was derived from the methods reported in Reed (2005).

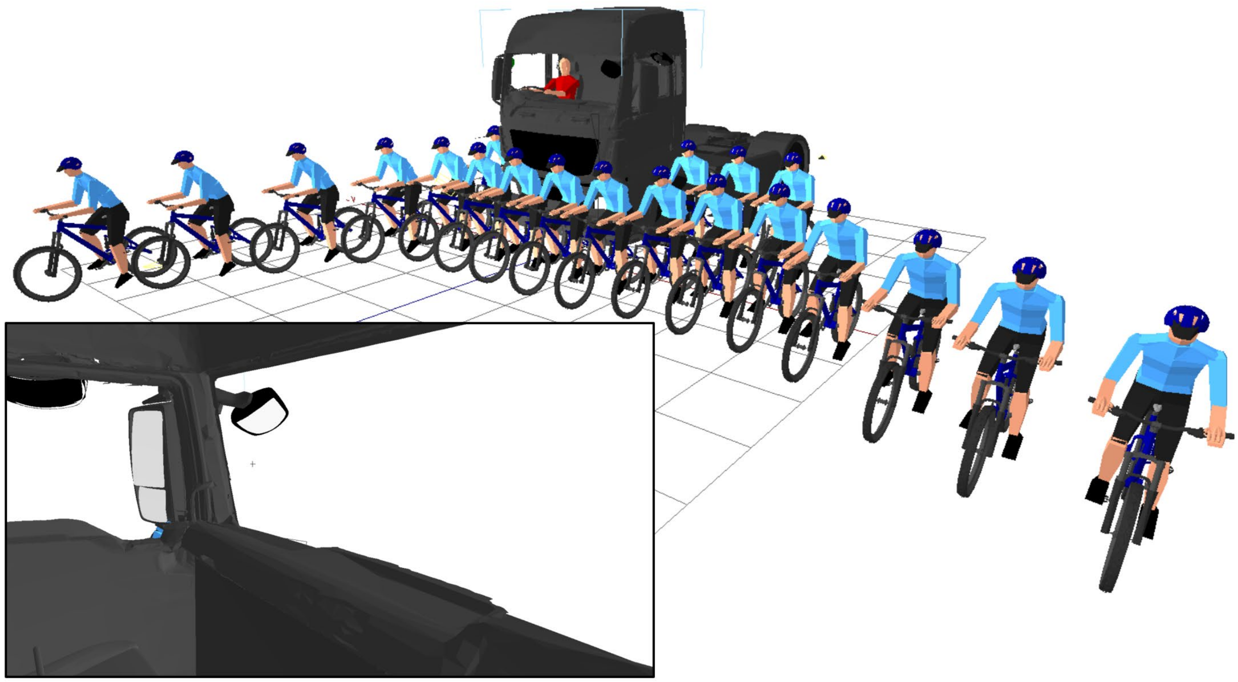

Figure 1. From the defined eye point, none of the cyclists can be seen using direct vision.

In Summerskill (2015a) a blind spot was reported which existed between the volume of space visible to a driver through windows (direct vision) and the volume of space visible through mirrors (indirect vision). The identification of this blind spot led to the revision of UNECE regulation 46 which improved the coverage of the Class V mirror (UNECE, 2015). Further work has been reported in Summerskill (2015b) to examine and measure blind spot locations for all sides of 19 European HGV cab designs. The findings of this work indicated there were multiple factors in the design and use of HGV cabs that potentially contribute to the size and location of blind spots for HGV drivers. These included the height of the driver's eye point above the ground, the position of the driver in relation to the front and sides of the cab and height of the windscreen and lateral window bottom edges with respect to the driver's eye point.

This is mitigated for by the use of six standardized mirrors which must meet the coverage specification of UNECE regulation 46 (UNECE, 2015). The use of six mirrors and multiple windows produces a minimum of nine 'viewports' that must be scanned to enable situational awareness of the areas in close proximity to the vehicle cab in urban environments. Mole (2017) examined this situation in a simulator study and determined that when comparing the use of direct vision and indirect vision to identify VRU's, indirect vision use increased the reaction time of HGV drivers by 0.7 seconds. This, combined with the findings of Summerskill (2015a) led to the definition of a requirement for a direct vision standard by the authors. The aim of the direct vision standard was to determine a minimum direct vision requirement for HGVs to be used in urban environments, and therefore foster safer cab designs which refine direct vision capabilities in future vehicles. This direct vision standard uses DHM and CAD methods to accurately measure the direct vision performance of a cab design. This is achieved by placing an assessment volume around the vehicle determining the volume of the assessment volume that can be direct seen from a predefined set of eye points (Summerskill, 2019a and 2019b). Figure 2 shows the keys stages of this process. The test produces a volume of visible space that can be split into the views provided by the windscreen and lateral windows. The result is presented in m3. However, it is clear that it is difficult to determine what a minimum requirement is for the volume is in isolation as a value of 12.4m^3 is a difficult measure to relate to real world accident scenarios. This paper presents the method that was used to quantify the volumetric scores that were produced for the 56 vehicle variants that were included in the sample. The method described in Summerskill (2019a) has now been adopted in a direct vision standard which applies to all vehicles entering London. A minimum direct vision requirement of 10.04m^3 has been defined.

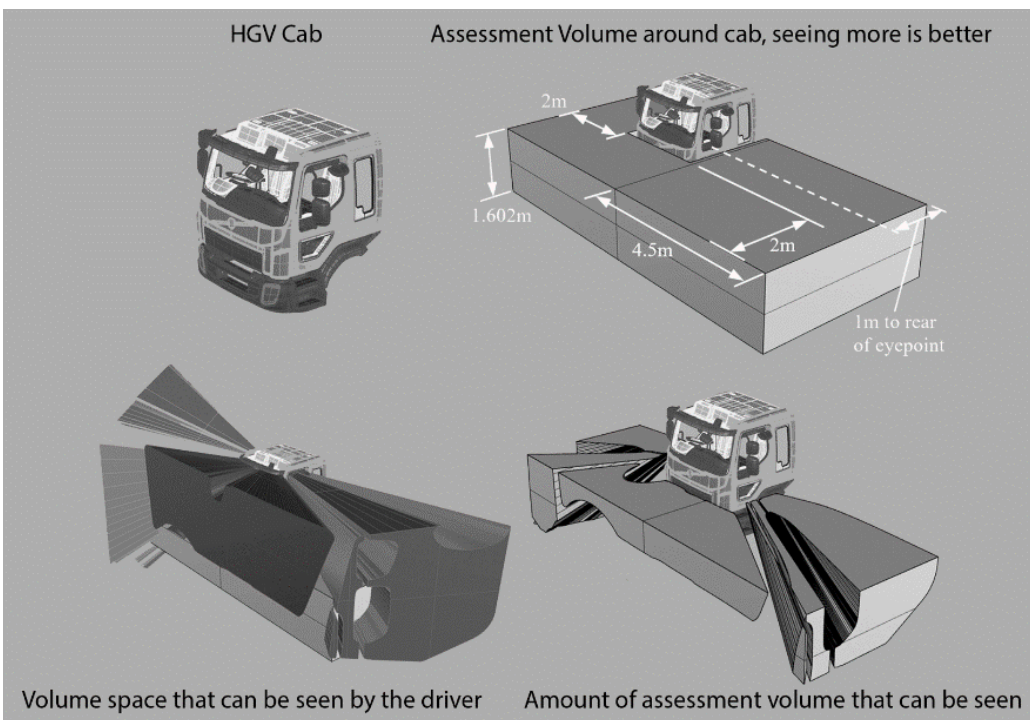

Figure 2. The key stages of the process used to measure the direct vision performance of HGVs

Methods

The following section describes the methodology used to explore the issue of quantifying the volumetric scoring system.

Sample of vehicles

The project that defined the DVS was funded by Transport for London (TfL), the organization that runs the public transport and road network in the UK capital. TfL built a working group which included all major European HGV manufacturers. The specification of European vehicles in terms of engine size and suspension type can lead to a wide variability in the driver height above the ground plane. One example vehicle that was analyzed in the project had a cab mounting height range of over 800mm. This issue needed to be accounted for in the definition of the sample. In order to address this each manufacturer was asked to provide CAD data for the cab designs, and data on the absolute maximum and minimum height at which the cab can mounted based upon component specification. Therefore two variants were tested for each of 28 different designs, leading to a sample of 56 vehicles. This covered over 98% of the vehicle cab designs sold in the UK.

Accident scenarios considered

A review of accident data in the UK was performed to determine which are the most common accident scenarios. This resulted in the identification of two scenarios which accounted for 90% of accidents in the UK. These were, a vehicle pulling away from a crossing point and hitting a pedestrian that was not seen, and cyclists colliding with HGVs which are turning left, with the cyclist on the passenger side of the vehicle. The detail on the accident statistics analysis can be seen in Summerskill (2019a).

The definition of the driver eye points to be used for the projection of volumes and viewing VRU locations

The definition of the eye points used in the DHM simulations has been detailed in Summerskill (2019b). It involved the definition of a common H-point envelope by combining data from all vehicle designs, determining a common achievable H-point. An offset was then produced from the H-point to the front eye point using an average of Dutch, British, German, Italian and French 50^{th}%ile Drivers with 90:10 male female ration. The left and right eye points were then determined by a rotation based upon UNECE regulation 125.

Design of the assessment volume

The concept of defining a volume of space around the vehicle and determining how much of that volume can be seen was defined in the proposal for the project work. The actual size and shape of the assessment volume was determined as part of the project. A number of alternatives were considered in the design of the standard (See Appendix B in Summerskill, 2019a). The end result shown in Figure 2. The rationale for the final assessment volume is that direct vision should, where ever possible, allow the volume of space that is currently visible through indirect vision (mirrors) to be directly visible to drivers. Hence, the assessment volume in plan view covers the same area as the mirror coverage zones defined by UNECE regulation 46. That is, 2m to the front of the vehicle, and 4.5m to the passenger side of the vehicle. Whilst accidents to the driver side of the vehicle account for 10% of accidents between VRUs and HGVs, and direct vision is generally good in the area due to the proximity of the driver the driver's window. With no other evidence found for the definition of a specific value, the area to the driver's side matched the distance from the front, 2m. The height of the assessment volume was defined by the shoulder height of the 99^{th}%ile Dutch Male (the tallest population in the world).

Methods for quantifying the minimum volume requirement for urban environments

The research performed in Cook (2011) and Summerskill (2015a) used DHM simulations of VRUs, and determined the distance from the sides and front of the cab at which those VRUs could be hidden from the driver's view. This was a model that was followed in the work to quantify what a particular volumetric score means in terms of a real-world accident scenario. The hypothesis was that the distance at which VRUs can be visible from the side and front of the truck could correlate with the volumetric score for each cab design assessed. However, some modification to the method were required. In this case it was important to determine the distance at which a VRU could be seen, whereas the previous methods measured to the point at which they just invisible. A review of the literature was performed to try and determine how much of a VRU should be visible to allow recognition, but none was found. Therefore, an approach was taken which linked to the data gathered in surveys of pedestrians by TfL. This highlighted that making eye contact with a driver was seen as important by pedestrians as it gave some assurance that their presence had been noted. The solution was determined to be that the driver should be able to see the head and shoulders of the VRU simulation. The size of the VRU simulation was a great source of debate. The accident data showed that collisions with children were rare, and that elderly people were more likely to be involved in the pedestrian scenario. This led to an adult population being selected. The smallest population in Europe is the Italian Females (Peebles, 1998). Italian females with a stature of 5^{th}%ile weere selected for the VRU simulation as this allowed over 95% of the adult European population to be visible to the driver for a vehicle that passes the minimum requirement. A rig of VRU simulations was created in the DHM system which were arranged around the vehicle in a predetermined manner as shown in Figure 3. The was based upon the position of VRU simulations in Summerskill (2015a). The two VRUs closest to rear of the cab shown in Figure 3 were located in the X axis by an offset of one body width from the forward eye point. The ten lateral VRU simulations were then moved in the Y axis until their head and shoulders were visible from the predefined eye points. The front three VRUs were located in the center of the HGV cab and at the lateral extents of the cab, and were again moved in the X axis until their head and shoulders were visible from the predefined eye point. The aim was to determine the quality of the correlation between VRU distance and volume. Nine VRU simulations were initially considered, but this was increased to thirteen as this improved the quality of the correlation between VRU distance and volumetric score.

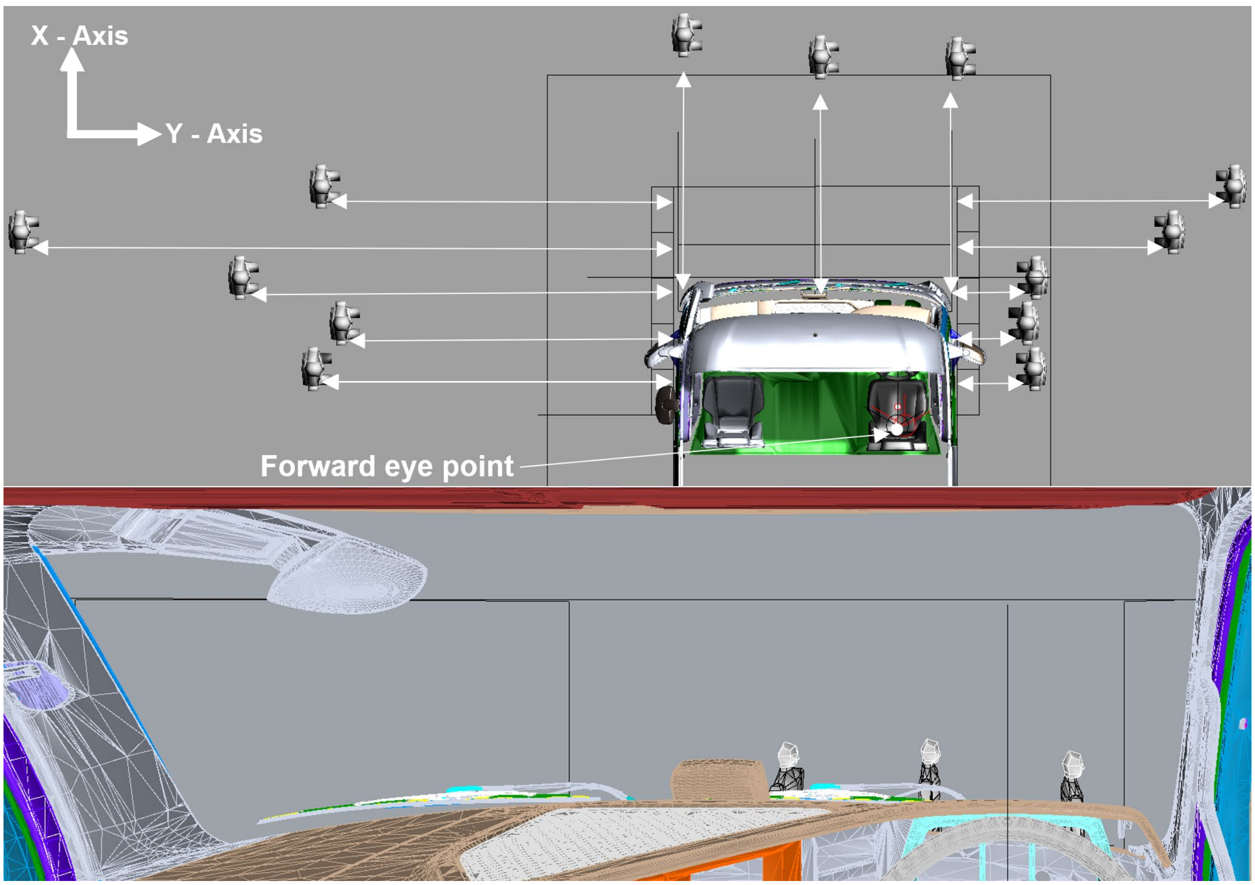

Figure 3. The arrangement of the VRU simulations and the view from the eye point used to determine the VRU location where the head and shoulders were visible

Results

Figure 4 shows the results of the volumetric and VRU distance scoring of each of the design variants included in the sample. The correlation between these measures is 0.97 using Pearson's test, where a value of 1 is a perfect correlation. Values above 0.5 are considered to be strong. As discussed, other versions of the assessment volume were tested, including a much larger assessment volume, and a version that was weighted by area in terms of accident risk (see Appendix B, Summerskill, 2019a). However, the result shown in Figure 2 provided the best differentiation between the vehicle designs and was considered the superior method due to the design of the assessment volume.

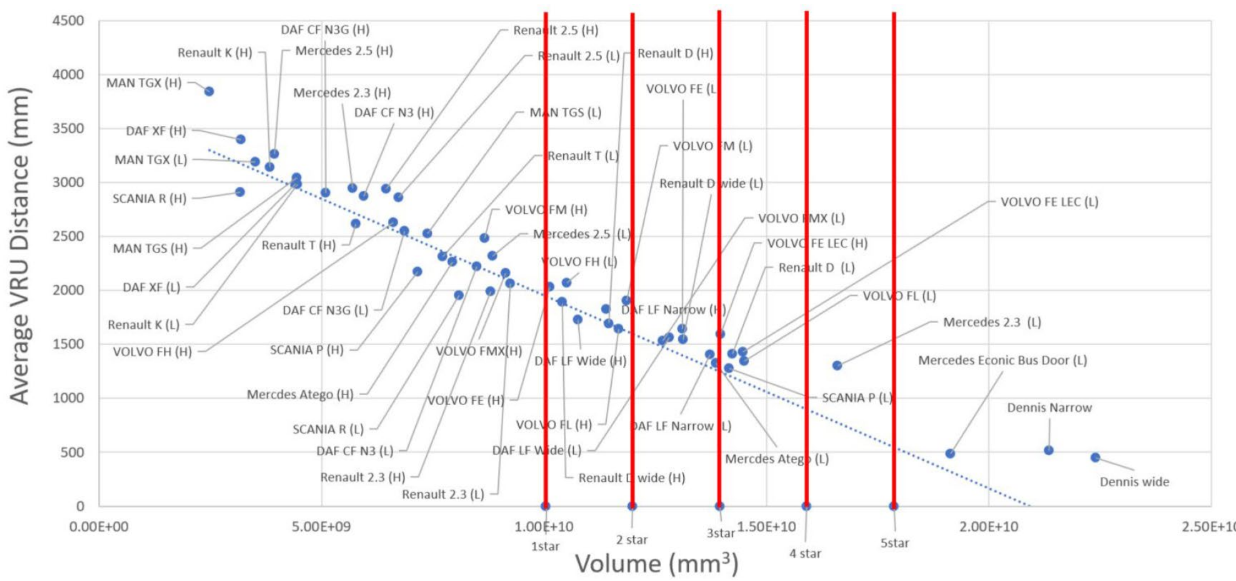

Figure 4. Graph showing the correlation between VRU distance and volumetric score for each cab design

With a good correlation achieved the method was seen as sufficient for defining the minimum volumetric requirement by consideration of the acceptable distance at which VRUs can be seen from the side and front of the HGV. The TfL working group was involved in the decision of how to define the minimum requirements for direct vision. The rationale was that should not be a situation in which a VRU can be located around the vehicle, and not be seen in either direct or indirect vision. Figure 5 shows such a situation.

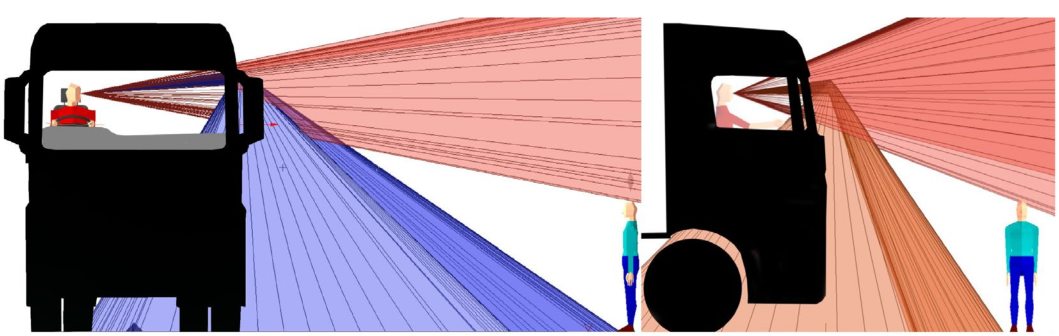

Figure 5. A situation in which the VRU simulation cannot be seen by the driver in either direct vision though windows or indirect vision through mirrors

This equates to a maximum average VRU distance of 2m to the front of the cab, 4.5m to the passenger side and 0.6m to the driver's side. A Vehicle was identified which had VRUs distances at these values or better. The volumetric performance of this vehicle defined the minimum volumetric requirement for the direct vision standard, with a total visible volume of 10.4m^3

Discussion and Conclusions

The methodology that has been defined to quantify volumetric performance with a test that shows the real-world implications has been successful. There is a high correlation between the two methods of measuring direct vision. The CAD based approach allows the effect of design changes on direct vision to be quantified in an accurate manner and the VRU distance measure provides context for what a volume score means. As can be seen in Figure 4, the majority of the vehicles in the sample are unable to meet the minimum requirement 10.4m^3. This means that VRUs can be obscured from direct vision at a distance beyond the mirror cover zone, creating a blind spot. The original announcement of the Direct Vision Standard by the London Mayor included a policy of banning HGV designs which did not meet the minimum direct vision requirement. However, the poor performance of the fleet was unexpected and an impact assessment of banning such a large proportion of the vehicle fleet showed that the economic impact would be too severe. Therefore, TfL defined a system of safety measures which would need to be fitted to any vehicle not meeting the minimum requirement. Interest in the DVS increased from cities in Europe and the USA where HGV-VRU accidents were also increasing. The research team supported TfL's lobbying efforts of the European Parliament, which added to the calls for a DVS for all HGVs. This policy was adopted by the EU in 2019 (EU, 2019), and subsequently the research team has been supporting the development of a UNECE standard for all HGVs in Europe. The UNECE DVS adopts the methodology defined by the authors in its entirety, with modifications that increase the minimum direct vision requirements and specific minimum to each side of the vehicle. This new standard will finally be adopted in November of 2022. The minimum requirements for direct vision will be applied to all vehicles from 2026, and all vehicles by 2029. A substantial proportion of the European cab designs will need to be redesigned. An impact assessment funded by the European Commission (EC, 2015) states that the DVS should save 550 lives per year in Europe by reducing the size of HGV blind spots.

Acknowledgments

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