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A Method for Determining and Presenting Driver Visibility in Commercial Vehicles

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ABSTRACT

Driver visibility from commercial vehicles is often an issue in post-accident litigation. While the visibility through the windows of most vehicles is restricted due to the required structure of the vehicle itself, most manufacturers and users incorporate a series of mirrors to enhance driver visibility and to reduce blind spots. The challenge for an engineer is to first demonstrate what the driver could see to a reasonable degree of engineering certainty, and then to convey this information in a form that is easy for the lay person to grasp. This paper outlines procedures for calculating and modeling the driver visibility from commercial vehicles. The primary techniques presented require access to the vehicle, although the paper also presents techniques by which visibility can be analyzed through photogrammetry and 3-D computer models, both for the vehicle and for any mirrors incorporated onto the vehicle. Finally, this paper presents several techniques which have been used successfully to convey visibility information to adjusters and juries.

INTRODUCTION

Often, when a commercial vehicle is involved in an accident, one of the issues raised is whether or not the driver could have seen the vehicle or pedestrian that was struck. The answer to this question is a critical part of the case, since the effects of the answer will have a direct impact on the damages awarded. Sometimes, the answer to this question may result in a determination that the visibility from the commercial vehicle was entirely reasonable, and therefore the driver (or owner of the vehicle) is responsible for any damages to the claimant. On the other end of the spectrum, the answer to the question may result in an award of punitive damages if it is determined that the lack of visibility from the vehicle due to poor mirror design or configuration indicated a reckless disregard for public safety.

The issue of whether an object is visible to a driver depends on many variables. The most basic variable is line-of-sight, or in other words, was the object geometrically visible to the driver with no obstructions getting in the way. The issue of whether or not the object could be distinguished from the background is another matter, and this paper does not attempt to address issues of conspicuity. While it may seem that the easiest way to show geometric, or line-of-sight, visibility is through photographs taken from the driver's point of view, it must be remembered that an accident is a dynamic event. In other words, in order for a collision to have occurred, the commercial vehicle had to be in motion, and the other vehicle or pedestrian could also have been in motion. As a result, static photographs of the visibility from the driver's point of view do not always adequately convey the time-space relationship between the involved vehicles/pedestrians throughout the accident sequence. Therefore, animations have become the most viable means of showing visibility throughout the accident sequence [6, 7]. In addition to showing the relative motion between colliding objects, the animations can also be constructed with three-dimensional models in true time and distance scale. Therefore, the visibility can be studied and portrayed both from the driver's point of view and the claimant's point of view.

In order for the animations to be admissible in a court of law, they must be based on a solid scientific foundation. Proper application of Newton's laws and basic time-distance-velocity equations will provide the basis for the motion of the colliding bodies. Measuring the visibility for a driver through windows or flat mirrors has been extensively discussed in the literature, and various techniques have been presented for both monocular and binocular measurements. Burger et al. [1, 2] used multiple techniques including an observer with an assistant outside the vehicle to map the visible areas, object sighting techniques, and photographs of an external target grid taken from the driver's point of view. Olson [3] and Reed [4] used pole-sighting techniques to measure the mirror field of view from a driver's perspective. More recent work [5] has used a Faro arm to measure and record the positions of the driver's eye and the limits of visibility. The basic measurement technique in the current work uses similar methods to Burger in which an assistant outside the vehicle is used to mark field of view. While the measurement techniques are not new, presenting the field of view dynamically through the accident sequence is presented as a means of conveying the geometric visibility issues.

It is more difficult to justify scientifically an animation when the type of vehicle involved in the accident is no longer in use and not available. This paper will also show the results of such a case in which photogrammetric methods were successfully used to illustrate driver visibility throughout the accident.

CASE 1: BASIC TECHNIQUES WITH THE VEHICLE AVAILABLE FOR STUDY

The first case presented involved a Volvo refuse truck that had dual controls. In other words, the vehicle could be operated from both the left and right sides of the cab. The vehicle was being driven from the right side, and the driver was merging onto a freeway. The driver merged into the right travel lane, but then continued to move left into the #2 lane. As the truck was merging, a Honda was overtaking the truck with a calculated passing speed of 10 mph above the truck's speed. As the truck merged into the #2 lane, the left front corner of the truck contacted the right rear of the Honda, causing the Honda to spin into the Jersey barrier. The driver of the Honda sued for various injuries. However, the truck driver told police that he could not see the car due to the large blind spots from his point of view in the cab. His statement motivated a claim of punitive damages against the company for unreasonably large blind spots. The task facing the engineers was to determine what areas were visible to the driver throughout the accident sequence and to accurately convey this to a jury.

MEASURING DRIVER VISIBILITY

Measurement of the driver's visibility "cones" began by acquiring the incident truck and driver. The driver was instructed to adjust the mirrors as he normally did, so that their adjustment was reasonably close to their position at the time of the accident. The driver was also instructed to sit in the driver's seat (on the right side) so that the position of his eyes could be measured and documented in three-dimensions.

Once the truck was thus set-up, an engineer took the place of the driver, and the seat was adjusted so that the engineer's eye position matched that of the driver. The engineer had a walkie-talkie and gave instructions to an assistant outside the truck. The first area of visibility to be mapped out was the visibility through the front and side windows. The assistant was verbally told to move until the engineer could just see the assistant's feet out the right front window, and at that point the assistant placed a marker at his feet. The assistant then moved to the left of the truck and around the left front such that the engineer could just maintain sight of the assistant's feet. At various points, the assistant would place markers at his feet so that the field of view at ground level from the driver's point of view could be measured and documented. The documentation of the markers is shown in Figures 1 and 2.

Figure 1. Visibility markers for front window.

Figure 2. Visibility markers for front window and marking corner/A-pillar.

This process was repeated for the left side flat mirror and the left side convex mirror. For the mirror visibility, the forward edge of visibility at ground level was marked. The visibility cone markers for the flat mirror are shown in Figure 3, while those for the convex mirror are shown in Figure 4.

Figure 3. Visibility markers for flat mirror.

Figure 4. Visibility markers for convex mirror.

Once all of the markers were placed, their position was surveyed in an X-Y grid, and the dimensions of the truck were documented. An exemplar Honda was also acquired, and its dimensions were also documented. Finally, a video camera was mounted in the driver's position with the focal plane of the camera in the same position as the driver's eyes. The Honda was driven past the truck at a speed of 10 mph (the calculated relative speed during the accident) and the pass was filmed with the camera focused on the mirrors and left A-pillar area.

A three-dimensional model of the truck was constructed in 3D Studio Maxx, and the measured visibility cones were applied as shown in Figures 5 – 7.

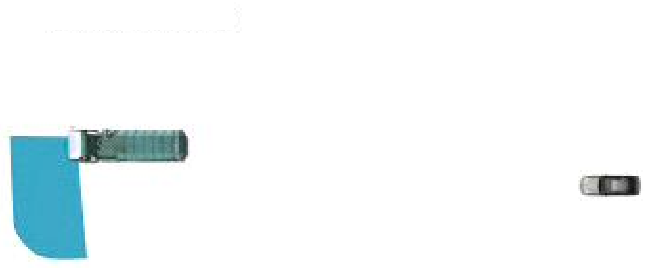

Figure 5. Modeled visibility area through front and side windows at ground level.

Figure 6. Addition of modeled visibility area for convex mirror at ground level.

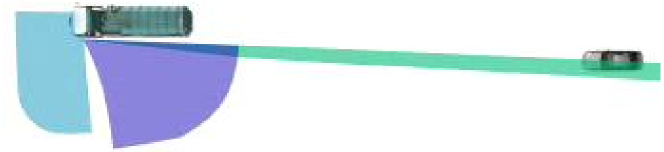

Figure 7. Addition of modeled visibility area for flat mirror at ground level.

Having modeled the areas visible to the driver, and animation was constructed that composited the video obtained during the inspection with the time-space and visibility cone relationships. Screen captures from the animation are shown in Figures 8 – 11 that show the visibility of the Honda from several yards behind the truck up to the point of impact.

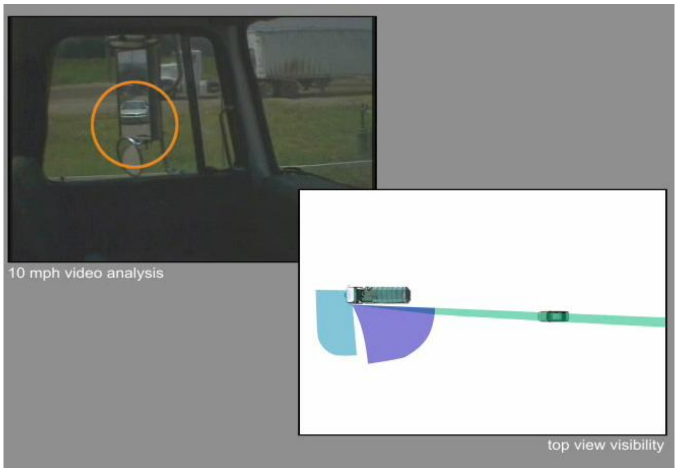

Figure 8. Screen capture from animation showing driver view of Honda in flat mirror.

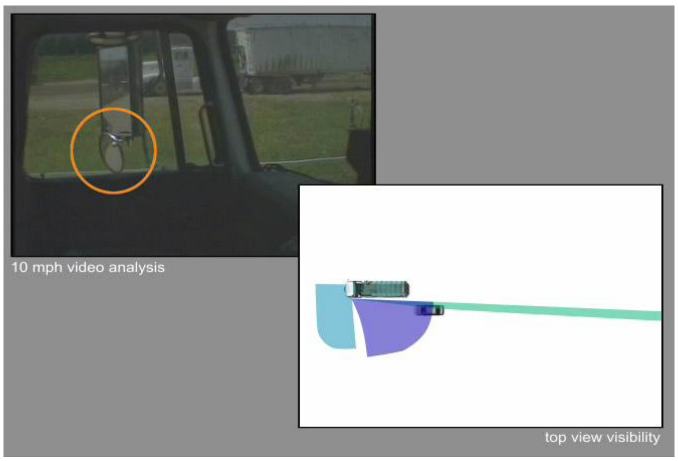

Figure 9. Screen capture from animation showing driver view of Honda as Honda transitions from flat mirror to convex mirror.

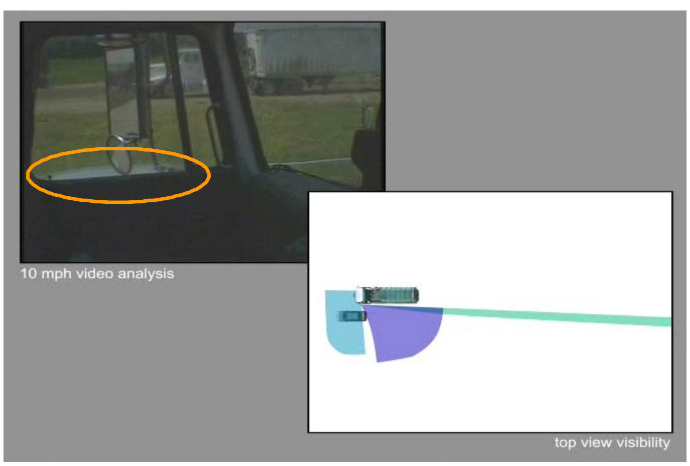

Figure 10. Screen capture from animation showing driver view of Honda through left window as Honda passes left side of cab.

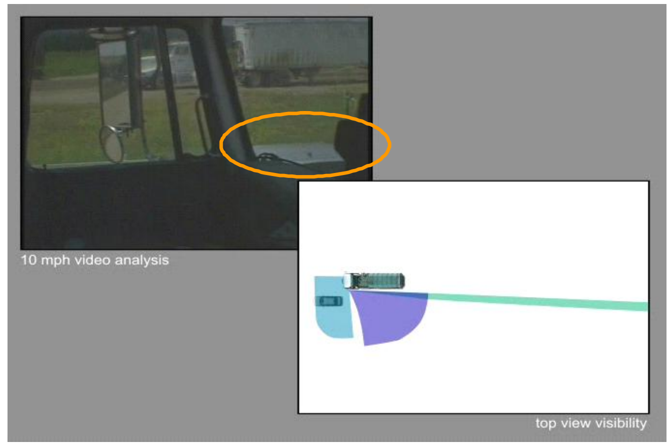

Figure 11. Screen capture from animation showing driver view of Honda just prior to impact.

Again, the screen captures do not convey the entire story like the animation. However, the animation does show that the Honda was visible to the driver at all times when the Honda was abeam the truck in either a mirror or out a window. Therefore, the conclusion was reached that the driver DIDN'T see the car, not that the driver COULDN'T see the car. This animation negated claims for punitive damages, and the case settled prior to trial.

CASE 2: TECHNIQUES WHEN THE VEHICLE IS NO LONGER AVAILABLE FOR STUDY

The second case presented involved a White refuse truck that also had dual controls. In this case, the driver was outside the truck emptying residential refuse cans into the right-side semi-automated loader. While the driver was outside, a young child who had forgotten to take out the trash was approaching from the left side of the truck. As the child rounded the left front corner of the truck, the driver had re-entered the cab, and began to move forward to his next stop while operating the truck from the right side controls. The truck struck the child, and the child rolled underneath the truck and received multiple injuries and lacerations from objects under the truck. The child waited until he became a legal adult, and then filed his own lawsuit against the refuse company. Due to the length of time between the accident and the lawsuit, no companies in the U.S. were operating this type of semi-automated side loader. The engineers retained by the refuse company did find an exemplar vehicle in a salvage yard in another state. However, the exemplar vehicle had been struck by a train rendering it useless for measurement or analysis purposes.

What was available to the engineers were four photographs taken by a company supervisor on the day of the accident, as well as a series of photographs of the truck at the scene taken approximately a month after the accident. Two photos showed the driver in the driving position on the right side of the cab. The engineers were then able to use photogrammetric software to construct a three-dimensional model of the truck, and to calculate the position of the driver's eyes. The model is shown overlaid on the photograph in Figure 12.

Figure 12. Truck model overlaid on police photo.

The engineers also determined the height of the child from medical records, and created a scaled biped model of the claimant. The engineers performed a time-space analysis of the accident based on published human factors data for a child of the claimant's size and age. The three dimensional models allowed the engineers to virtually calculate those areas in which a child of the claimant's size would not be visible to the driver due to the structure of the truck. The calculated "blind areas" are shown in Figure 13.

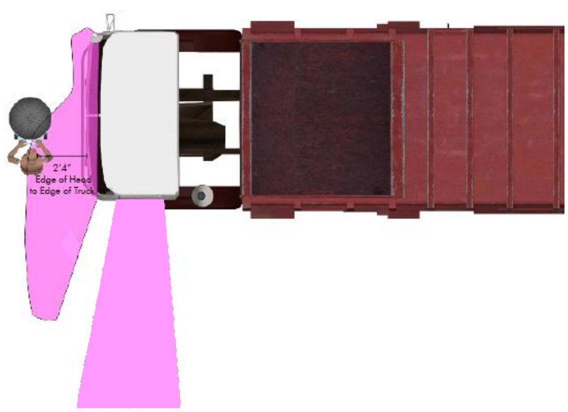

Figure 13. Photogrammetrically modeled blind areas.

Modeling the visibility through the flat mirror was straightforward since the lines of sight were straight. The convex mirror on the side could also be modeled on the basis of measurements taken on prior occasions. However, sometime prior to the accident the refuse company had added a convex mirror above the right A-pillar to assist the driver with visibility directly in front of the truck. Since the truck was not available to perform visibility measurements for this upper right convex mirror, the visibility was calculated in virtual space. The first step in this process was to photogrammetrically model an exemplar mirror. The results of this modeling are shown in Figure 14, in which the reflection in the modeled mirror is compared to the reflection in the actual mirror.

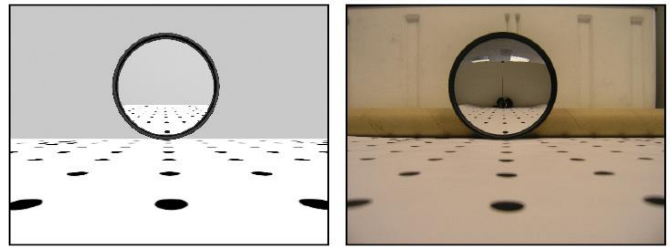

Figure 14. Computer generated mirror and reflection (left) and photograph of actual mirror (right).

The next step was to model the position of the mirror at the time of the accident. This was achieved through camera matching with the provided photographs. As in the previous case study, once the three-dimensional models and the time-space analysis were completed, animations were produced that illustrated when the child became visible to the driver in the mirrors. A screen capture from one animation is shown in Figure 15. This animation showed that prior to impact, the pedestrian was visible to the driver in the upper right mirror.

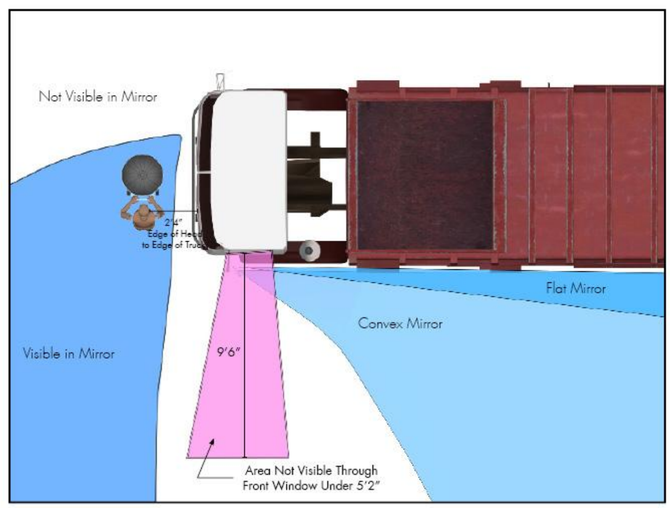

Figure 15. Screen capture showing visibility of pedestrian in modeled visibility cones.

The modeled mirror was also used to show what the driver could have seen from the driver's point of view. A camera match was used to model the position of the mirror on the day of the accident. A capture from this animation is shown in Figure 16.

Figure 16. Driver's view of child in mirror three seconds prior to truck moving.

The screen capture in Figure 16 shows that the child was fully visible to the driver at least 3 seconds prior to the truck moving. It should be noted that this animation does not attempt to indicate the conspicuity of the pedestrian, but is merely a geometric or line-of-sight presentation of the pedestrian. The animations showed that the refuse company had taken steps to address the blind area in front of the truck by installing a proper convex mirror, and that the driver could have observed the child prior to impact.

CONCLUSION

Driver visibility from the cab of a commercial vehicle continues to be a factor in many accidents. It is imperative for the engineer to accurately document the areas of visibility for the driver. Today's computing power and the animation software that is currently available allow the engineer to convey time-space data throughout the accident sequence, whereas series of still graphics are not as able to illustrate the time-space relationship in a continuous manner. The techniques presented in this paper are straightforward when either the accident vehicle or an exemplar are available for study. In the event the vehicle is no longer available, photogrammetric techniques have been successfully used to model and present visibility data in a court of law. Such presentations are crucial in assisting jurors and judges to determine whether or not punitive damages are justified. For the court system, there is a big difference between "I couldn't see them" and "I didn't see them."

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