NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C. 20594

April 7, 2020

Video Study

NTSB Case Number:
HWY20MH002

A. ACCIDENT

Location:	Mount Pleasant, Pennsylvania
Date:	January 5, 2020
Time:	3:30 AM
Vehicle No.1:	2005 Van Hool motorcoach ('motorcoach')
Vehicle No.2:	2018 Freightliner Cascadia truck-tractor in combination with a semitrailer, operated by FedEx Ground ('truck')

B. AUTHOR

Dan T. Horak
NTSB

C. ACCIDENT SUMMARY

For a summary of the accident, refer to the *Crash Summary Report* which is available in the docket for this investigation.

D. DETAILS OF INVESTIGATION

The goal of this study was estimating the speed of the truck, the speed of the motorcoach, and the response time of the truck driver. Analysis was based on videos recorded by a Lytx DriveCam event recorder installed on the truck. Two videos were available, one from an outside-view, forward-facing camera and the other from an inside-view camera that recorded the truck driver. The videos had 640x352 resolution and frame rate of 10 fps. During the last 8 seconds before the truck impacted the motorcoach, the DriveCam also recorded lateral and longitudinal accelerations measured by its built-in accelerometers and vehicle GPS coordinates measured by its built-in GPS receiver.

Interstate 70 westbound near the accident location had two lanes that were separated by a white broken lane line. The lane line consisted of 15-foot-long white segments followed by a 25-foot-long gaps so that a moving vehicle encountered a new white segment every 40 feet. The accuracy of the 40-foot distance was examined in Google Earth aerial views across 10 and 20 white segments and it was found that it was better than 1%. Therefore, the segments could be used for estimating traveled distance.

The motorcoach, traveling in the left lane, was seen in the forward-facing video passing the truck that was in the right lane about 5400 feet before the accident site. The truck speed at that location was estimated as 46±1 mph based on the white segments and the video frame rate. Three estimates of the motorcoach speed were derived, as described next.

Motorcoach Speed Estimate Based on Motorcoach Length

Figure 1 is a frame from the forward-looking camera video that shows the motorcoach when it was passing the truck. The motorcoach was 45 feet long and it took 13 video frames for the length of the motorcoach to pass the same location in the video frame from the forward-looking camera. Considering the 10 fps frame rate, the motorcoach was moving faster than the truck by 45/(13/10)=34.6 ft/s or 23.6 mph. Therefore, the nominal estimated speed of the motorcoach was 46+23.6=69.6 mph. Adding the inaccuracy of estimating the relative speed of the two vehicles, the motorcoach speed was 69±2 mph when it passed the truck.

Motorcoach Speed Estimate Based on Increasing Distance from Truck

There was a concern that the speed of the motorcoach when it was passing the truck could have been changed by its driver because he was starting the process of passing the truck. Therefore, it was desirable to estimate the speed of the motorcoach after it passed the truck. After the motorcoach passed the truck, its distance from the truck was measured in terms of the increasing number of the 40-foot white line plus gap segments visible in the video. Figure 4 shows the motorcoach when three segments were visible. It was possible to estimate the location of the motorcoach when 1, 2, 3 and 4 segments were visible. The estimated speed of the motorcoach relative to the truck using this method was 21.5±2.5 mph.

This estimate, the accuracy of which is limited because it was difficult to estimate accurately the location of the motorcoach along the road using a camera that was aligned parallel to the road, compares well to the more accurate estimate of 23.6 mph faster than the truck derived above. Therefore, it was concluded that the motorcoach speed remained constant at about 23.6 mph faster than the truck for at least six seconds after it passed the truck.

Lower Limit on Motorcoach Speed Estimate

When the motorcoach passed the truck, its distance to the crash location was about 5400 feet. It was only possible to estimate the location of the motorcoach based

on the video for six seconds or 600 feet after it passed the truck. After 21 seconds, the motorcoach was no longer visible in the video. Consequently, estimation of the speed of the motorcoach as it was nearing the crash location was not possible.

Figure 1. Video Frame Showing the Motorcoach Passing the Truck

Figure 2. Video Frame Showing the Motorcoach after It Passed the Truck

However, it was possible to set a lower limit on that speed. The forward-facing camera first detected the overturned motorcoach 71.2 seconds after the motorcoach passed the truck. If it is assumed that the motorcoach overturned at the time when it was first detected, the average speed of the motorcoach was 5400/71.2=75.8 ft/s or 51.7 mph. This is a lower limit that says nothing about the actual average speed of the motorcoach after it passed the truck or its speed when it overturned. It is so because it is not known how much time passed from when the motorcoach overturned to when it became detectable in the DriveCam video.

Estimated Lateral Acceleration of the Motorcoach on the Accident Curve

The radius of the curve on which the motorcoach crashed was estimated by fitting circular arcs to the curve seen in a Google Earth aerial image. Figure 3 shows the geometry of the estimation process. The estimated radius was 1360 feet. The blueprints used to construct the road, dated April 2005, specify the radius as 395 meters or 1296 feet and the superelevation as 8%.

The lateral acceleration on the curve, assuming speed of 69 mph and curve radius of 1360 feet, is $V^2/R=(69x1.467)^2/1360=7.53$ ft/s^2 or 0.23 g. The minimum coefficient of friction required to provide the centripetal force required for negotiating the curve is $\mu=0.23-0.08=0.15$. This estimate takes into account the 8% superelevation. Note that this lateral acceleration estimate is for a vehicle that successfully negotiates the curve while moving at the assumed 69 mph speed of the motorcoach.

Figure 3. Estimation of Accident Curve Radius

Response Time of the Truck Driver

Figure 4 shows the frame from the forward-facing camera video that corresponds to the time when the inward-facing video shows the driver starting to change his posture and focusing on something on the road ahead. This frame was recorded 5.3 seconds before impact. Until 5.4 seconds before impact, the video shows the driver leaning forward and looking straight ahead. At the time of detection, the video shows that the driver started moving to an upright sitting position while continuing to look straight ahead.

The accident happened on a curve where the road surface elevation was significantly lower than the elevation of the terrain beyond the right shoulder. This limited the visibility of what was ahead of the truck in its right lane. The presence of the overturned motorcoach had to be detected against the background of the cut slope (also called back slope) and the trees that were to the right of the right shoulder. Detection of the motorcoach required realizing that there was an object closer to the truck than the cut slope and the trees.

Figure 4. Video Frame Recorded when the Truck Driver Detected Obstacle ahead (5.3 seconds before impact with the motorcoach)

Figure 5 is a frame from an NTSB daytime drive-through video. It illustrates the visibility problem caused by the cut slope and the trees. The inside-view camera video recorded the driver and made it possible to estimate the time when he detected the overturned motorcoach and started dealing with the new situation, as detailed below.

The DriveCam recorded the GPS coordinates of the truck during the last 8 seconds before it impacted the overturned motorcoach. Figure 6 is a plot of the GPS-based truck

speed vs. time in a 6-seconds-wide time window. The window was set to start shortly before the driver detected the motorcoach and to end shortly after impact. The figure shows that the driver started braking shortly after detecting the overturned motorcoach.

Figure 5. Frame from NTSB Daytime Drive-through Video Showing the Cut Slope

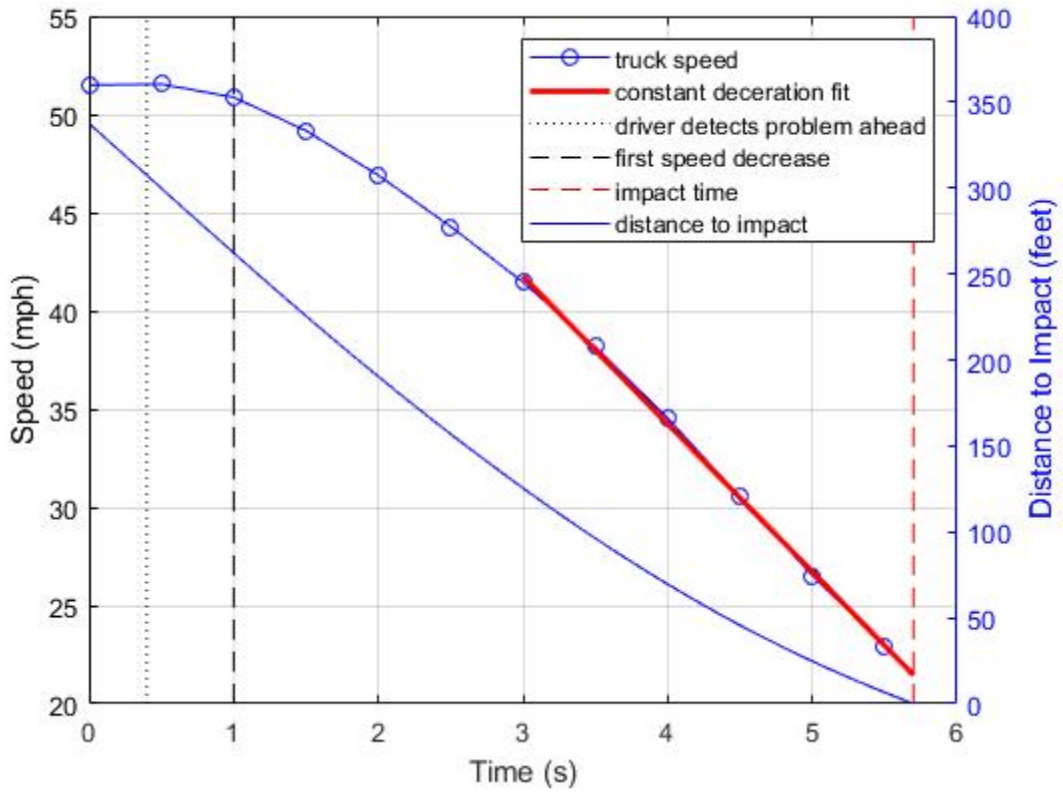

Figure 6. Estimated Speed of the Truck as It Approached the Motorcoach

The longitudinal acceleration, measured by the DriveCam accelerometer, showed that the truck acceleration turned negative as soon as 0.3 seconds after detection. The truck speed was 51.5 mph before the detection and down to 51 mph 0.6 seconds after detection. Two seconds later, the speed was down to 42 mph as the truck reached its maximum achievable deceleration of 0.34 g that was estimated by fitting a constant deceleration line to the last 2.5 seconds of speed data. Speed and deceleration estimates based only on the visual information in the video agreed with the GPS-based values.

The slope of the road near the accident location was -3% or -1.7º. If the accident occurred on a leveled road, the deceleration of the truck would have been about 0.34+0.03=0.37 g. Such deceleration corresponds to a wet but not icy road surface.

The truck impacted the motorcoach with the speed of about 22 mph at time 5.7 seconds in the 6-seconds-wide time window in Figure 6. The figure also shows the distance to the impact location. It was computed by integrating the truck speed back in time starting at the time of impact. The figure shows that the driver noticed the overturned motorcoach when he was about 310 feet from it (5.3 seconds to impact). First speed decrease was observed when the distance to the motorcoach was about 265 feet (4.7 seconds to impact). When the distance was down to about 125 feet (2.7 seconds to impact), the truck reached its maximum achievable deceleration of 0.34 g.

The forward-looking video shows the truck moving from the right lane to the left lane during the last three seconds before impact. There was a debris field along the road, extending from the right shoulder to the left shoulder, left there by the motorcoach as it was losing control. The debris in the left lane was farther along the road than the debris in the right lane. It is likely that the driver changed lanes because the distance to the debris in the left lane was longer than it was in the right lane.

E. CONCLUSIONS

Videos and data recorded by a DriveCam event recorder installed in a truck were used for estimating the speed of the truck, the speed of a motorcoach passing the truck, and the response time of the truck driver. The estimated motorcoach speed when it passed the truck was about 69 mph. Before detecting the overturned motorcoach, the truck was moving along the accident curve at about 51.5 mph, below the posted advisory speed limit of 55 mph. The truck driver responded quickly after detecting the overturned motorcoach and started braking. The truck impacted the motorcoach with the speed of about 22 mph.