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

January 15, 2015

Video Study

NTSB Case Number:
HWY15MH009

A. ACCIDENT

Location:	Chattanooga, Tennessee
Date:	June 25, 2015
Time:	7:10 PM
Vehicle:	2011 Peterbilt truck tractor and 2005 Great Dane refrigerated semitrailer combination

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 investigation was estimating the speed of the truck tractor-semitrailer combination ('the accident truck') based on videos captured by surveillance cameras installed on buildings. Two cameras captured the accident truck shortly before the accident. One was at a Cracker Barrel restaurant (Camera 1) and the other at a Hampton Inn hotel (Camera 2). Camera 1 recorded the accident truck for approximately 3 seconds ending approximately 0.31 miles before the location where it impacted the first slowly-moving car. Camera 2 captured the truck in motion for approximately 4.5 seconds starting approximately 300 feet past the location where it impacted the first slowly-moving car.

Camera 1 video had resolution of 704x480 and frame rate of 15 fps. Camera 2 video had resolution of 928x480 and frame rate of 30 fps. Both cameras had wide angle lenses that caused barrel distortion. The distortion was corrected mathematically so that the corrected frames from the videos that were used for speed estimation were free of barrel distortion.

Camera Calibration

Truck speed estimation was based on mathematical models of the cameras. These models had to be calibrated. The camera calibration parameters are its x-y-z location in ground coordinates, its roll, pitch and yaw angles with respect to ground, and the horizontal field of view angle. The x-y-z locations were known approximately but the accurate locations are necessary for speed estimation. The angles were not known. The calibration was based on mapping of reference points specified in ground coordinates and visible in the videos onto frames from the video. The reference points included trees, poles holding signs, road markings and curbs.

A camera is considered calibrated when the mathematical model maps all the reference points accurately on the images of these reference points in frames from the video. The calibration was performed in an iterative process where the values of the seven calibration parameters were varied until all reference points were mapped accurately.

Speed Estimation

Truck speed was estimated by first estimating the location of the truck in ground coordinates using its image in frames from the video. Speed was then estimated by dividing distances between any two locations by the time difference between the corresponding video frames. Since the frame rates of the videos were known, time difference between any two frames could be computed by dividing the difference between the two frame numbers by the frame rate.

Truck locations were estimated using software-generated distance markers along the highway lane in which the truck was moving. The calibrated camera models provided means of mapping locations in ground coordinates onto frames from the video. They were used to map the distance markers onto the frames. Truck locations were estimated by finding frames in which the truck was at a marker. For all such frames, both the location along the lane and the time when the truck was there were known, making speed estimation possible.

Speed Estimate in Field of View of Camera 1

Figure 1 shows a frame from the Camera 1 video before removal of barrel distortion. The I-75 segment in which vehicles can be seen is approximately 300 feet long. The accident truck was moving from left to right. Nine evenly-spaced locations of the accident truck were estimated using video frames in which the truck was at markers superimposed on the frames with the camera model. The markers were spaced by 10

meters. Since the time when each frame was acquired was known, it was possible to plot traveled distance vs. time. The plot is in Figure 2 where the time was set to zero at the first analyzed point. The blue markers and the solid blue line are the raw data. The speed estimate is most accurate when based on the second half of the analyzed time segment, between 1.4 seconds and 2.7 seconds. In that interval, the road is closer to being perpendicular to the line of sight from the camera which makes locating the truck with respect to the markers more accurate. That road segment is also closer to the accident location.

The broken red line in Figure 2 is a constant speed fit to the raw data between time 1.4 seconds and 2.7 seconds. The close match between the constant speed fit and the raw data indicates that the speed was constant in this interval. The slope of the fitted line is 111 ft/s or 76 mph. The accuracy of this speed estimate is ±2 mph.

Figure 1. Frame from Camera 1 Video (not showing the accident truck)

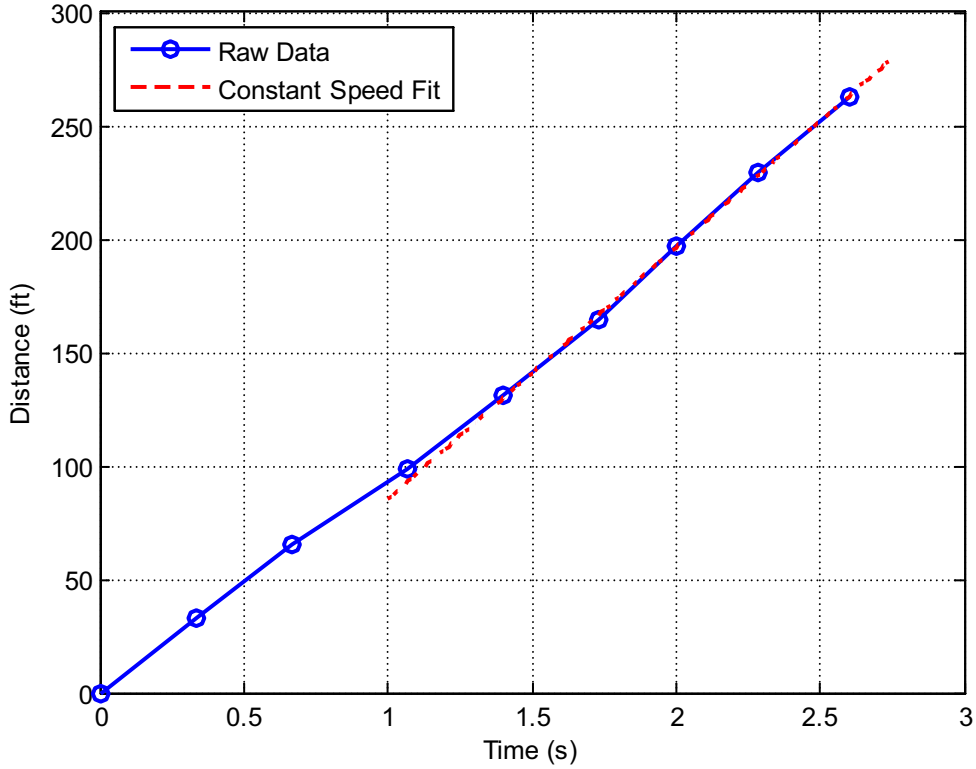

Figure 2. Accident Truck Locations vs. Time Estimated Based on Camera 1 Video

Speed Estimate in Field of View of Camera 2

Figure 3 shows a frame from the Camera 2 video before removal of barrel distortion. The I-75 segment in which vehicles can be seen is approximately 260 feet long but the accident truck stops moving approximately 130 feet after entering the camera field of view from left. Seven locations of the accident truck were estimated using video frames in which the truck was at markers superimposed on the frames with the camera model. The markers were spaced by 5 meters. Since the time when each frame was acquired was known, it was possible to plot traveled distance vs. time. The plot in Figure 4, where time was set to zero at the first point, shows that the truck was decelerating. The blue markers and the solid blue line are the raw data. The truck stopped moving approximately 1.5 seconds and 15 feet past the last data point shown in Figure 4.

The red broken line in Figure 4 is a second order polynomial fit to the raw data. Since the order of the fitted polynomial is two, it represents motion with constant deceleration. That deceleration was 0.17 g. Figure 5 shows the truck speed derived based on the polynomial fit to the distance vs. time data. It shows that the truck entered the field of view of Camera 2 at approximately 26 mph and 4.5 second later its speed dropped to approximately 8 mph. The uncertainty of the speed data in Figure 5 is ±2 mph.

Figure 3. Frame from Camera 2 Video (not showing the accident truck)

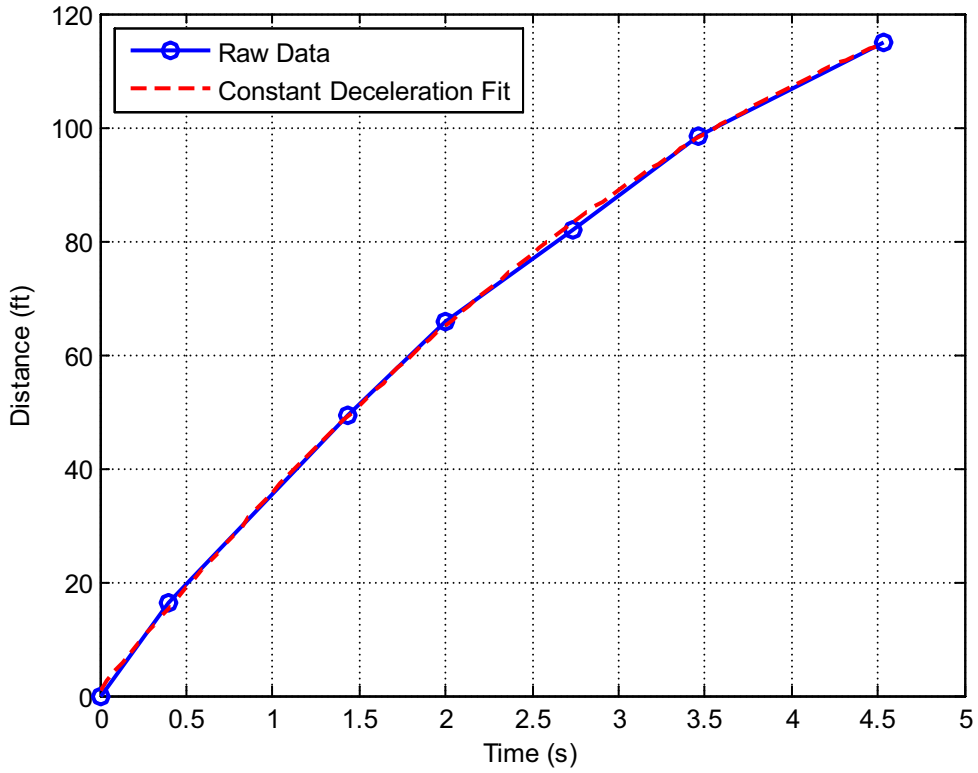

Figure 4. Accident Truck Locations vs. Time Estimated Based on Camera 2 Video

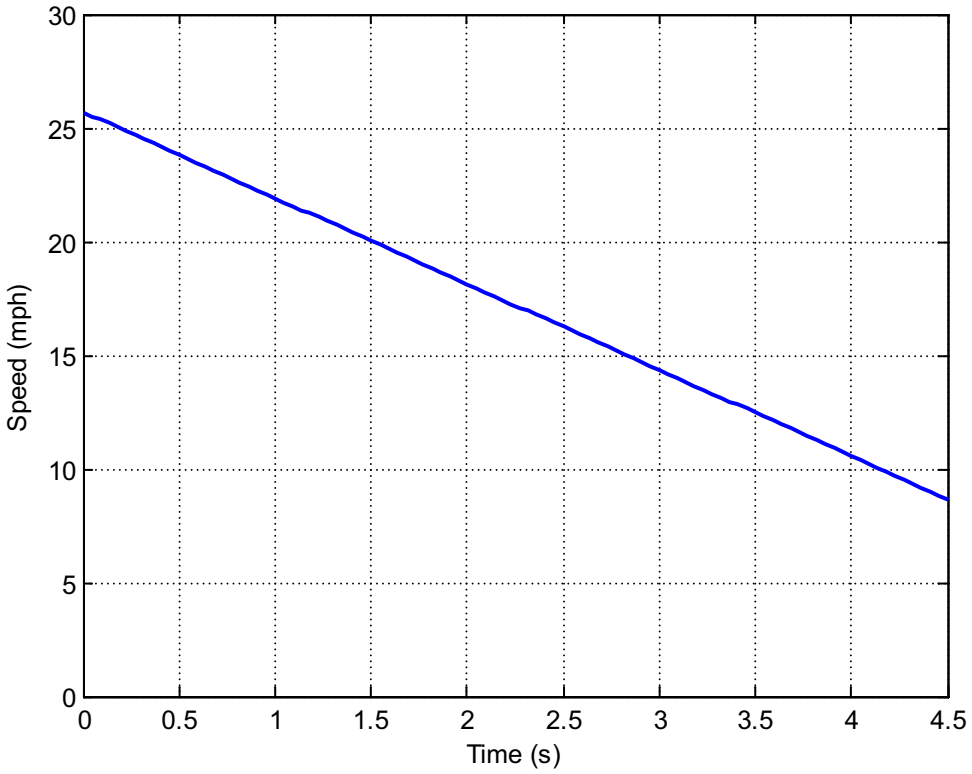

Figure 5. Accident Truck Speed Estimated Based on Camera 2 Video

Comments

The distance between the location on the highway where the accident truck was exiting the field of view of Camera 1 and the location of first impact was approximately 0.31 miles. The truck moved approximately 0.06 miles (300 ft) past the location of first impact before entering the field of view of Camera 2. Therefore, there was a 0.37 miles long road segment where the truck was not captured by either camera and its speed could not be estimated. Based on videos alone, nothing can be said about how the speed changed from 76 mph when exiting the field of view of Camera 1 to 26 mph when entering the field of view of Camera 2.

With the speed unknown in the 0.37 mile long road segment, the time to travel across it, which is speed-dependent, is also not known. Time can only be estimated for assumed speeds. For example, if the average speed in the segment is assumed to be 65 mph, the time to travel across the segment is about 20 seconds and if the assumed speed is 50 mph, the time to travel across the segment is about 27 seconds.

E. CONCLUSIONS

Videos acquired by two surveillance cameras were used for estimating the speed of a truck involved in a highway accident. Each camera recorded a different road segment.

The first analyzed road segment ended when the truck was approximately 0.31 miles before the location where it impacted the first slowly-moving car. The constant speed estimate based on a 1.3 seconds long interval when the truck was exiting the field of view of the camera and was closest to the accident location is 76±2 mph.

The second analyzed road segment started when the truck was approximately 300 ft past the location where it impacted the first slowly-moving car. That segment ended shortly before the truck stopped moving. The estimated speed in that segment started at 26±2 mph and ended at 9±2 mph. It was assumed that the deceleration was constant during the 4.5 seconds long video segment. The deceleration rate, estimated under the assumption that it was constant, was 0.17 g.