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

February 5, 2016

Video Study

NTSB Case Number:
HWY15MH004

A. ACCIDENT

Location:	Penwell, Texas
Date:	January 14, 2015
Time:	7:49 a.m. CST
Vehicle:	2015 Bluebird bus operated by the Texas Department of Criminal Justice

B. AUTHOR

Dan T. Horak
NTSB

C. ACCIDENT SUMMARY

For a summary of the accident, refer to the *Accident Summary* report in the docket for this investigation.

D. DETAILS OF INVESTIGATION

The accident bus was captured in a video acquired by a camera installed in a patrol car that was parked on the right shoulder. The video had resolution of 704x480 and frame rate of 30 fps. The accident bus was moving in the left lane of the two-lane highway and can be seen in the video for 6.9 seconds. During the first 3.9 seconds, it was moving straight in its lane. At time 3.9 seconds, the first evidence of collision with the roadside barrier can be seen in the video. The bus then started moving to left and at time 6.9 seconds was seen rolling to left and departing the elevated highway. It could not be seen after time 6.9 seconds because a truck moving in the right lane was between the camera and the bus. When the truck advanced and was no longer obstructing the view, the bus was already off the elevated highway.

Speed Estimate

Bus speed estimation was possible over 1.6 seconds at the beginning of the 6.9 second period when the bus was visible in the video. After 1.6 seconds, the bus was too far from the camera to allow accurate speed estimation.

Analysis of the video consisted of two stages. First, a model of the camera optics and camera location and orientation were estimated. This was done using a mathematical model of the camera that was capable of mapping reference points along the highway that were seen in the video onto synthesized video frames. The reference points included a highway light pole, a highway sign, two power line poles, points on a solid white lane line and points on the guardrail on the right side of the highway. The ground coordinates of some reference points were measured by NTSB staff at the accident scene. Additional reference point coordinates were derived from Google Earth images.

An iterative process was used where the camera field of view angle, location and orientation were varied until the mathematical model of the camera accurately mapped all the reference points onto their images in frames from the video. At that point, the camera model was accurately calibrated.

The second stage of the analysis estimated the locations of the accident bus along the highway. This was done by adding simulated reference markers along the right side of the lane in which the bus was traveling. The markers were spaced by 10 meters longitudinally and were 2 ft to the left of the right lane line. The 2 ft offset was used to align the markers with the right side of the 8 ft wide bus traveling centered in a 12 ft wide lane. Two markers were placed at each longitudinal location. One was at ground level and one at 8 ft above ground. The camera model mapped these markers onto frames from the video.

An iterative process was then used that identified frames from the video in which the rear right corner of the bus was aligned with the two markers at a longitudinal location. Since the frame rate of the video was known to be 30 fps, identifying a frame also estimated the time when the bus was at that location. It was possible to accurately estimate the bus location at five longitudinal marker locations and assign time to each location. The speed of the bus was then estimated by dividing marker-to-marker distances by the times it took to travel these distances. The analysis showed that the bus speed was constant as it traveled along the five marker locations. The estimated speed was 57±2 mph.

The tolerance on the speed estimate accounts for possible errors due to finite time resolution of 1/30 of a second due to the video frame rate, imperfections of the camera model, and the bus possibly not traveling centered in its lane. The tolerance was determined in a sensitivity analysis of the speed estimation process.

Following Distance Estimate

The speed of a tanker truck moving ahead of the accident bus was estimated as a constant 61±3 mph using the method described above. It has higher tolerance than the bus speed estimate because the truck is seen in the video for a shorter period of time and its image is less clear in the frames than the bus image.

Since the bus speed estimate is 57±2 mph, the two estimated speed regions overlap in the 58 mph to 59 mph range. Therefore, it was concluded that the two vehicles were moving at approximately the same speed, keeping the following distance constant.

The following distance was estimated by first estimating the distance between the front end of the tank on the tanker trailer that the truck tractor was towing and the front bumper of the accident bus. It was done over a time interval that started approximately 6 seconds before the bus impacted the guardrail and ended approximately 4 seconds before the impact. More specifically, the exact (accurate to 1/30 second) truck arrival time at a location was estimated approximately 4 seconds before the impact and the exact bus arrival time at the same location was estimated approximately 6 seconds before impact. The following distance was estimated by multiplying the difference between these two times by the estimated speed of the bus.

The estimated distance between the front end of the tank on the trailer that the tractor was towing and the front bumper of the bus was 127±5 ft. This distance included the length of the tank. Common lengths of tanks are between 40 ft and 53 ft. Even if it was not a standard tanker trailer (its image is not clear and only its front is seen in the video), this length range applies to other types of trailers. The length of the tank must be subtracted from the above estimate of 127±5 ft to get the rear bumper to front bumper following distance. The resulting following distance estimate is 87±5 ft if the tank was 40 ft long and 74±5 ft if the tank was 53 ft long. These two estimates can be combined into one, yielding following distance estimate of 81±12 ft. The ±12 ft tolerance includes the 13 ft uncertainty due to the unknown length of the tank.

E. CONCLUSIONS

Video captured by a patrol car camera was used for estimating the speed and following distance of an accident bus. The estimated speed was 57±2 mph. The estimated following distance was 81±12 ft.