

Truck-Tractor Semitrailer
Median Crossover Collision
With Medium-Size Bus on Interstate 35
Davis, Oklahoma
September 26, 2014



Accident Report

NTSB/HAR-15/03
PB2016-10022



**National
Transportation
Safety Board**

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Notation 8610B
Adopted November 17, 2015

Highway Accident Report

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Safety Board**

490 L'Enfant Plaza SW
Washington, DC 20594

National Transportation Safety Board. 2015. *Truck-Tractor Semitrailer Median Crossover Collision With Medium-Size Bus on Interstate 35, Davis, Oklahoma, September 26, 2014*. Highway Accident Report NTSB/HAR-15/03. Washington, DC.

Abstract: On September 26, 2014, about 9:05 p.m., a 2013 Peterbilt truck-tractor in combination with a 2014 Great Dane semitrailer, operated by Quickway Transportation Inc., was traveling north on Interstate 35 (I-35), near Davis, Oklahoma. About the same time, a 2008 Champion Defender 32-passenger medium-size bus—transporting 15 members of the North Central Texas College softball team—was traveling south on I-35. In the vicinity of milepost 47, after negotiating a slight rightward curve at a speed of about 72 mph, the truck-tractor departed the left lane and entered the 100-foot-wide earthen median. The truck-tractor continued through the median, traveling more than 1,100 feet without evidence of braking or steering. The combination vehicle then entered the southbound lanes of I-35 and collided with the bus. Following the impact, the bus rolled onto its right side, and the truck-tractor continued off the roadway into a wooded area. Four passengers on the bus were fully or partially ejected and died, and both drivers and the remaining passengers were injured. This investigation identified the truck driver’s drug use, passenger restraint systems, crashworthiness of medium-size buses, vehicle data recording, and median barriers as safety issues. The NTSB made new recommendations to the Federal Motor Carrier Safety Administration; the National Highway Traffic Safety Administration (NHTSA); the Federal Highway Administration (FHWA); the 50 states, the District of Columbia, and Puerto Rico; the American Trucking Associations, American Bus Association, United Motorcoach Association, Owner-Operator Independent Drivers Association, and Commercial Vehicle Safety Alliance; and the American Association of Community Colleges. In addition, the NTSB reiterated five recommendations to NHTSA and two each to the FHWA and the American Association of State Highway and Transportation Officials.

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Acronyms and Abbreviations

AACC	American Association of Community Colleges
AADT	annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
ABS	antilock brake system
AEX	Aerials Express
BASIC	behavior analysis and safety improvement category [FMCSA]
BMI	body mass index
CDC	Centers for Disease Control and Prevention
CDL	commercial driver's license
<i>CFR</i>	<i>Code of Federal Regulations</i>
CMV	commercial motor vehicle
CNES	Centre National d'Etudes Spatiales
CVSA	Commercial Vehicle Safety Alliance
DEA	US Drug Enforcement Administration
DNA	deoxyribonucleic acid
DOT	US Department of Transportation
DRE	drug recognition expert
DVFD	Davis Volunteer Fire Department
ECM	engine control module [medium-size bus]
EDR	event data recorder
EECU	engine electronic control unit [truck-tractor]
EMS	emergency medical service
ESC	electronic stability control
5-fluoro-AMB	(S)-methyl 2-(1-(5-fluoropentyl)-1H-indazole-3-carboxamido)-3-methylbutanoate

FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
<i>FMVSS</i>	<i>Federal Motor Vehicle Safety Standard</i>
<i>FR</i>	<i>Federal Register</i>
GHSA	Governors Highway Safety Association
GPS	global positioning system
GVWR	gross vehicle weight rating
hp	horsepower
I-35	Interstate 35
IC	incident command(er)
ICS	incident command system [NIMS]
IGN	Instituto Geografico Nacional
IGP	Instituto Geografico Portugues
LSD	lysergic acid diethylamide
MC	motor carrier [number]
MCI	mass casualty incident
MCMIS	Motor Carrier Management Information System [FMCSA]
MDMA	3,4-methylenedioxy-methamphetamine
mph	mile per hour
MV PICCS	motor vehicle prioritizing interventions and cost calculator for states [CDC model]
NCAA	National Collegiate Athletic Association
NCHRP	National Cooperative Highway Research Program
NCTC	North Central Texas College
NHTSA	National Highway Traffic Safety Administration
NIMS	National Incident Management System
NJCAA	National Junior Collegiate Athletic Association

NTSB	National Transportation Safety Board
NYT	<i>New York Times</i>
ODOT	Oklahoma Department of Transportation
OHP	Oklahoma Highway Patrol
OOS	out-of-service
OSBI	Oklahoma State Bureau of Investigation
PCP	phencyclidine
PELA	pre-existing landing area
RDG	<i>Roadside Design Guide</i> [AASHTO]
rpm	revolution per minute
SC	synthetic cannabinoid
SOAS	Southern Oklahoma Ambulance Service
THC	delta-9-tetrahydrocannabinol
TL	test level [for longitudinal barriers; NCHRP]
TRB	Transportation Research Board
<i>USC</i>	<i>United States Code</i>
USDOT	US Department of Transportation [motor carrier number]

Executive Summary

Investigation Synopsis

On September 26, 2014, about 9:05 p.m., a 2013 Peterbilt truck-tractor in combination with a 2014 Great Dane semitrailer, operated by Quickway Transportation Inc., was traveling north in the left lane of Interstate 35 (I-35), near Davis, Oklahoma. About the same time, a 2008 Champion Defender 32-passenger medium-size bus—transporting 15 members of the North Central Texas College (NCTC) softball team—was traveling south in the right lane of I-35. The college owned and operated the bus.

In the vicinity of milepost 47, after negotiating a slight rightward curve at a speed of about 72 mph, the truck-tractor departed the left lane and entered the 100-foot-wide depressed earthen median at an approximate 2 degree angle. The truck-tractor continued through the median, traveling over 1,100 feet without evidence of braking or steering. The combination vehicle then entered the southbound lanes of I-35 at an approximate 9 degree angle and collided with the bus.

Following the impact, the bus rolled onto its right side, and the truck-tractor continued off the roadway into a wooded area. As a result of the crash, four passengers on the bus were fully or partially ejected and died, and both drivers and the remaining passengers were injured.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the Davis, Oklahoma, crash was the failure of the truck-tractor driver to control his vehicle due to incapacitation likely stemming from his use of synthetic cannabinoids. Contributing to the severity of injuries were the lack of restraint use by the bus passengers and the lack of appropriate crashworthiness standards for medium-size buses.

The crash investigation focused on the following safety issues:

- ***Truck driver's drug use:*** The truck driver's use of synthetic cannabinoids (SC) was identified as a safety issue based on evidence from the truck cab, his lack of corrective action as he departed the roadway, and his history of drug use. Research is needed on the extent of SC use among commercial motor vehicle (CMV) drivers. Federal regulations specifying the drugs for which CMV drivers are tested include only a limited number of drugs. The inconsistency between the drug-testing regulations and the stated ban on the use of any impairing substances while driving, including SCs, should be resolved.
- ***Passenger restraint systems:*** The bus was equipped with seat belts, but none of the passengers wore the restraints. Although the NCTC had a seat belt use policy, it was not enforced. Moreover, motorcoaches and medium-size buses are excluded from

state seat belt use laws, whether with primary or secondary enforcement. The Davis crash demonstrates the need for seat belt use laws with primary enforcement for all vehicles.

- ***Crashworthiness of medium-size buses:*** Currently, for medium-size buses, there are no crashworthiness standards for side impact and occupant crash protection. The level of injury among bus occupants would have been reduced if the accident bus had met the current and future federal standards for large buses—for occupant protection and for rollover structural integrity. Further, side impact protection standards would enhance the crashworthiness of medium-size buses.
- ***Vehicle data recording:*** The truck-tractor was equipped with two recording devices, but neither module was a dedicated event data recorder. The bus had no such recording systems. With critical crash data on driver inputs and vehicle dynamics, investigators and researchers would be better able to understand crashes, leading to improvements in safety.
- ***Median barriers:*** No median barrier was in place at the crash site. Certain states—including Oklahoma—have developed more advanced guidelines for the installation of median cable barriers, leading to reduced crossover crashes and fatalities. Such guidelines and the circumstances of this crash can provide critical information in the development of comprehensive state or national guidelines for the installation of median barriers.

Recommendations

As a result of this investigation, the NTSB makes new safety recommendations to the Federal Motor Carrier Safety Administration; the National Highway Traffic Safety Administration (NHTSA); the Federal Highway Administration (FHWA); the 50 states, the District of Columbia, and Puerto Rico; the American Trucking Associations, American Bus Association, United Motorcoach Association, Owner-Operator Independent Drivers Association, and Commercial Vehicle Safety Alliance; and the American Association of Community Colleges. The NTSB also reiterates five recommendations to NHTSA, and two recommendations each to the FHWA and to the American Association of State Highway and Transportation Officials; and reclassifies one recommendation to the governors and legislatures of the 50 states, the US Territories, and the District of Columbia.

1 Factual Information

1.1 Crash Narrative

On Friday, September 26, 2014, about 9:05 p.m., a 2013 Peterbilt truck-tractor in combination with a 2014 Great Dane semitrailer, operated by Quickway Transportation Inc. and driven by a 53-year-old male, was traveling north in the left lane of Interstate 35 (I-35) near Davis, in Murray County, Oklahoma.¹ About the same time, a 2008 Champion Defender 32-passenger medium-size bus—transporting 15 members of the North Central Texas College (NCTC) softball team—was traveling south in the right lane of I-35 (see figures 1 and 2).² The bus was owned and operated by the college, and was being driven by the team’s 48-year-old male coach.

The truck-tractor had departed the Quickway terminal in Fort Worth, Texas, the starting point of the trip, around 3:30 p.m. It was traveling to Chandler, Oklahoma, from its previous stop in Irving, Texas. The bus was returning to Gainesville, Texas, following a softball scrimmage in Bethany, Oklahoma. The bus had departed Bethany around 6:15 p.m. (See appendix A for additional information on this National Transportation Safety Board [NTSB] investigation.)

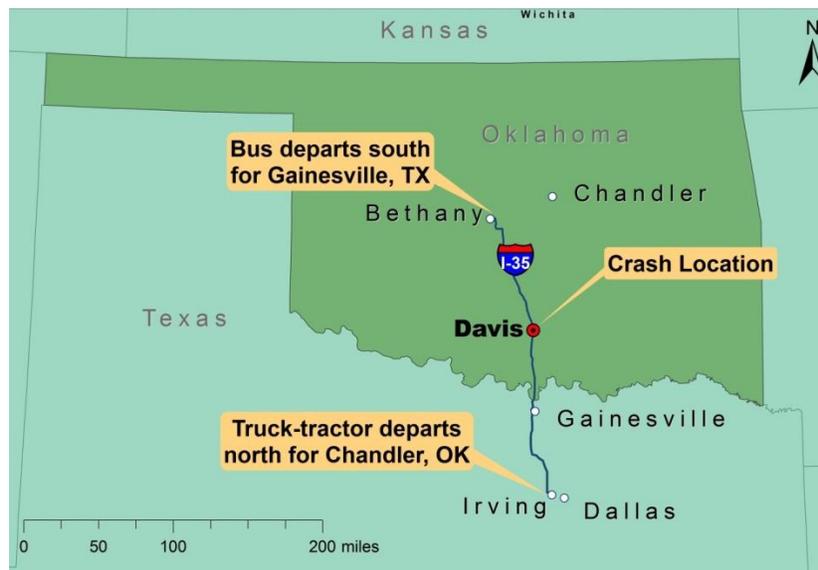


Figure 1. Map of travel routes for truck-tractor and bus, showing crash location on I-35.

¹ Throughout this report, the accident truck-tractor, in combination with one trailer, is interchangeably referred to as the “truck-tractor” or the “combination vehicle.”

² A medium-size bus is typically designated as such because it is built on a medium-duty truck chassis. The weight range for a medium-size bus is 10,001–26,000 pounds gross vehicle weight rating (GVWR). These buses are generally associated with travel within cities and towns—such as for shuttle and commuter service—and not with long-distance tour or charter service.

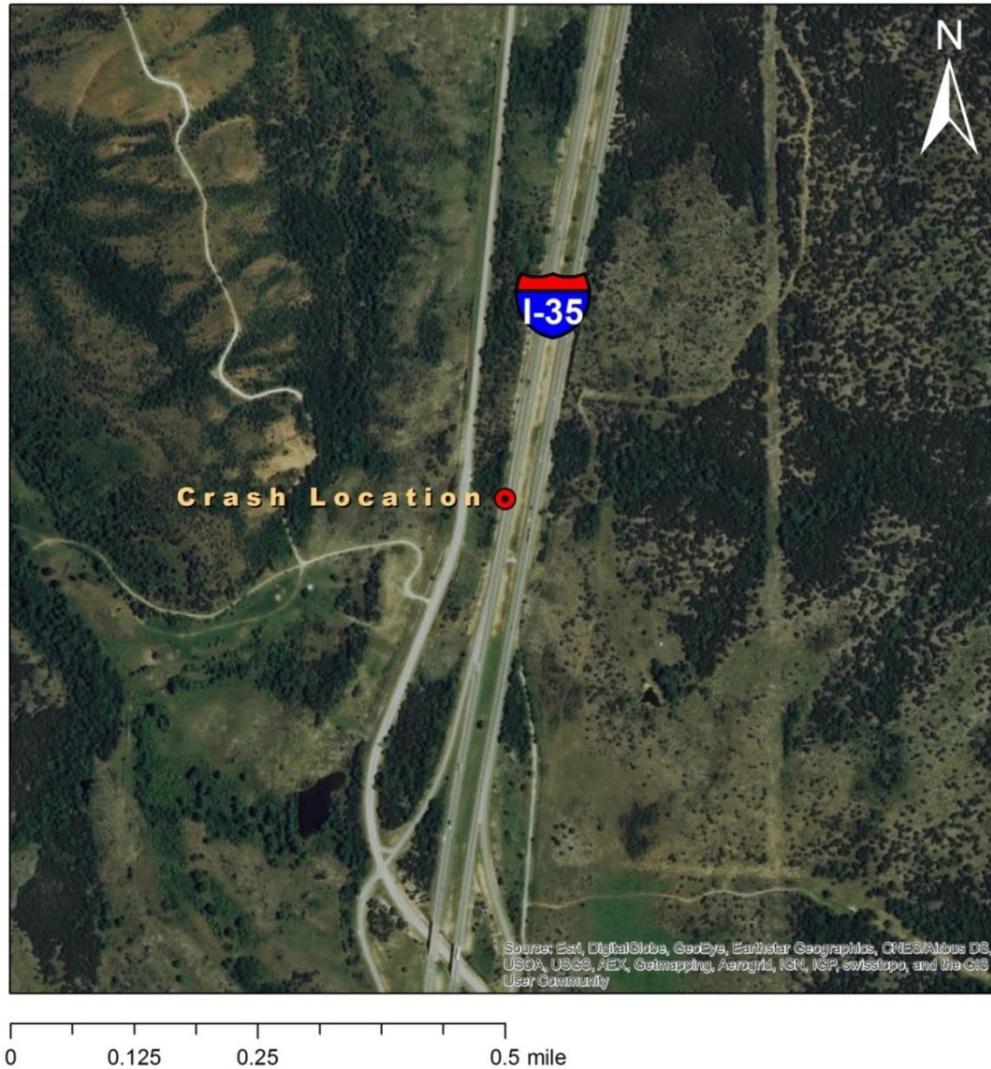


Figure 2. Aerial view of crash location, photographed June 12, 2013.
(Sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, US Department of Agriculture, US Geological Survey, AEX, Getmapping, Aerogrid, IGN, IGP, Swisstopo, and GISuser)

After negotiating a slight rightward curve near milepost 47, the truck-tractor departed the left lane and entered the 100-foot-wide depressed earthen median at an approximate 2 degree angle (see figure 3). The truck-tractor continued through the median at an estimated speed of 72–73 mph, traveling more than 1,100 feet. It then entered the southbound lanes of I-35 at an approximate 9 degree angle and collided with the bus. As a result of the collision, four bus passengers were fully or partially ejected and died. The remaining passengers and both drivers were injured.

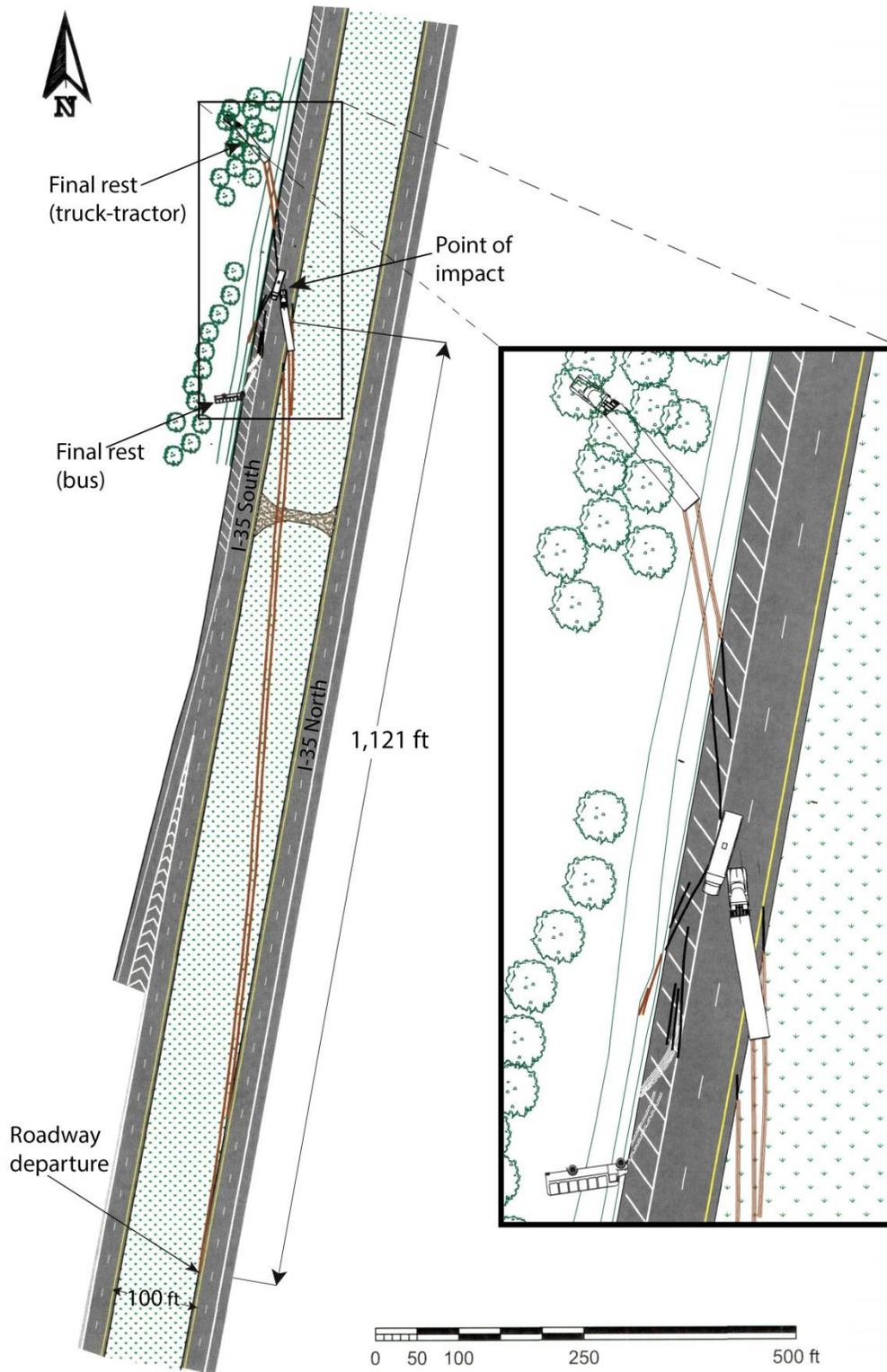


Figure 3. Crash scene diagram showing location of roadway departure, point of impact, and final rest positions for truck-tractor and bus.

Following the collision, the truck-tractor continued off the roadway into a wooded area, and the bus rolled one-quarter turn onto its passenger side, blocking the loading door as a point of egress (see figures 4 and 5). The bus driver reported that he exited the bus after kicking out the windshield. The 11 survivors egressed through the emergency roof hatch either under their own power or with help from the bus driver and bystanders.



Figure 4. At-rest position of truck-tractor in wooded area. (Source: Oklahoma Highway Patrol)



Figure 5. At-rest position of bus just off roadway. (Source: Oklahoma Highway Patrol)

1.2 Injuries

As a result of this crash, four of the 15 bus passengers died, five sustained serious injuries, and six received minor injuries. Each of the drivers had minor injuries. The 11 surviving passengers and the truck driver were transported to area hospitals (three passengers were transported by helicopter and the rest by ground transport). See table 1 for injury information.

Table 1. Injury levels for truck driver, bus driver, and bus occupants.

Injury Severity ^a	Truck Driver	Bus Driver	Bus Passengers	Total
Fatal	0	0	4	4
Serious	0	0	5	5
Minor	1	1	6	8
Total	1	1	15	17

^a Title 49 *Code of Federal Regulations (CFR)* 830.2 defines fatal injury as any injury that results in death within 30 days of the accident, and serious injury as any injury that (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date of injury; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burn affecting more than 5 percent of the body surface.

Three of the four passengers who died were fully ejected from the bus. Their injuries included multiple fractures, lacerations, abrasions, and blunt force head injuries. These three passengers were seated on the driver side of the bus in rows 6 through 8. According to interviews with surviving passengers, they were each lying down across two seats. Based on the Oklahoma Highway Patrol (OHP) diagram, the final rest positions of two of the passengers were 15–20 feet north of the bus and west of the paved shoulder. The third fully ejected passenger was located about 8 feet south of the bus roof.

The fourth fatally injured passenger sustained extensive blunt force head trauma, a cervical spine fracture, lacerations, and multiple abrasions. She was seated on the passenger side of the bus in row 5, adjacent to the window. As a result of the collision, she was partially ejected through the window and trapped under the sidewall of the bus.

The seriously injured passengers sustained fractures and lacerations. The passengers with minor injuries had scrapes, lacerations, and abrasions to arms, legs, and heads. Figure 6 shows the seating location and classification of injuries for each bus occupant.

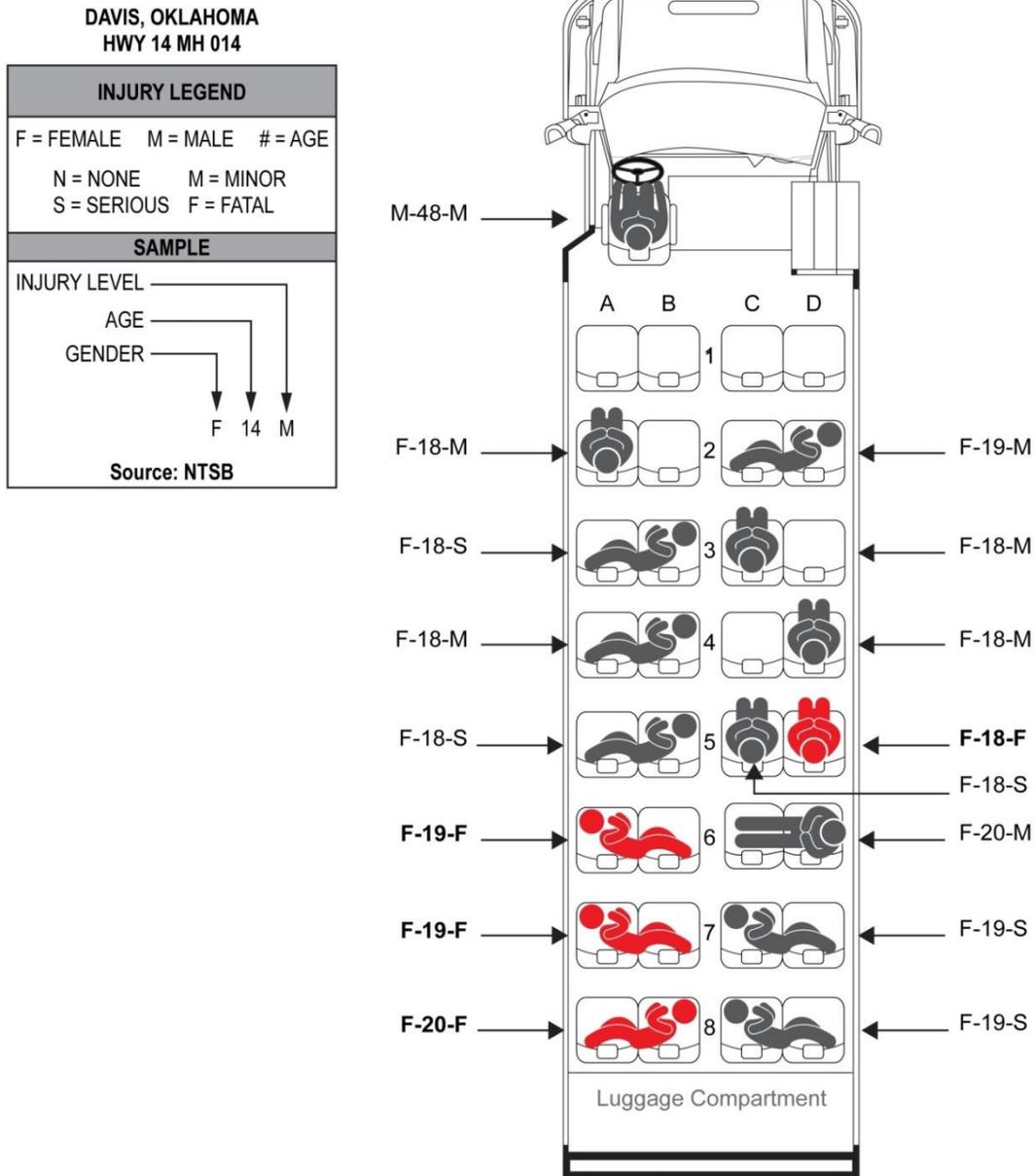


Figure 6. Bus seating chart, showing gender, age, and injury classification of occupants. Note: The exact positions of the three fatally injured passengers on the driver side are unknown, but according to interviews, they were lying down.

First responders had to cut a path through a wooded area to reach the truck driver because of the distance the combination vehicle had traveled immediately following the collision. The driver was extricated from the truck cab at 9:52 p.m.

1.3 Emergency Medical Services

1.3.1 Emergency Protocols

At the time of the crash, Murray County used the state of Oklahoma 2014 emergency medical service (EMS) protocols for handling mass casualties. These protocols define a mass casualty incident (MCI) as an incident involving fire, five or more critical patients, or 10 or more total patients, regardless of the severity of their injuries. The procedure of assigning incident command (IC) during an MCI follows the guidelines of the National Incident Management System (NIMS) and its subcomponent, the incident command system (ICS).³

1.3.2 Emergency Communications

The Murray County 911 dispatcher was notified of the crash at 9:05 p.m. The first ambulance to arrive was Murray County EMS unit 2 at 9:15 p.m. Its most senior member assumed the role of EMS IC.

Two OHP units arrived on scene at 9:18 p.m. Rescue unit 1, consisting of four firefighters from the Davis Volunteer Fire Department (DVFD), arrived on scene at 9:19 p.m. The most senior member of rescue unit 1 assumed the role of fire IC. He told NTSB investigators that he did not set up a unified command post—per ICS protocols—because of the limited personnel on scene, and because he was needed to help direct extrication and assess the injured.

Following additional requests for aid from the Murray County dispatcher, the Southern Oklahoma Ambulance Service (SOAS) dispatched two ambulance units.⁴ While en route, the SOAS supervisor—deviating from ICS protocols—requested from Ardmore police dispatch that a medevac unit go to the crash site rather than to the pre-existing landing area (PELA).⁵ This medevac request resulted in a 21-minute delay in transporting the last injured passenger.⁶ The passenger was later determined to have sustained a minor injury. Table 2 presents a detailed timeline of the emergency communication and response.

³ NIMS is a comprehensive management program developed by the Federal Emergency Management Agency that applies at all jurisdictional levels. ICS provides a flexible, yet standardized core mechanism when incidents require additional resources or involve different organizations within a single jurisdiction. ICS may also address incidents outside the jurisdiction or complex incidents with national implications. It provides procedures for assigning the role of fire and EMS IC, as well as for establishing the unified command post.

⁴ SOAS is located in Ardmore, Oklahoma, about 18 miles from the crash site. It sent a total of three ambulance units.

⁵ The Oklahoma State Department of Health has established trauma regions throughout the state and accompanying landing areas from which patients are transported to hospitals. The PELA serving this area was located about 5 miles from the crash site. Because SOAS was an outside agency in this crash, a medevac request from the SOAS supervisor conflicted with ICS protocols.

⁶ The SOAS supervisor requested that the medevac unit be sent to the crash site, but the passenger was waiting at PELA.

Table 2. Emergency response timeline, September 26, 2014.

Time (p.m.)	Narrative of Selected Events^a
9:05	Witness calls 911 to report seeing combination vehicle leave roadway and witnessing crash
9:11	OHP notified of crash ^b
9:15	Murray County EMS unit 2 arrives on scene and senior member assumes EMS IC
9:18–9:19	First OHP units and fire IC and DVFD rescue unit 1 arrive on scene
9:27	Murray County dispatcher requests aid from surrounding counties and SOAS
9:28	SOAS supervisor requests Eagle-Med unit 35 respond to scene and requests another unit to be placed on standby
9:33	Murray County EMS unit 1 arrives on scene
9:33	Murray County EMS unit 2 departs with patient to meet Eagle-Med unit 17 at PELA and transitions EMS IC to senior member on EMS unit 1
9:39	Patient at PELA goes into cardiac arrest, requiring ground transport to Arbuckle Hospital, with Eagle-Med unit 17 crew joining EMS unit 2
9:44	SOAS unit 81 from Carter County arrives on scene and senior member assumes EMS IC position even though Murray County EMS unit 1 is still on scene
9:48	SOAS requests Air-Evac unit 26 respond to scene and land on southbound I-35
9:52	Truck driver is extricated
9:56	Murray County EMS director arrives on scene, assumes EMS IC, and sets up unified command post
9:55–10:04	Two SOAS units arrive on scene
10:07	Pauls Valley EMS units 1 and 4 arrive on scene
10:09	Murray County EMS unit 1 transports three people to Mercy Hospital in Ardmore
10:10	Air-Evac unit 26 arrives on scene (but is unable to make contact with SOAS supervisor on ground)
10:20	Eagle-Med unit 35 and Air-Evac unit 26 land on southbound I-35
10:29	Pauls Valley EMS units 1 and 4 transport four people to Pauls Valley General Hospital
10:33	Air-Evac unit 26 transports last seriously injured patient to Oklahoma University Medical Center in Oklahoma City
10:36–10:37	SOAS units 81 and 88 transport three people to Mercy Hospital
10:46	Eagle-Med unit 35 is redirected from crash site to PELA to meet SOAS unit 84
11:06	Eagle-Med unit 35 transports one person to Norman Medical Center in Norman ^c
<p>^a Items highlighted in blue indicate requests consistent with NIMS and ICS protocols. Items highlighted in gray indicate requests made outside those protocols.</p> <p>^b The Davis Police Department arrived on scene without being dispatched, before OHP was notified.</p> <p>^c This patient suffered a head wound and was initially assessed as having a serious injury. However, her injury was later deemed minor, and she was released the next morning.</p>	

Nineteen local emergency service agencies responded. Fourteen ambulance units responded, seven of which transported 11 injured bus passengers. Of four medical helicopters on scene, three transported one passenger each (one from the scene, one from PELA, and one from Pauls Valley General Hospital to a hospital in Oklahoma City).

As a result of this crash, Murray County has incorporated MCI drills into its annual training. The first annual drill with the specific MCI component occurred in November 2015 as part of a state disaster drill.

1.4 Occupant Restraints

Oklahoma has a primary enforcement seat belt use law requiring that the driver and all front seat passengers age 13 and older be restrained.^{7,8} The law has no restraint requirement for adult passengers seated behind the front seat. The Texas seat belt use law with primary enforcement requires that drivers and all passengers in passenger vehicles be restrained regardless of age and seat position. These laws do not extend to the passengers of medium-size buses or motorcoaches, even when those vehicles are equipped with passenger restraint systems. The Texas seat belt use law applies to truck-tractors, but the Oklahoma law exempts truck-tractors.

1.4.1 Truck-Tractor

The truck-tractor was equipped with a bucket air-ride driver seat with an integrated headrest manufactured by National Seating and a three-point lap/shoulder belt. Examination of the lap/shoulder belt showed wear marks consistent with seat belt use at the time of the crash. During the initial assessment, the driver told the ambulance crew that he had been restrained.

1.4.2 Medium-Size Bus

1.4.2.1 Seat Belt Use Policy. The NCTC vehicle use policy includes 19 procedures a driver is expected to follow (NCTC 2013). Each driver is required to sign a document agreeing to abide by all of the listed policies and procedures. One of these procedures (no. 5) states:

I will use a seat belt or other available occupant restraint and require all passengers to also use seat belts or occupant restraints in accordance with Texas State Law, and not operate the vehicle unless all occupants are wearing the appropriate restraints.

⁷ The Oklahoma Mandatory Child Restraint Law applies to seat belts and child safety seats, and requires that passengers 12 years old and younger be restrained regardless of seat position.

⁸ (a) Primary enforcement seat belt use laws allow enforcement officers to ticket a driver/vehicle occupant for not wearing a seat belt without the driver having committed any other traffic offense. Typically, drivers are cited for themselves and other passengers under a certain age; the maximum age varies across states. Adult occupants not wearing a seat belt are themselves cited. (b) Secondary enforcement seat belt use laws allow enforcement officers to ticket a driver/vehicle occupant for not wearing a seat belt only after stopping the vehicle for another offense.

The bus driver had signed the agreement on May 21, 2013.⁹ According to an NCTC administrator, the document signing was a one-time procedure. The college did not evaluate compliance with the policies or provide periodic refresher training to help reinforce seat belt usage.

The bus was equipped with two-point lap belts in all passenger seating positions and a three-point lap/shoulder belt in the driver position. Based on interviews with the driver and the surviving student passengers, the driver was restrained, but none of the passengers used their seat belts. The students stated that they did not receive any instructions about the lap belts on this trip or previous trips. In addition, most of the students stated that they were not aware that the passenger seats were equipped with lap belts.

1.4.2.2 Condition of Occupant Protection Systems. NTSB examination of the driver seat belt revealed a slight friction rub mark on the webbing in the area of the buckle, which is consistent with seat belt use at the time of the crash. The webbing near the latch had some slight cupping as a result of stretching.

NTSB examination of the passenger seat belts revealed their worn condition and inaccessibility. The passenger seats—manufactured by Freedman Seating Company—included a side-slide seat option for those positions adjacent to the aisle. This option enables the occupant to adjust the seat so that it transitions laterally 3 inches into the aisle. The lap belts were an aftermarket item, installed by National Bus Sales. NTSB investigators found that many of the belts were wrapped around the seat bases and were inaccessible. Other belts were trapped above and around the side-slide seat track (see figure 7, left). Further, the seat belt webbing on the aisle seats in rows 4 and 6 on the driver side was abraded and slightly torn (see figure 7, right). As a result of these findings, on July 20, 2015, the NTSB issued recommendations to the National Highway Traffic Safety Administration (NHTSA) pertaining to the effects of side-slide seats on seat belt load capacity and egress.¹⁰

⁹ As a regular driver of NCTC vehicles, the coach/bus driver voluntarily went to the administrative office and signed the policy before it went into effect.

¹⁰ The NTSB issued recommendations to NHTSA to develop requirements for minimum aisle width for safe evacuation in all buses, including those with moveable seats (Safety Recommendation H-15-10); and to determine whether the design of side-slide seats can result in seat belt entrapment (Safety Recommendation H-15-11). These recommendations are classified “Open—Await Response.”



Figure 7. Seat belt webbing pinched above side-slide seat track (left) and torn seat belt webbing on side-slide seat (right).

1.5 Vehicles

1.5.1 Truck-Tractor

1.5.1.1 General. The combination vehicle consisted of a 2013 Peterbilt truck-tractor and a 2014 Great Dane refrigerated semitrailer. The truck-tractor was equipped with a PACCAR MX-10, 485-hp diesel engine and an Eaton Fuller 13-speed manual transmission. At the time of manufacture, the truck-tractor had a gross vehicle weight rating (GVWR) of 52,000 pounds; the GVWR of the trailer was 68,000 pounds. The speed of the truck-tractor was electronically limited to 72 mph.

1.5.1.2 Damage. The truck's hood, front bumper, fenders, grille, and radiator were all displaced from the vehicle. All of the truck engine mounts were broken, and the oil pan was peeled rearward. The right and the left bumper mounts were broken. The forward portion of the left frame rail, with the attached steering gear, was bent outward to an angle of about 90 degrees (see figure 8).



Figure 8. Truck-tractor postcrash, showing extensive damage overall.

The lower rear portion of the fuel tank on the driver side was damaged, resulting in the loss of nearly all of the fuel from the tank. The exhaust stack was crushed and bent over at the level of the frame, and was found atop the frame rails just behind the cab. The suspension mounts on the right side of axle 2 were broken, allowing the right wheel end to be displaced toward the rear of the vehicle. As a result, the driveshaft separated at the slit joint.

The driver seat was intact and in place. The driver seat belt was found unbuckled, retracted, and hanging from the upper attachment point.

The front wall of the semitrailer, along with the attached refrigeration unit, was torn away at the left and right corners. This portion of the semitrailer was found in the woods near the final rest position of the combination vehicle. The roof was peeled rearward from the front of the semitrailer, about 1 foot on the left side and 6 feet on the right side (see figure 9). The fuel tank for the refrigeration unit, located just behind the landing gear area, was ruptured and crushed upward and to the rear.¹¹ At the time of the crash, the semitrailer was empty except for the racks designed to hold dairy products.

¹¹ The landing gear supports the front of the semitrailer when it is detached from the truck-tractor.



Figure 9. Semitrailer postcrash, showing damage to front end and roof.

1.5.1.3 Mechanical Systems. NTSB investigators performed functional checks of braking, suspension, and electrical systems, as well as of wheels and tires. The examination revealed no evidence of preexisting vehicle damage or defects.

During detailed external examination of the steering gear, damage to the worm gear was determined to be from a single set of ball imprints, consistent with a single impact overload event.¹² The location of the impact near the center of the worm gear indicates, more specifically, that the truck-tractor's steering would have been nearly straight with a slight right turn when the combination vehicle struck the bus.

1.5.1.4 Inspection, Maintenance, and Safety Recalls. The truck-tractor and the semitrailer had passed their most recent annual inspections on April 15 and September 1, 2014, respectively. The maintenance records for both the truck-tractor and the semitrailer documented a variety of regularly scheduled preventive maintenance and repairs. There were no recalls on the truck-tractor or the semitrailer.¹³

1.5.1.5 Event Data Recording. The engine electronic control unit (EECU) controlled engine timing and fuel injection based on various engine and sensor inputs. This module was also capable of diagnostics associated with engine or sensor faults, as well as of recording vehicle

¹² The worm gear consists of a spirally threaded shaft and a wheel with teeth that mesh into it. The collision generated a high load compression in the drag link, resulting in recirculating ball bearing marks on the worm helix near the center of the steering gear's travel range.

¹³ A search of the NHTSA safety recall database indicated two voluntary recall campaigns for the same make, model, and model year of the truck-tractor involved in this crash, but neither of these recalls applied to the accident truck-tractor. The NHTSA database listed no safety recalls for the make, model, and model year of the semitrailer. A search of the defect investigation database, also maintained by NHTSA, revealed no active or inactive defect investigations for either the truck-tractor or the semitrailer.

speed, engine speed, and other parameters during triggered events. A fault produced by the EECU, or any module interacting with the EECU, would trigger a 10-second recorded event. Parameters recorded would include speed, engine speed, and accelerator pedal position. The EECU was removed from the vehicle for further evaluation and downloaded at the Peterbilt truck facility in Dallas, Texas.¹⁴ The module recorded only an “improper shutdown” fault code; it captured no data at the time of the collision.¹⁵ The EECU has minimal crash protection. Data recording is not ensured in the event of an abrupt power loss, which is consistent with findings pertaining to similar devices from other NTSB highway investigations.

The truck-tractor was also equipped with a Bendix EC-60 advanced controller, which combined an antilock brake system (ABS) with electronic stability control (ESC). The ESC consisted of yaw control and roll stability features. When either an ABS or an ESC event is detected, the EC-60 logs a 7.5-second event at two samples per second to its internal memory; the log consists of 2.5 seconds of pretrigger data and 5 seconds of post-trigger data. A download of the EC-60 was coordinated between NTSB and Bendix personnel at the manufacturer’s facility in Elyria, Ohio. The download revealed that an ESC event was triggered about the time of the crash and was stored under the “most recent trigger” log.¹⁶ This recording was incomplete due to a power interruption and captured only four data points (a maximum of 2 seconds) from the onset of the event. Similar to the EECU, the EC-60 is not crash protected, and data recording is not ensured in the event of an abrupt power loss. Because there are no applicable crash protection regulations, neither of the recorder units was required to meet standards that could prevent this considerable data loss. The recorded data are shown in table 3. At the initial onset of the event, the vehicle speed was 62.8 mph, with the accelerator nearly fully depressed at 99.2 percent.

Table 3. Select parameters recorded by truck-tractor ABS–ESC module during stability control event.

Time (seconds)	Steering Angle (degrees)	Accelerator Position (%)	Vehicle Velocity (mph)	Engine Speed (rpm)
0.0 (start of ESC event)	99.4	99.2	62.8	1,280
0.5	64.5	99.2	61.6	1,664
1.0	0.0	86.4	64.7	1,792
1.5 (power failure)	-126.3	99.2	0.0	640

¹⁴ NTSB staff was present throughout the download and evaluation process for all recorders examined in the course of this investigation.

¹⁵ An “improper shutdown” fault code indicates a sudden loss of power to the EECU.

¹⁶ The yaw control event occurred at an engine time of 4,098.85 hours, which is consistent with the total engine operating time—an indicator of the time of the crash, as recorded by the truck-tractor EECU. The EC-60 logs four events, consisting of the “most recent trigger,” the harshest yaw control brake intervention, the harshest roll stability program brake intervention, and the last near electronic stability program event. A new event in each category overwrites the previous event.

The cruise control was found in the “ON” position, which indicates that it was powered on and ready for use. To determine how the ABS–ESC module would record the output of the “accelerator position” and its relation to the cruise control status, additional testing was performed on December 19, 2014, at the Peterbilt facility test track using a similarly equipped exemplar vehicle.¹⁷ Testing revealed that though the cruise control *may* have been actively maintaining the speed, the accelerator pedal had to have been manually depressed to produce the recorded ABS–ESC data.¹⁸

A Garmin Dezl 760LM—a handheld global positioning system (GPS) device—was found in the truck cab. It was successfully downloaded using the manufacturer’s recommended procedures. The extracted data covered the day of the crash, as well as the time surrounding the event. The device recorded date, time, latitude, longitude, and altitude parameters, while groundspeed and track were derived from recorded parameters. GPS data showed that the average velocity of the truck-tractor for the 5 minutes before the roadway departure was 71.5 mph, ranging from 65 to 74 mph. The last recorded data point before the truck-tractor crossed the median showed a velocity of 72.3 mph.

The truck-tractor was also equipped with a PeopleNet g3 E-log system, a fleet management system that records vehicle dynamics and transmits the information to a carrier. However, examination of the downloaded data revealed that the unit had not been powered on since September 2013.¹⁹

1.5.2 Medium-Size Bus

1.5.2.1 General. The 32-passenger bus had been manufactured in two stages. The first build stage was completed in June 2007 and consisted of the Chevrolet cab and chassis. Champion Bus, Inc., completed the second stage in June 2008, which involved configuring the chassis with a medium-size bus body and associated equipment. At the time of manufacture, the vehicle’s speed was electronically limited to 75 mph.

The bus was equipped with an Allison 6-speed automatic transmission and a Chevrolet Duramax 300-hp, 6.6-liter diesel engine. The vehicle had a GVWR of 26,000 pounds.

1.5.2.2 Damage. All of the large windows on the driver side of the bus were broken and displaced, and the bus driver had kicked out the windshield. The roof hatch had been removed for the egress of bus occupants. The outer body panels and insulation on the driver side of the bus were torn away, starting at row 1 and extending to the rear of the passenger seating area (see figure 10). An area of increased intrusion extended inward on the driver side of the bus, starting

¹⁷ Before the test runs, PACCAR engineers were able to verify that the “accelerator position” parameter generated by the throttle pedal was in fact the same parameter the ABS–ESC module pulled from the vehicle’s communication network.

¹⁸ When the cruise control was maintaining speed without the driver manually pressing the accelerator, the test showed the accelerator output at 0 percent.

¹⁹ Quickway leased the accident truck 6 days before the crash, and the PeopleNet unit in the truck was not covered by Quickway’s subscription.

at the end of the left rear wheel and continuing to the rear of the vehicle. The left end of the rear axle was displaced rearward about 22 inches.



Figure 10. Driver side of bus postcrash, with all main windows broken out and outer body panels missing.

As shown in figure 11, the rear cargo door frame was skewed toward the driver side of the bus. The vertical members of the door frame were leaning to the left by 17 to 22 degrees. The rear cargo area door was separated from the vehicle. All of the large windows on the passenger side of the bus were broken out except for the most forward window.



Figure 11. Rear view of bus postcrash, showing extent of frame damage.

1.5.2.3 Mechanical Systems. NTSB investigators performed functional checks of multiple vehicle systems for evidence of precrash damage and defects. The investigators examined braking, steering, suspension, and electrical systems, as well as wheels and tires. Although certain checks could not be performed due to vehicle damage, no evidence of preexisting vehicle damage or defects was found.²⁰

1.5.2.4 Safety Recalls. A search of the NHTSA safety recall database indicated six voluntary safety recall campaigns for vehicles with the same make, model, and model year of the Chevrolet cab and chassis involved in this collision.²¹ None of these recalls, however, applied to the accident bus.

1.5.2.5 Event Data Recording. The Chevrolet Duramax engine was equipped with an engine control module (ECM) that recorded diagnostics associated with engine or sensor faults.²² General Motors informed NTSB investigators that vehicle speed or engine revolutions per minute (rpm) may have been captured if one of the fault codes had been initiated at the time of the collision. Six fault codes were present in the vehicle's electronic systems, but none of them captured speed or rpm data. The ECM was not capable of recording any other typical collision-related events or preimpact parameters.

1.5.3 Crashworthiness of Medium-Size Buses

Medium-size buses (with GVWRs between 10,001 and 26,000 pounds) are required to meet very few crashworthiness standards when compared with new motorcoaches and school buses. The accident bus had a GVWR of 26,000 pounds and was required to provide occupant crash protection for the driver position only. However, Champion Bus designed the model series of the accident bus to meet multiple crashworthiness-related *Federal Motor Vehicle Safety Standards (FMVSS)* available at the time (see appendix B for *FMVSS* requirements for different types of buses). For example, the bus was equipped with lap belts at all passenger seating locations, which met regulations addressing the seating systems standard, the seat belt assemblies standard, and the anchorages standard (FMVSSs 207, 209, and 210).

1.5.3.1 School Bus Rollover Protection. Information provided by Champion Bus showed that its buses of similar design and weight class as the accident bus were tested to the school bus rollover protection standard (FMVSS 220), though this was not a requirement. This standard specifies that when a force equal to 1.5 times the unloaded vehicle weight is applied to the roof, the downward vertical intrusion must be less than 5.125 inches and the emergency exits must be functional. The accident bus series meets the requirements of FMVSS 220.

²⁰ NTSB investigators could not conduct functional checks of the rear brakes because of damage to the brake lines leading to that axle—which likely occurred during the crash.

²¹ See www-odi.nhtsa.dot.gov/owners/SearchSafetyIssues, accessed October 4, 2014.

²² Sensor faults refer to icons or lights on the dashboard indicating vehicle systems, such as air bag, hand brake, or engine.

1.5.3.2 School Bus Body Joint Strength. The documents provided by Champion Bus also showed that buses of similar design and weight class as the accident bus were tested to the school bus body joint strength standard (FMVSS 221), though this level of testing was not required. The testing for this standard consists of two parts:

- In the first stage, the tensile strength of each body panel (solid panel, not jointed) is tested to identify the weakest panel.²³
- Each body panel *joint* is then tested for the capacity to hold the body panels when subjected to a force equal to 60 percent of the tensile strength of the *weakest* panel, as determined in the first stage of testing.²⁴

FMVSS 221 does not specify the minimum tensile strength of an individual body panel (not jointed); however, the standard is based on the assumption that body panels are of corrugated steel, the traditional school bus construction. School bus body panels are typically joined with rivets, whereas the Champion bus series body panels are joined with screws or adhesives.

Based on the test results, one of the weakest areas of the bus was the juncture between the sides and the lower roof (no. 4 in figure 12). The strength of this area was less than 10 percent of the strength of the weakest body panel. The accident bus had joint failures in the area between the side and the lower roof; additionally, there was separation between the side panel and the lower roof panel (see figure 13, on which a broken joint and displaced panel are circled). The accident bus series does not meet the school bus joint strength standard.

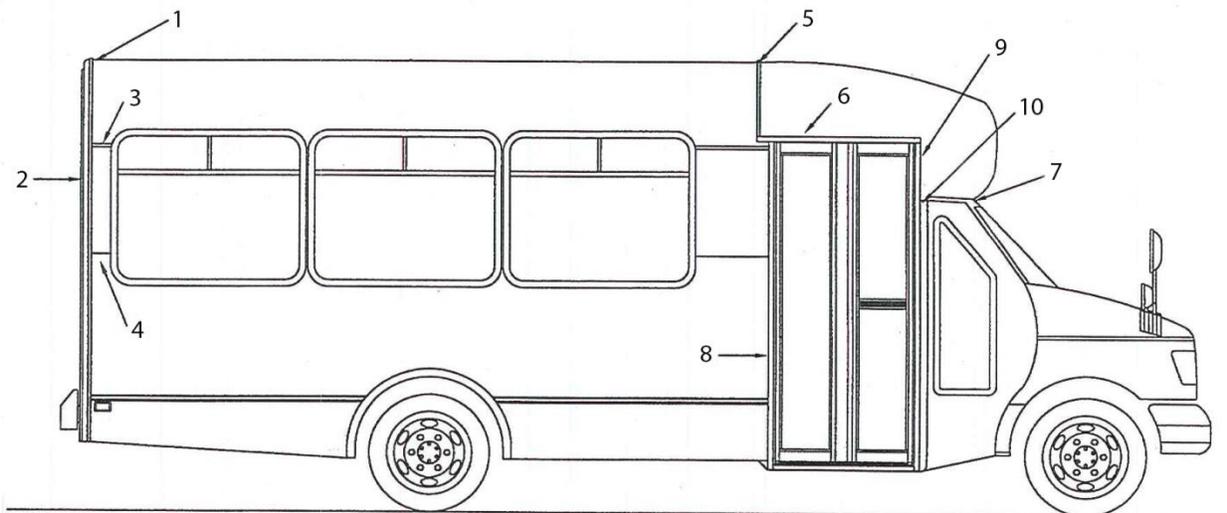


Figure 12. Locations of 10 test samples taken from Champion bus body at selected joints. (Source: Progressive Engineering, Inc.)

²³ (a) Tensile strength is the maximum amount of tensile force (by pulling in opposite directions) that a material can withstand before breaking or tearing. (b) Body panel refers to a body component (made from a single piece of material) used on the exterior or interior surface to enclose the occupant space of the bus.

²⁴ Body panel joint refers to the area of contact between the edges of a body panel and another body component.



Figure 13. Damage to sidewall support structures on driver side of bus, with yellow circle highlighting broken joint and red circle highlighting panel tearing. (Source: Oklahoma Highway Patrol)

1.6 Driver Factors

1.6.1 Truck Driver

1.6.1.1 Licensing, History, and Training. The 53-year-old Quickway truck driver possessed a Texas class A commercial driver's license (CDL) with "T" and "N" endorsements and no restrictions.²⁵ The CDL was issued on August 6, 2014, and expired on August 31, 2019. The truck driver's motor vehicle record did not list any violations or crashes. He had obtained his first CDL in May 2009 and held various commercial driver positions before joining Quickway on December 30, 2013.

According to Quickway, the truck driver completed initial training on January 5, 2014, which included classroom training and 3 days of on-the-road training. He had also attended three recurrent training sessions.

²⁵ A "T" endorsement allows the operation of double- or triple-trailers, and an "N" endorsement allows the operation of tanker vehicles.

1.6.1.2 Medical Certification, Health, and Toxicology

- **Medical certification:** The driver qualification file showed that the truck driver had a current medical certificate issued in December 2013, with an expiration date of December 2015. According to his last CDL medical examination, he was 5 feet 10 inches tall and weighed 211 pounds, with a corresponding body mass index (BMI) of 30.3. He passed visual and perceptual tests with a visual acuity of 20/20 in both eyes.²⁶ He did not report any illnesses, medical conditions, or the current use of any medications (prescription or over-the-counter). The medical examiner identified no medical issues. However, the NTSB investigation uncovered discrepancies between the self-reported medical certification form and the truck driver's personal medical records.
- **Medical records:** A review of the truck driver's personal medical records identified the following chronic conditions: hypercholesterolemia, chronic gastritis, migraine headaches, attention deficit disorder, and recurrent major depressive disorder. Following the crash, five prescription and seven over-the-counter medications were found in a bag in the truck cab.²⁷ The prescription medications included the following:
 - Trazodone: prescribed for major depressive disorder; carries a warning to users not to engage in dangerous activities until they learn how the drug affects them.²⁸
 - Sertraline: prescribed for major depressive disorder; carries a warning to users to use caution when driving a car or operating machinery until they learn how the drug affects them.²⁹
 - Simvastatin: prescribed for cholesterol; side effects may include headache or nausea.
 - Omeprazole: prescribed for chronic gastritis; side effects may include nausea.
 - Prednisolone eye drops: prescribed for inflammation of the eye.

The truck driver had been on the same doses of trazodone and sertraline, prescribed for major depressive disorder, for over 10 years. According to his primary care

²⁶ The horizontal field of vision was recorded as 85 degrees for both the right and left eyes. The examination noted that the driver could distinguish red, green, and amber colors.

²⁷ Each of the prescription medications was in the driver's name. The over-the-counter medications found in the truck cab were naproxen sodium, acetaminophen, oxymetazoline, fluticasone, Anbesol, Nexium, and Orajel. These over-the-counter medications are not typically associated with side effects that would impair driving.

²⁸ Common side effects of trazodone may include drowsiness, dizziness, or vision changes. According to the driver's primary care physician, the driver was not experiencing these symptoms. The driver was prescribed trazodone for major depressive disorder, with directions to take the medicine before bedtime.

²⁹ Common side effects of sertraline may include drowsiness, dizziness, or tiredness. According to the driver's primary care physician, the driver was not experiencing these symptoms.

physician—who prescribed all of the medications and was aware that her patient was a commercial motor vehicle (CMV) driver—the driver was complying with his treatment regimen, his condition was stable, and he was not experiencing any side effects.³⁰

- **History of illicit drug consumption:** Records from the truck driver’s licensed professional counselor showed that he visited the counselor six times between August and November 2013. The records indicate that he was using synthetic drugs, and he reported to the counselor that he had been using them while at work.³¹

Records from the truck driver’s primary care physician show that in August 2013, his wife had called the office, indicating that her husband had been smoking “K2”—a synthetic cannabinoid (SC)—and having “seizure-like” behavior when consuming the substance.³² The medical records contained no further information about this phone call.

Three days after the crash, a supervisor with the truck driver’s previous employer contacted NTSB investigators. He reported that he had observed signs of declining work performance, including missing work, lethargy, and forgetfulness. He stated that when he approached the driver to talk about these issues, he admitted using K2 and stated that the substance was legal and would not appear on drug tests. The supervisor reported his findings to the terminal manager. The manager, who had reasonable suspicion training, talked to the driver on two occasions but found no signs of impairment.³³ Appendix C presents additional information on the actions of this carrier.

- **Toxicology:** The truck driver underwent three drug tests during his employment at Quickway: a preemployment test on December 10, 2013; a postcrash test on February 12, 2014;³⁴ and a random test on April 14, 2014. All three tests screened for amphetamines, marijuana, phencyclidine (PCP), cocaine, and opiates. The postcrash test also screened for benzodiazepines, methaqualone, barbiturates, methadone, and propoxyphene. Each test produced negative results.

³⁰ Trazodone and sertraline can potentially interact, creating serotonin syndrome—which typically is exhibited in symptoms ranging from shivering to muscle rigidity, fever, and seizures. This condition occurs within the first day of beginning or changing the medication regimen. The driver, who was on the same dosage of these medications for 10 years, was not experiencing symptoms associated with serotonin syndrome.

³¹ Synthetic drugs typically affect the same brain receptors as known substances such as methamphetamine, marijuana, or cocaine, but have altered chemical structure and can have considerably more potent side effects. Examples of synthetic drugs are bath salts (which mimic the effects of methamphetamine or cocaine) and synthetic cannabinoids ([SC], which mimic the effects of marijuana).

³² Section 2.3.1 provides additional information on SCs.

³³ Title 49 *CFR* 382.603 governs the training for reasonable suspicion. See section 2.3.3.4 for additional discussion.

³⁴ The postcrash drug test was a nonregulated drug test administered after a minor loading accident at the Quickway terminal yard.

At the request of OHP, a blood sample was drawn from the truck driver at 11:50 p.m. on September 26—about 2 hours 45 minutes postcrash. The Oklahoma State Bureau of Investigation (OSBI) Forensic Science Center performed toxicological testing of that sample. The OSBI analysis was negative for the 12 drugs/drug classes it considers and also negative for alcohol and 15 SCs.³⁵ These analyses did, however, detect the presence of trazodone and sertraline.

OHP recovered a pipe during its search of the truck cab postcrash.^{36,37} The pipe contained a burnt residue and was sent to OSBI for analysis. Testing identified the residue as 5-fluoro-AMB—an SC, but not one of the 15 SCs for which OSBI tested initially.³⁸ OSBI conducted additional screening for 5-fluoro-AMB but did not identify its presence in the truck driver's blood sample.

The Federal Aviation Administration Bioaeronautical Sciences Research Laboratory at the Civil Aerospace Medical Institute also performed toxicological testing of the truck driver's blood sample. This analysis was positive for sertraline and trazodone. The laboratory lacks the capability to identify SCs.³⁹

NTSB investigators requested that the clinical toxicology and environmental biomonitoring laboratory at the University of California, San Francisco, conduct additional screening because of its extensive experience testing new compounds. This test detected a peak that could correlate with 5-fluoro-AMB, but because the signal-to-noise ratio and other confirmatory factors were outside acceptable parameters, it was unable to confirm either the presence or absence of 5-fluoro-AMB in the truck driver's blood sample.⁴⁰

1.6.1.3 Precrash Activities. In a written statement to the police, the truck driver indicated that he was reaching for a cooler to get a soft drink when he felt the truck drift into the median. His

³⁵ (a) Toxicological testing included barbiturates, benzodiazepines, cannabinoids, oxycodone/oxymorphone, cocaine/benzoylcegonine, phenethylamines, phencyclidine, carisoprodol, methadone, tramadol, opiates, and zolpidem. (b) OSBI tested for the following SCs as part of the initial postcrash drug screening: AM-2201, JWH-081, JWH-018, JWH-073, JWH-250, MAM-2201, UR-144, XLR-11, AB-fubinaca, AB-pinaca, PB-22, AB-chminaca, ADB-pinaca, MAB-chminaca, and FUB-PB-22.

³⁶ The dimensions, material, and shape of the pipe were consistent with a pipe typically used to smoke marijuana, not tobacco.

³⁷ The OSBI report on deoxyribonucleic acid (DNA) testing of the mouthpiece of the pipe stated that the DNA profile obtained was a "partial profile" and that the truck driver could not be excluded as a potential donor. The probability that this DNA sample did *not* belong to the truck driver was 1 in 38.

³⁸ The formal name of 5-fluoro-AMB is (S)-methyl 2-(1-(5-fluoropentyl)-1H-indazole-3-carboxamido)-3-methylbutanoate.

³⁹ The Civil Aerospace Medical Institute tested the truck driver's blood sample twice; each analysis was positive for sertraline and trazodone. The second test was done at the request of NTSB staff following discrepancies among test results from this laboratory, OSBI, and the University of California laboratory. The human performance reports in the NTSB public docket for this investigation provide additional information on these tests.

⁴⁰ The test was conducted using an LC-quadrupole time-of-flight mass spectrometer (Agilent LC 1260-QTOF655). The human performance factual report in the NTSB public docket for this investigation provides additional information on this test.

statement did not include recollection of any evasive maneuvers he might have taken or even the impact with the bus. He only recalled hitting the trees. The driver's attorneys later informed NTSB investigators that he was undergoing psychological treatment and could not be interviewed. Using information from the driver's logbook, cell phone records, his police statement, and the police report, NTSB investigators reconstructed the driver's activities and opportunities for rest in the days preceding the crash (see table 4). Based on the obtained information, the driver had more than 19 hours available for rest the night before the crash.

Table 4. Precrash activities of truck driver, September 24–26, 2014.

Wednesday, September 24		
Time	Description	Source
12:00 a.m.	Begins day in driving status, 2.1 miles SW of Hall Park, Oklahoma	Logbook
4:09	Logs on duty, not driving, 0.4 mile SE of Fort Worth, Texas	Logbook
4:25	Logs off duty, 0.4 mile SE of Fort Worth	Logbook
8:07	Receives incoming call (goes to voicemail)	Cell phone records
2:14 p.m.	Answers incoming call (only voice activity of day)	Cell phone records
Thursday, September 25		
Time	Description	Source
all day	Off duty	Logbook
8:32 a.m.	Makes outgoing call (first voice activity of day)	Cell phone records
2:30 p.m.	Answers incoming call (last voice activity of day)	Cell phone records
Friday, September 26		
Time	Description	Source
10:23 a.m.	Makes outgoing call (first voice activity of day)	Cell phone records
3:00 p.m.	Reports to work at Fort Worth terminal	Logbook
3:30	Departs terminal for South Star in Irving, Texas	Logbook
4:15	Arrives at South Star and drops trailer	Logbook
4:30	Departs South Star for Hiland Dairy in Irving	Logbook
5:15	Arrives at Hiland Dairy, picks up trailer	Statement
7:30	Departs Hiland Dairy for Chandler, Oklahoma	Statement
8:06	Answers incoming call (last voice activity prior to crash)	Cell phone records
9:05 p.m.	Crash occurs	Police report

1.6.2 Bus Driver

The bus driver (who was also the NCTC softball coach) was a 48-year-old male with a current Texas class B CDL issued in January 2014, with a “P” endorsement.⁴¹ The driver’s CDL was identified as “excepted interstate.” Per federal regulations, he was exempt from the requirements for medical certification. According to the driver, he did not attend a bus driving school or receive any formal training to obtain his CDL.

When interviewed by NTSB investigators, the bus driver confirmed diagnoses of asthma, hypertension, and high cholesterol—which were treated and controlled with medication. He was 5 feet 10 inches tall and weighed 240 pounds, with a corresponding BMI of 34.4. The driver stated that he did not have vision problems and was not wearing glasses or contacts.

Based on the interview with the bus driver and review of his cell phone records, he obtained 8–8.5 hours of sleep on each of the three nights preceding the crash, September 23–25. Table 5 shows the driver’s activities on the day of the crash.

Table 5. Activities of bus driver on day of crash, September 26, 2014.

Friday, September 26		
Time	Description	Source
~6:30 a.m.	Awakes	Interview
7:59	Makes outgoing call (first voice activity of day)	Cell phone records
unknown	Arrives at college in Gainesville, Texas	Interview
9:30	Departs Gainesville with team for Bethany, Oklahoma	Interview
~12:30 p.m.	Arrives in Bethany for softball games	Interview
~2:00	<i>Double-header softball games begin</i>	Interview
~6:15	Departs for Gainesville	Interview
7:53	Receives incoming text message (last text prior to crash)	Cell phone records
unknown	Stops for dinner in Norman, Oklahoma ^a	Interview
unknown	Departs Norman for Gainesville	Interview
8:48	Makes outgoing call (last voice activity prior to crash)	Cell phone records
8:55	Call ends	Cell phone records
9:05 p.m.	Crash occurs	Police report
^a Norman is located 60 miles north of Davis, Oklahoma.		

⁴¹ A “P” endorsement allows a driver to operate vehicles with a seating capacity of 16 or more passengers.

Following the crash, OHP collected a blood sample from the bus driver. Toxicological testing was performed by OSBI; the analysis was negative for the 12 drugs/drug classes it considers. The specific drug confirmation analysis was also negative for alcohol and SCs.

The bus driver told NTSB investigators that he was not using his cell phone around the time of the crash, though he had used it earlier in the trip. Cell phone data records show that the driver made an outgoing call at 8:48 p.m., which lasted until 8:55 p.m., about 10 minutes before the crash. NCTC policy prohibits drivers from using their cell phones while driving. Usage records from the driver's cell service provider show data activity beginning at 8:59 p.m. and lasting for 3 minutes 5 seconds, ending about 3 minutes before the crash.⁴²

The bus driver stated that at the time of the crash, he was in the right lane of travel, moving at an estimated speed of 65 mph. He reported seeing the lights of the truck-tractor and described them as bouncing, but appearing far away and still in the truck's lane of travel. The driver next described the lights as "almost coming over a hill" and heading toward the bus, at which point he veered to the right in an attempt to avoid being struck by the truck-tractor.

1.7 Motor Carrier Operations

Quickway Transportation Inc. began operating in 1998 and is registered as a for-hire motor carrier, domiciled in Nashville, Tennessee. Quickway operates with 337 truck-tractors and 509 drivers, and has 14 terminals located throughout the eastern half of the United States.⁴³ The truck driver involved in this crash was assigned to the Fort Worth, Texas, terminal.

The Fort Worth terminal houses 50 truck-tractors and 65 semitrailers, employs 46 drivers, and operates 24 hours a day. About 95 percent of the drivers are classified as day drivers and operate up to 12 hours a day. The carrier runs a "slip-seat" operation, wherein almost all drivers conduct daily routes and return to the terminal at the end of each shift.⁴⁴

1.7.1 Carrier Training Program

Quickway provides three types of training: initial training for newly hired drivers, which lasts 1 week; recurrent training, provided on a quarterly basis, consisting of classroom presentations and individual driving sessions; and remedial training for drivers whose performance is unsatisfactory.

The Quickway fleet is equipped with the PeopleNet E-log system, which automatically tracks hours of service and prevents data tampering.⁴⁵ Additionally, the system is capable of

⁴² Investigators could not conclusively determine whether this activity was due to the driver's active use of the phone or to background services that the phone performs independently.

⁴³ According to the Federal Motor Carrier Safety Administration (FMCSA) Safety Fitness and Electronic Records data, Quickway is assigned US Department of Transportation (USDOT) number 757161 and motor carrier (MC) number 341699.

⁴⁴ "Slip-seat" refers to CMVs that are operated by more than one driver.

⁴⁵ Quickway's regular fleet is equipped with PeopleNet systems, but the carrier occasionally leases a limited number of trucks depending on business demands.

tracking hard braking (triggered by a 9-mph deceleration in 1 second) and stability control events, and transmitting that information to the carrier. The carrier includes these events in a weekly safety score; drivers who do not meet a minimum safety standard are considered for disciplinary action. The truck driver had eight hard braking events on file; however, they had each occurred in the carrier yard during loading/unloading.

1.7.2 FMCSA Compliance

1.7.2.1 Motor Carrier Management Information System. Quickway had two compliance reviews by the Federal Motor Carrier Safety Administration (FMCSA), in April 2005 and September 2010. Both reviews resulted in a “satisfactory” safety rating. Although on eight occasions in 2013, Quickway had exceeded the crash indicator score of the behavior analysis and safety improvement categories (BASIC), at the time of the crash, the carrier had no BASIC alerts.⁴⁶

According to the FMCSA Motor Carrier Management Information System (MCMIS) profile, Quickway was subject to 163 driver and 90 vehicle roadside inspections between September 28, 2013, and September 27, 2014. The driver out-of-service (OOS) rate was 0.6 percent, and the vehicle OOS rate was 8.9 percent⁴⁷—which are below the national OOS rates of 4.9 percent for driver and 20.0 percent for vehicle. The accident driver had one roadside inspection, on August 2, 2014, resulting in two OOS violations for the trailer, but no violations for the driver or the truck-tractor. At the time of this crash, the MCMIS carrier profile indicated that Quickway had 15 recordable accidents in 2014.⁴⁸

1.7.2.2 Drug Testing Policies and Regulations. All Quickway management personnel underwent reasonable suspicion training, which teaches methods for detecting impairment through visual observation. Reasonable suspicion is used as a basis to compel a driver to take a drug and alcohol test.⁴⁹ In the previous calendar year, Quickway conducted no reasonable suspicion tests.

Quickway reported having no knowledge of the concerns of the previous employer regarding the truck driver’s use of synthetic drugs. At no point during his employment at Quickway was the truck driver suspected of using any impairing substances.

⁴⁶ At the time of the crash, the carrier’s BASIC scores were as follows: unsafe driving (13.6 percent), hours of service (23.4 percent), driver fitness (0 percent), controlled substances (0 percent), vehicle maintenance (12.4 percent), and crash indicator (59.5 percent)—each of which was within acceptable limits as set by the FMCSA. The thresholds for FMCSA intervention are 65 percent for unsafe driving and hours-of-service compliance; and 80 percent for driver fitness, controlled substances and alcohol, and vehicle maintenance.

⁴⁷ The Commercial Vehicle Safety Alliance establishes OOS criteria (CVSA 2015). A finding of an OOS condition by a qualified inspector precludes further operation by the driver or of the vehicle, as appropriate, until the condition is corrected.

⁴⁸ As defined in 49 *CFR* 390.5, a recordable accident is one involving a CMV operating on a public road in interstate or intrastate commerce that results in a fatality; bodily injury to a person who, as a result of the injury, immediately receives medical treatment away from the scene of the accident; or one or more motor vehicles incurring disabling damage as a result of the accident, requiring them to be transported from the scene by a tow truck or other motor vehicle.

⁴⁹ For additional information on reasonable suspicion training and testing, see section 2.3.3.4.

1.7.3 Postcrash Review

The FMCSA initiated a postcrash compliance review—which identified 10 violations, two of which were enforceable: one for the carrier and one for the driver.⁵⁰ The FMCSA determined that the carrier had 33 recordable accidents during the past 12 months, which is below the allowed threshold, resulting in a “satisfactory” accident rate factor.

OHP also conducted a postcrash roadside inspection, which resulted in the following citation for the truck driver under 49 *CFR* 392.4(a): “Driver in possession of narcotic substance, marijuana smoking pipe containing marijuana, residue found in cab of CMV.”⁵¹ Under FMCSA regulations, this citation is both an OOS violation and an “acute” violation.⁵²

1.8 Highway Factors

1.8.1 Description and Characteristics

This crash occurred in the southbound lanes of I-35 in the vicinity of milepost 47, near Davis, Oklahoma. Both the southbound and the northbound roadways at this location consisted of two 12-foot-wide lanes. The left shoulders in both directions of travel were paved and 4 feet wide, while the right shoulders were paved and 13 feet wide on the southbound lanes and 10 feet wide on the northbound lanes. Five-inch solid lines, yellow and white, respectively, delineated the left and the right shoulders from the travel lanes. The left shoulders also included rumble strips, in addition to the right shoulder on the northbound side only.

The median width at the crash site was measured to be 92 feet from the northbound edge of pavement to the southbound edge of pavement, or 100 feet measured from one solid yellow edge line (edge of traveled way) to another. The median was slightly depressed. Its lowest point was about 6 feet lower than the elevation of the southbound lanes and 3–4 feet lower than the elevation of the northbound lanes. The median contained no type of barrier, natural or manufactured.

1.8.1.1 Highway Geometry. In the vicinity of the crash site, the horizontal alignment curved to the right in the truck’s direction (northbound) of travel.⁵³ The horizontal curve terminated just before the location at which the truck-tractor departed the travel lane.

⁵⁰ The postcrash review was a “focused” review and, as such, per FMCSA regulations, did not result in the issuance of a safety rating. The FMCSA issued a notice of claim to the carrier for “one (1) violation of §382.303(b) - Failing to conduct post-accident testing on driver for controlled substances” and to the driver for “one (1) violation of §390.35 - Making, or causing to make fraudulent or intentionally false statements, fraudulent or intentionally false entries on records, and/or reproducing records for fraudulent purposes.”

⁵¹ As noted previously, the pipe did not contain marijuana but 5-fluoro-AMB, an SC.

⁵² As defined in 49 *CFR* Part 385, appendix B, acute regulations are those where noncompliance is so severe as to require immediate corrective actions by a motor carrier regardless of its overall safety posture.

⁵³ The horizontal alignment consisted of a 0 degree 20-minute curve (17,188.73-foot radius) to the right in the vicinity of the US 77 interchange.

1.8.1.2 Traffic Volume and Speed. The speed limit on I-35 in the vicinity of the crash site is 70 mph, with a minimum of 40 mph. A speed survey conducted by the Oklahoma Department of Transportation (ODOT) in Murray County in July 2007 showed that the 85th percentile speed of vehicles traveling in the southbound and northbound lanes was 75.5 and 76.5 mph, respectively.⁵⁴ In 2013, the average daily traffic count on I-35 in Murray County was 26,300 vehicles.

1.8.1.3 Truck-Tractor Roadway Departure. Evidence at the crash site indicated that the truck-tractor departed the left lane at a 1.9 degree angle, traversed 1,121 feet from the edge of the northbound lanes across the median, and entered the edge of the southbound lanes at an angle of 8.9 degrees. Figure 14 shows the tire marks from the combination vehicle.



Figure 14. Tire marks alongside I-35 northbound, showing path followed by truck-tractor as it crossed 100-foot-wide median and entered southbound lanes.

1.8.2 Median Barriers

The American Association of State Highway and Transportation Officials *Roadside Design Guide* (RDG) is the primary national roadside design guidance (AASHTO 2011).⁵⁵ Based on a combination of factors, such as traffic volume and median width, the RDG is typically used by state departments of transportation to determine the need for median barriers (see figure 15).⁵⁶ For locations with median widths greater than 50 feet, such as the crash site, the RDG does not recommend a barrier except in special circumstances, such as at a location with a significant

⁵⁴ The 85th percentile speed refers to the speed at or below which 85 percent of vehicles are traveling.

⁵⁵ The RDG is a synthesis of current information and operating practices on roadside safety. It focuses on safety treatments that can minimize the likelihood of serious injuries and provides guidance on the use of roadside barriers.

⁵⁶ Median barriers are longitudinal roadside obstructions designed to redirect vehicles that may strike either side of the barrier. Their purpose is to prevent vehicles departing the travel lanes from crossing the median, entering traffic traveling in the opposite direction, or striking a fixed object or terrain feature that is less forgiving than the barrier itself.

history of median crossover crashes or high heavy vehicle volume. However, the RDG does not formally define these factors or the thresholds beyond which a median barrier should be considered.

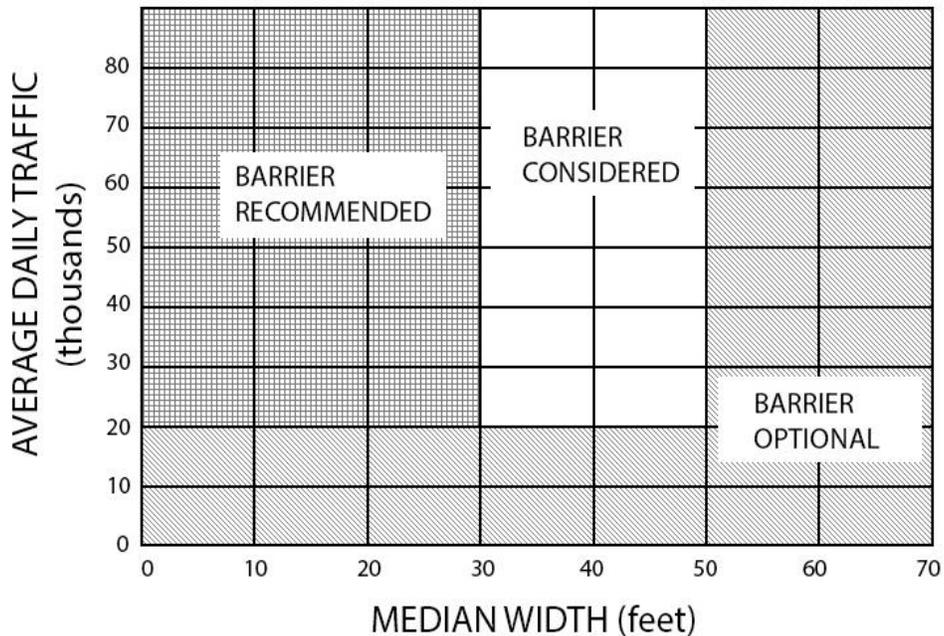


Figure 15. Guidelines for determining whether to install median barriers on high-speed, fully controlled-access roadways (adapted from AASHTO 2011, figure 6.1.)

1.8.3 ODOT Median Cable Barrier Guidelines

Nine median crossover crashes occurred on I-35 in Murray County between 2007 and 2013, four of which were located within 0.5 mile of the Davis crash site (see table 6). In four of the nine crashes, a heavy vehicle departed the roadway and crossed the median.

Table 6. Median crossover crashes on I-35 in Murray County, January 1, 2007–December 31, 2013.

Date	Fatalities	Injuries	Property Damage	Milepost	Type of Collision
06-26-2007	0	1	0	50.10	Head-on
12-21-2009	0	0	1	51.80	Rollover
12-24-2009	0	0	1	47.18	Angle–other
06-13-2011	0	0	1	50.30	Rear-end
12-13-2011	0	0	1	47.03	Angle–other
03-07-2012	0	1	0	55.72	Rollover
12-13-2012	0	1	0	47.39	Rollover
07-28-2013	0	0	1	47.02	Angle–turning
11-16-2013	0	0	1	50.80	Fixed object bridge rail

The ODOT *Roadway Design Manual* had warrants for the installation of concrete, W-beam, and Thrie-beam median barriers (ODOT 1992, 11.6[1]–11.6[2]).^{57, 58} At the time of the crash, ODOT was developing a guideline for the installation of cable barriers. The guideline was completed on October 28, 2014.

The new cable barrier guideline includes two stages of requirements (see appendix D):

- The first stage consists of seven requirements, each of which should be met before considering a cable barrier at a particular location.
- The second stage consists of four guidelines. If a particular highway segment meets any one of these four guidelines, as well as *all* of the first-stage requirements—it should be considered a candidate for the installation of a cable barrier.

One of these four guidelines (no. 2) examines crash history and annual average daily traffic (AADT):

The entirety of any portion of a highway, not less than one mile, with substantially similar characteristics of traffic flow, speed, median width, access

⁵⁷ Warrants identify specific metrics—such as accident rate, average daily traffic, and percentage of heavy vehicle traffic—which, if exceeded, indicate the need for a median barrier. The RDG defines a warrant as “the criteria by which the need for safety treatment or improvement can be determined.”

⁵⁸ (a) A W-beam is a steel beam rail element shaped in the form of a “W.” (b) A Thrie-beam is a steel beam rail element shaped in the form of a “W” but including an additional undulation.

density, terrain, and geometrics, within which 0.23 or more crossovers per mile have occurred within a five year period, and having an average AADT of 10,500 or greater.

1.9 Weather and Visibility

Historical data from the weather station at the municipal airport in Ardmore, Oklahoma, about 10 miles southeast of the crash site, indicated that—on September 26, 2014, at 8:55 p.m.—the temperature was 69.8°F, with a visibility of 10 miles and wind direction to the east at 5.8 mph, with clear weather conditions. According to the US Naval Observatory, on September 26, 2014, in Davis, civil twilight ended at 7:45 p.m. and moonset was at 8:48 p.m.

2 Analysis

2.1 Introduction

This crash involved two vehicles. A truck-tractor was traveling north on I-35 in Davis, Oklahoma, when it crossed the median and entered the southbound traffic lanes, striking a medium-size bus. Four bus passengers died, who were among 15 members of the NCTC women's softball team returning to campus from a game in Bethany, Oklahoma. The remaining 11 passengers and both drivers were injured.

This analysis discusses possible reasons why the truck driver departed the northbound lanes of I-35, crossed the median, entered the southbound lanes, and struck the bus (see sections 2.2 and 2.3). In addition, the following safety issues are reviewed:

- Truck driver's drug use (section 2.3)
- Passenger restraint systems (section 2.4)
- Crashworthiness of medium-size buses (section 2.5)
- Vehicle data recording (section 2.6)
- Median barriers (section 2.7).

As a result of its investigation, the NTSB determined that the following factors did *not* contribute to the cause of the crash:

- ***Driver licensing and experience:*** Both the truck driver and the bus driver held current CDLs with appropriate endorsements and had several years of driving experience.
- ***Bus driver distraction, fatigue, substance impairment, and medical conditions:*** Although—about 10 minutes before the crash—the bus driver engaged in a cell phone conversation, in violation of NCTC policy, this distraction was not a factor in the crash. Further, there were no witness statements indicating that the driver was engaged in any other activity that might have distracted him. The NTSB investigation found no evidence of fatigue, impairment, or medical issues with the bus driver. Additionally, postcrash toxicology tests confirmed that the bus driver did not use alcohol or drugs (prescription or otherwise) before the crash.
- ***Motor carrier operations:*** All available FMCSA and state motor carrier oversight data indicated that Quickway was rated as a “satisfactory” carrier, the OOS numbers for both driver and vehicle inspections were below the national average, and Quickway had appropriate procedures for training and monitoring driver performance, as well as for maintaining its vehicles.

- **Vehicles:** NTSB investigators examined the accident truck-tractor, the semitrailer, and the bus and found no preexisting mechanical conditions that could have contributed to the circumstances of the crash.
- **Traffic hazards:** Just prior to the median crossover, the truck-tractor did not interact with other moving vehicles in the northbound lanes or encounter extraneous hazards (such as debris) that could have caused it to depart the roadway.
- **Weather:** The weather was clear, there was no precipitation at the time of the crash, and the road surface was dry. The crash occurred under nighttime conditions when the moon was below the horizon.

The NTSB, therefore, concludes that none of the following were primary or contributory factors in the crash: (1) truck or bus driver licensing and driving experience; (2) bus driver distraction due to cell phone use, fatigue, substance abuse, or medical conditions; (3) motor carrier operations; (4) mechanical condition of either vehicle; (5) traffic hazards; or (6) weather conditions.

The EMS provided by first responders was efficient and appropriate. However, the communication among EMS personnel was characterized by some deviations in NIMS and ICS protocols. These deviations resulted in delayed establishment of the unified command post and transportation of one passenger, but they did not exacerbate the injuries of the occupants of the truck-tractor or the bus. Thus, the NTSB concludes that though the emergency response deviated from NIMS and ICS protocols in some instances, and there was a delay in the transportation of one injured passenger, these circumstances did not affect the extent of injuries to the occupants of either vehicle.

2.2 Roadway Departure

The crash sequence analysis indicates that the truck driver departed the roadway at the end of a right curve, at a 1.9 degree angle; crossed the rumble strips; traversed the median for 1,121 feet in a relatively straight line affected only by terrain changes; entered the oncoming lanes of traffic at an 8.9 degree angle; and struck the bus.

Because the truck-tractor EECU was damaged during the crash and the bus ECM was not capable of recording data, NTSB investigators were unable to determine the precise speed of either vehicle at impact. However, based on data from the truck-tractor ABS-ESC module, which showed a travel speed of 62.8 mph following impact with the bus, NTSB investigators determined that the combination vehicle was traveling 63–72 mph at the time of the collision. Based on truck-tractor GPS data, the combination vehicle was traveling about 72 mph moments before departing the roadway.

In a written statement to police, the truck driver indicated that he was reaching for a cooler to get a soft drink when he felt the truck drift into the median. Although it is possible that reaching for an object could cause a loss of control and lane departure, it is reasonable to expect the driver to have attempted to regain control of the truck-tractor during the more than

10 seconds it was traveling through the median.⁵⁹ Instead, there is no evidence that the driver attempted to steer back to the roadway or to apply the brakes. In fact, the steering was nearly perfectly straight at the time of the collision. Moreover, the NTSB investigation indicated that the accelerator was fully depressed for almost 2 seconds following the collision. The NTSB concludes that the truck driver's claim that he was reaching for a soft drink cannot account for his lack of corrective action following the roadway departure.

NTSB investigators examined whether such loss of control and lack of corrective action could be due to fatigue. The crash occurred about 9:00 p.m.—a time that is not associated with a circadian low. The truck driver had more than 19 hours available for rest the night before the crash, which occurred at the start of the seventh hour of his work shift (which had begun at 3:00 p.m.). Although he was on two prescription medications that could have affected his alertness, he had been on the same dosages for 10 years. The truck driver's primary care physician stated that those medications are not likely to have affected his alertness.

Although the angle of departure from the roadway is consistent with a fatigued or distracted driver, the progression through the rough, uneven terrain of the median without any corrective action and the full throttle following impact with the bus are not indicative of a fatigued driver.

The NTSB concludes that the lack of any type of evasive steering or braking by the truck driver while traveling across the median for more than 10 seconds—and the full throttle following impact with the medium-size bus—are inconsistent with a fatigue-related crash.

2.3 Truck Driver Drug Use

2.3.1 Synthetic Cannabinoids

Following the crash, a pipe containing 5-fluoro-AMB was recovered from the cab of the truck-tractor. This SC is one of a large family of compounds that are functionally similar to delta-9-tetrahydrocannabinol (THC), the main active ingredient of marijuana, in that they bind to cannabinoid receptors in the brain. Originally developed as potential pharmaceutical agents, SCs are now marketed as ostensibly legal alternatives to cannabis. SCs are typically developed in liquid form and then applied to a base plant material and smoked. They are sold in convenience stores, in stores that sell drug paraphernalia, or online—and are typically known as “spice” or “K2,” among many other names. They are commonly labeled as herbal incense or potpourri, with warnings that they are “not for human consumption.”

Although SCs target the same brain receptors as THC, their effects can be considerably more adverse. Research examining the pharmacological effects of SCs associated these substances with a number of psychoactive and physical effects, including psychosis, seizures, anxiety, sedation, and drug dependence (Seely and others 2012). Chronic use may be associated with auditory and visual hallucinations, paranoid delusions, attention impairment, seizures, suicidal ideation, and nonresponsiveness (Spaderna and others 2013).

⁵⁹ At the estimated speed of the truck-tractor, it would take 10.5 seconds to travel 1,121 feet.

Musshoff and others (2014) reviewed a series of cases involving drivers who were driving under the influence of SCs. In each of the examined cases, the drivers exhibited impaired behavior, including disorientation, dizziness, and unconsciousness. Yeakel and Logan (2013) examined the toxicological results of drivers who had been arrested for suspicion of driving under the influence of drugs following standardized field sobriety tests conducted by drug recognition experts (DRE). They noted that in all 12 cases studied, the subjects tested positive for at least one SC but no other performance-impairing drugs. In all cases, the officers classified the observed driver impairment as in the “cannabis” category.⁶⁰

The truck driver’s blood—which was collected approximately 2.75 hours after the crash—was tested for 5-fluoro-AMB, but neither its presence nor absence could be confirmed. Because the elimination rate of 5-fluoro-AMB is unknown, it is likely that this testing procedure could not have detected the substance nearly 3 hours after use.⁶¹ According to the US Drug Enforcement Administration (DEA), the elimination rate for the few SCs for which this property is known can vary between about 20 minutes and several hours.⁶² Beyond toxicology findings, the NTSB investigation revealed that the truck driver had a history of SC use (including seizure-like behavior), as reported by his wife and a supervisor with his previous employer. Furthermore, he had visited a licensed counselor between August and November 2013, to whom he reported using synthetic drugs.

Although the presence of 5-fluoro-AMB could not be confirmed in the truck driver’s blood, the following factors are consistent with his being incapacitated by SC use:

- The presence of the pipe containing 5-fluoro-AMB in the truck cab.
- The driver’s documented history of using SCs.
- His documented history of having seizure-like behavior when using SCs.
- His lack of corrective action (braking, steering, or reducing throttle) as the truck-tractor departed the roadway, crossed the median, and struck the bus.

The NTSB concludes that the truck driver’s lack of corrective actions following the roadway departure was due to incapacitation, likely from the use of SCs.

2.3.2 Prevalence of Synthetic Cannabinoids

There are hundreds of different types of SCs. When existing varieties are deemed illegal, new substances, with slightly modified chemical structures, are developed to replace them. The unknown and sometimes considerably more negative effects of new SCs may help explain the

⁶⁰ DRE officers are trained to identify indicators of impairment in seven categories: depressants, stimulants, hallucinogens, dissociative anesthetics, narcotic analgesics, inhalants, and cannabis. The observed behavior of the drivers in this study was most similar to the requirements of the cannabis category.

⁶¹ Biological elimination rate refers to the time required for a drug to be eliminated from the body.

⁶² This information was communicated to NTSB staff by a DEA medical doctor. As of November 2015, there are no published peer-reviewed articles on the elimination rates of SCs.

recent increase in related adverse effects and deaths. Reports from the American Association of Poison Control Centers show sharp increases in visits to emergency rooms following the use of SCs (NYT 2015). For example, in the first 3 *weeks* of April 2015, state poison control centers received about 1,000 reports of adverse reactions to SCs—which is more than double the number of reports for the first 3 *months* of 2015. In April 2015, health departments in Alabama, Mississippi, and New York issued alerts on SCs. The number of deaths due to SC use is also on the rise; three times as many SC-related deaths occurred in the first 5 months of 2015 compared with the same period in 2014 (Centers for Disease Control and Prevention [CDC] 2015a).⁶³

In a 2013 national survey on drug use among school-aged children and young adults, 4 percent of eighth graders, 7.4 percent of tenth graders, and 7.9 percent of twelfth graders reported using SCs in the past 12 months (Johnson and others 2014a). The researchers also reported low perceived risk from the use of these substances, possibly due to their availability over the counter. In the same survey, 2.3 percent of college students and 3.2 percent of young adults reported using SCs in the past 12 months (Johnson and others 2014b).

The prevalence of SC use in the general population is still unclear, though recent data suggest that usage is on the rise. The use of SCs is also a considerable concern within the segment of population that is regularly tested for drug use. For example, among a recent sample of young adults (up to 30 years of age) in the District of Columbia parole and probation system, 39 percent of those who had negative results from a traditional drug screen tested positive for SCs (Wish, Artigiani, and Billing 2013). Additionally, tests of random urine samples from US Army personnel revealed that the use of SCs by active duty members exceeded the use of THC (Castaneto and others 2014). As a result, in November 2013, the US Department of Defense incorporated SC screening into the military drug abuse testing program (US Army 2014).

2.3.3 Synthetic Cannabinoids in Commercial Transportation

2.3.3.1 Current Drug Testing Requirements. CMV drivers represent another segment of the population that is regularly tested for drug use. Drivers are subject to pre-employment, random, and postcrash toxicological testing. Title 49 *CFR* 40.85 specifies that the following substances be tested for:⁶⁴

- Marijuana metabolites
- Cocaine metabolites
- Amphetamines
- Opiate metabolites
- PCP.

⁶³ Fifteen deaths were reported in the first 5 months of 2015, compared with five deaths in the same period in 2014.

⁶⁴ The rule specifically prohibits testing “DOT specimens” for any drugs other than those listed.

Drug use is also covered by 49 *CFR* 382.213, which states that no (commercial) driver shall report for duty or remain on duty when using any controlled substance, such as those identified in 21 *CFR* 1308.11 (Schedule I drugs).⁶⁵ As of October 2015, Schedule I includes a total of 25 SCs—though 5-fluoro-AMB is not one of them.

Title 49 *CFR* 392.4 specifically prohibits the possession or use of Schedule I drugs, but also adds that no driver shall be on duty and possess, be under the influence of, or use any of the following drugs or other substances:

1. Any 21 *CFR* 1308.11 Schedule I substance.
2. An amphetamine or any formulation thereof (including, but not limited, to “pep pills” and “bennies”).
3. A narcotic drug or any derivative thereof.
4. Any other substance, to a degree that renders the driver incapable of safely operating a motor vehicle.

2.3.3.2 Safety Recommendations (Drug Use/Testing). Had 5-fluoro-AMB been classified as a Schedule I drug at the time of the crash, the truck driver would have been in violation of item (1) of 49 *CFR* 392.4. The driver was, however, in violation of item (4), because he was clearly incapable of safely operating a motor vehicle due to the use of an impairing substance. Although item (4) covers incapacitating substances, such as SCs, 49 *CFR* 40.85 does not allow testing for any substances that are not on its list. The NTSB concludes that there is a disconnect in the regulations between the drug prohibitions for CMV drivers, found at 49 *CFR* 392.4, and the substances for which they are screened, found at 49 *CFR* 40.85.

The inconsistency in the regulations between the broad prohibitions on drug use and limited drug testing leaves a gap that the users of synthetic drugs or any other substances not tested for under 49 *CFR* 40.85 could take advantage of. Indeed, the truck driver exploited this gap when employed at a previous carrier (see appendix C). Because there are no data on the prevalence of SC use among CMV drivers, the extent to which other drivers exploit this gap is unknown. The NTSB concludes that research is needed on the extent to which CMV drivers use impairing substances, particularly SCs and other substances not tested for under 49 *CFR* 40.85.

Therefore, the NTSB recommends that the FMCSA determine the prevalence of CMV driver use of impairing substances, particularly SCs, and develop a plan to reduce the use of such substances.

2.3.3.3 Screening for Synthetic Cannabinoids. Expanding the list of substances tested for under 49 *CFR* 40.85 to include SCs would aid in addressing the use of these drugs by CMV

⁶⁵ Schedule I drugs, substances, or chemicals are defined as drugs with no currently accepted medical use and a high potential for abuse, such as heroin, lysergic acid diethylamide (LSD), marijuana, and 3,4-methylenedioxy-methamphetamine (MDMA, also known as ecstasy).

drivers.⁶⁶ However, the variety of SCs and the constantly changing chemical structure of new products developed to evade regulations present challenges in determining the legality of a substance and developing standardized screening procedures.

Among other responsibilities, the DEA monitors drug use and abuse. When a substance meets a number of criteria, including a history and current pattern of abuse as well as a risk to public health, the DEA can temporarily place it in Schedule I to avoid an imminent hazard to public safety. Following further evaluation, the substance can be permanently added to an appropriate schedule (DEA 2015). During the course of this crash investigation, NTSB investigators requested that the DEA determine if 5-fluoro-AMB can be defined as a Schedule I controlled substance analogue under 21 *United States Code (USC)* 802(32).⁶⁷ In a letter dated February 10, 2015, the DEA responded that if the evidence proves that 5-fluoro-AMB is intended for human consumption, it may be treated under federal law as a controlled substance in Schedule I (21 *USC* 813). In September 2015, legislation was proposed in the US Congress to amend the Controlled Substance Act; if enacted, more than 200 synthetic drugs would be classified as Schedule I drugs, though 5-fluoro-AMB is not on that list.⁶⁸

Testing for the presence of a particular SC in a biological sample requires a standardized procedure. But the development of testing procedures is expensive and time consuming. The pipe retrieved from the cab of the truck-tractor was found to contain traces of 5-fluoro-AMB. Without the pipe, it would have been extremely difficult to determine if the driver had used an SC. OSBI initially tested for 15 SCs—but the total number of SCs on the market at any one time is in the hundreds. Compounding the difficulty in testing is the great variability among SCs—not only in terms of effect and potency, but also in their elimination rates. Furthermore, the lack of knowledge pertaining to the breakdown processes for these substances precludes the detection of their metabolites, which can remain in the body for a considerably longer time.⁶⁹

Developing a standardized testing procedure for each SC is not feasible, because as one substance becomes illegal and is rated as a Schedule I drug, manufacturers develop another compound with a slightly modified chemical structure to replace it. The time from the initial availability of a particular synthetic substance to its classification as a Schedule I drug can extend to over 1 year.

2.3.3.4 Reasonable Suspicion Testing. In addition to preemployment, random, and postcrash drug testing, CMV drivers are also subject to reasonable suspicion testing under

⁶⁶ Title 49 *CFR* 382.601(c) includes optional provisions that allow carriers to exceed the minimum drug testing requirements. However, any such additional policies or consequences must be clearly and obviously described as being based on independent authority.

⁶⁷ (a) A substance is an analogue of another drug if it is chemically substantially similar and if its effects are similar to a Schedule I or II substance. (b) The Federal Analogue Act, 21 *USC* 813, allows any chemical that is an analogue of a controlled substance listed in Schedule I to be treated as if it were also listed in that schedule. This allowance applies only to substances that are intended for human consumption.

⁶⁸ The Synthetic Drug Control Act (HR 3537) was introduced on September 19, 2015.

⁶⁹ Because the DOT-regulated drug test (at 49 *CFR* 40.85) tests for the metabolites of marijuana, cocaine, and opiates, it can detect these substances even an entire day after their use.

49 *CFR* 382.307.⁷⁰ Most of the time, such testing is initiated at the request of a terminal manager or another supervisor with reasonable suspicion training, following the visual observation of signs of impairment.

A supervisor at the truck driver's previous employer had informed the terminal manager about the driver's reported use of SCs. On two occasions, the terminal manager visually examined the driver for symptoms of impairment. However, reasonable suspicion drug testing was not administered because the manager did not detect any impairment. Because 49 *CFR* 40.85 does not include screening for SCs, visual examination by appropriately trained personnel is the only method of detecting CMV impairment from the use of certain synthetic drugs. Reasonable suspicion training is not a perfect solution, however. In this case, it was not effective even for a driver who was suspected of using SCs.

Title 49 *CFR* 382.603 covers reasonable suspicion training for supervisors. Carriers must provide at least 1 hour of training on detection of alcohol impairment and another hour, at a minimum, on detection of controlled substances impairment. Although the training is required to include physical, behavioral, and speech indicators of impairment, it is very short. The regulation does not require recurrent training.

The FMCSA (2014) estimates that 15.7 percent of reasonable suspicion drug tests in 2011 were positive. The low number of positive test results indicates either ineffective training (a very high number of drivers are incorrectly identified as impaired) or, more likely, driver impairment due to substances not tested for under 49 *CFR* 40.85. It is quite possible that 1 hour of reasonable suspicion training is insufficient to provide supervisors with an effective method of detecting impairment, particularly impairment due to the use of new synthetic drugs. However, even with optimal training, the problem of substances not tested for under 49 *CFR* 40.85 remains. A terminal manager could accurately identify an impaired driver, yet have the US Department of Transportation (DOT) drug test fail to find evidence of impairment.

2.3.3.5 Safety Recommendations (CMV Driver Impairment). The seemingly inadequate reasonable suspicion training and the low number of positive tests indicate a need for improved training or other means of addressing impairment due to the use of substances not tested for under current DOT regulations. Several potential approaches could provide an effective alternative—from prevention and counseling, to expansion of impairment detection training, to performance-based evaluations. Motor carrier industry associations are well equipped to aid in identifying the best practices of leading carriers in addressing impairment due to prohibited substances.

As a means of encouraging a drug-free driving environment, some carrier drug policies include employee assistance program counseling to which drivers are referred following reasonable suspicion tests, regardless of results. The confidential counseling, which is available to drivers at all times, can also serve as a preventive measure.

⁷⁰ Under 49 *CFR* 382.307, employers must require a driver to submit to an alcohol or drug test when they have reasonable suspicion based on specific, contemporaneous, articulable observations concerning the appearance, behavior, speech, or body odors of the driver.

Reasonable suspicion training, which is used primarily by motor carriers, is very basic, particularly when compared with the DRE training that law enforcement officers receive. Moreover, the determination of impairment by a DRE-certified law enforcement officer can be used as evidence of impairment in court, even without a positive drug test. Without additional provisions, the detection of impairment by a terminal manager trained in reasonable suspicion lacks such authority.⁷¹

Even with optimal training, motor carrier supervisors face another obstacle: the limited time they spend with drivers each workday. Drivers spend almost all of their working hours away from their home terminal. Some carriers have equipped their vehicles with both road- and driver-facing cameras. These cameras are typically used as training tools to improve driving performance by recording video near the time of critical events, such as hard braking. Driver-facing cameras could also provide motor carriers with greater access to and better means of monitoring their drivers.

Drug tests are surrogate measures of driver impairment. Considering current challenges to the detection of impairing substances such as synthetic drugs, performance-based tests may provide an effective alternative for evaluating a driver's ability to operate vehicles.

The NTSB concludes that the incongruity between the trained visual detection of impairment and the results of drug and alcohol tests indicates a need for improved methods of addressing driver impairment.

Therefore, the NTSB recommends that the FMCSA work with motor carrier industry stakeholders to develop a plan to aid motor carriers in addressing CMV driver use of impairing substances, particularly those not covered under current drug-testing regulations—such as by promoting best practices by carriers, expanding impairment detection training and authority, and developing performance-based methods of evaluation.

The development of effective countermeasures for addressing CMV driver use of synthetic drugs may be a time-consuming process, particularly for those countermeasures that require regulation. In the meantime, the motor carrier industry and safety associations could take important preventive steps to raise awareness concerning the dangers of driver use of synthetic drugs. Because of the increasing availability and use of such substances, motor carriers will benefit from learning more about them and the dangers of their use. The NTSB concludes that to reduce the likelihood of drug-impaired driving, motor carriers should educate their drivers about the dangers of synthetic drugs.

The NTSB recommends that the American Trucking Associations, American Bus Association, United Motorcoach Association, Owner-Operator Independent Drivers Association, and CVSA inform their members about the dangers of driver use of synthetic drugs and encourage them to take steps to prevent drivers from using these substances.

⁷¹ A terminal manager could take additional actions beyond requesting a drug and alcohol test in accordance with the carrier's policies and union guidelines, particularly in the case of a reasonable suspicion drug test with negative results.

2.4 Passenger Restraint Systems

2.4.1 Accident Bus

Seat belts prevent drivers and passengers from being thrown from their seats and ejected during a crash, in addition to mitigating injury-causing forces. Those not wearing seat belts are 30 times more likely to be ejected from a vehicle, and more than 75 percent of people ejected during a fatal crash die as a result of their injuries (NHTSA 2009). For front seat occupants in passenger vehicles, NHTSA (1984) estimates that seat belts reduce serious crash-related injuries and fatalities by half.

The accident bus was equipped with passenger lap belts, though none of the passengers wore them. On many seats, the lap belts were not well maintained and were inaccessible. Had the lap belts been well maintained, accessible, and properly worn, they would have kept the occupants in their seats, preventing ejection and reducing overall injuries. The NTSB concludes that the lack of seat belt use likely exacerbated the injuries of passengers in the medium-size bus.

2.4.2 Collegiate Level Seat Belt Policies

2.4.2.1 Review of Policies. During postcrash interviews, the bus passengers indicated a lack of knowledge concerning the use—and even the existence—of the seat belts. This fact is particularly relevant considering that the softball team had taken numerous trips over the past year in the same bus.⁷²

Although drivers for the college, including the accident driver, signed a policy on the implementation of seat belt requirements, the NCTC did not have an established review process to monitor adherence to this policy. Nor did the NCTC have an established yearly review of the policy.

The NTSB concludes that though the NCTC had a policy requiring that drivers operate vehicles only if all passengers were wearing their seat belts, the accident driver did not ensure that his passengers were wearing the available seat belts; and the college had no procedure in place to ensure that its drivers complied with the policy.

Since the crash, the NCTC has established a policy requiring that all drivers read and sign the vehicle use policy each year, rather than only once. Additionally, the college has developed new procedures that specifically address seat belt inspection before each trip and the notification of passengers (students) of procedures and policies related to college travel, including the proper use of seat belts. Drivers are required to document the application of these policies on a revised vehicle checkout form.⁷³ The NCTC also established a procedure for its human resources staff to monitor driver adherence to the new policies by examining the vehicle checkout form for completeness. Although the monitoring step represents an improvement over the previous policy,

⁷² Some of the passengers were freshmen students who were taking that trip for the first time.

⁷³ The driver is required to visually inspect more than a dozen vehicle systems, including seat belts. The form also contains a section that requires the driver to mark and sign that the passengers were informed of the importance of seat belts and the NCTC policy regarding their use.

it is not an optimal solution. The transportation safety policies of small junior colleges with limited resources, such as the NCTC, would be considerably strengthened by state laws mandating the use of seat belts in all vehicles, as discussed in section 2.4.3.

The NCTC newly established policies—if adhered to—can improve safety. However, the circumstances of this crash raise concerns about other schools and their access to comprehensive travel procedures. The National Collegiate Athletic Association (NCAA) has developed a transportation safety guide for its members, *Safety in Student Transportation: A Resource Guide for Colleges and Universities*.⁷⁴ One chapter explains how to minimize the risk of injury by requiring that anyone traveling on a school-sponsored trip or for institutional business use a seat belt.⁷⁵ The NCAA developed this document in cooperation with two organizations: the American Council on Education and United Educators. It was then provided to all member colleges and universities. The guide was not provided to junior colleges, and the NCTC staff reported no knowledge of the document.

2.4.2.2 Safety Recommendations. NTSB investigators contacted several college associations and inquired about transportation safety policies. The National Junior College Athletic Association (NJCAA) director stated that it does not have this type of document, nor does it have the financial resources or staffing to develop such guidelines. NTSB investigators were informed that the NJCAA can relay safety information to all junior college athletic programs. However, the junior colleges without athletic programs would not benefit from such an outreach effort.

The American Association of Community Colleges (AACC) represents nearly all junior colleges in the country and can relay transportation safety information to its members. The NCAA's comprehensive transportation safety guidelines, if adopted, could improve the safety of all school-sponsored trips for junior colleges as well.

The NTSB concludes that junior colleges can improve transportation safety by following the travel policy guidelines developed by the NCAA. Therefore, the NTSB recommends that the AACC urge its members to adopt and follow the NCAA's *Safety in Student Transportation: A Resource Guide for Colleges and Universities*.

2.4.3 State Level Seat Belt Use Laws

2.4.3.1 Review of Laws and Statistics of Use. Although school policies may increase seat belt use in buses used for school-related activities, state laws have a broader, more comprehensive effect. As of November 2015, 34 states (including Oklahoma and Texas) and the District of Columbia have primary enforcement of seat belt use laws for front seat occupants (see table 7; Governors Highway Safety Association [GHSA] 2015). The remainder of the states have

⁷⁴ See fs.ncaa.org/Docs/NCAANewsArchive/2006/Association-wide/student+transportation+safety+guide+-caps+cooperative+effort+to+limit+risk+-+7-3-06+ncaa+news.html, accessed November 17, 2015.

⁷⁵ The NCAA developed this guide as a result of the NTSB investigation of the crash of an airplane transporting members of the Oklahoma State University basketball team (Safety Recommendation A-03-1; NTSB 2003). In 2007, this recommendation was classified “Closed—Exceeds Recommended Action.”

secondary enforcement, with the exception of New Hampshire, which has no seat belt use laws for adults.⁷⁶ For adult occupants in rear seats, 22 states do not have any seat belt use laws.

Table 7. State seat belt use laws by means of enforcement and seating positions, as applied to adults, June 2015.

	Front Seats	Rear Seats
Primary enforcement ^a	34 ^b	18 ^b
Secondary enforcement	15	10 ^c
<p>^a Most states have additional primary enforcement of seat belt use laws for minors.</p> <p>^b Includes the District of Columbia.</p> <p>^c Six of these states have secondary enforcement of seat belt use laws for front seats, while four have primary enforcement for front seats.</p>		

Data for 2008–2009 show that seat belt usage was 9 percentage points higher in the states with primary enforcement of seat belt use laws (Beck and West 2011). More recent data show that seat belt usage has been increasing, generally in the states with primary enforcement (Chen 2015). In 2014, seat belt usage in the 33 states with primary enforcement was nearly 90 percent, compared with 82 percent in the 17 states with secondary enforcement. Seat belt usage in these 17 states has remained essentially the same since 2007, when the estimated rate was 81 percent.

In New Hampshire, the estimated seat belt usage in 2014 was only 70 percent, the lowest in the nation.

Primary enforcement of seat belt use laws has also been associated with a reduction in fatalities. Based on a 2004 study examining 10 states that moved from secondary to primary enforcement of seat belt use laws, the change resulted in a 7 percent reduction in fatalities (Farmer and Williams 2004). A similar reduction in fatalities (about 10 percent) was observed in Minnesota, which introduced primary enforcement in 2009 (Douma and Tilahun 2012).

The CDC has developed a model to determine the impact of introducing transportation safety measures, including primary enforcement of seat belt use laws. The model—referred to as MV PICCS (motor vehicle prioritizing interventions and cost calculator for states)—is designed to calculate the expected number of injuries and fatalities prevented, at the state level, following implementation of an intervention such as primary enforcement of seat belt use laws (CDC 2015b).⁷⁷ For example, if Virginia—which currently has secondary enforcement only for front seats—implements primary enforcement, the model predicts that 45 fatalities per year

⁷⁶ In some states with secondary enforcement, the seat belt use law enforcement is primary for those under 18 years of age.

⁷⁷ This model also considers the resources required for, or lost after, the implementation of an intervention.

would be prevented. In 2013, 663 vehicle occupants suffered fatal injuries in crashes in Virginia.⁷⁸

State seat belt use laws, whether with primary or secondary enforcement, do not extend to motorcoaches and medium-size buses (except for the driver position) and are frequently unclear for specialty vehicles, such as limousines. Although state seat belt use laws apply to light vehicles, the definitions of such vehicles vary among the states. For example, seat belt use laws in Texas also apply to vans with a capacity of up to 15 occupants, to trucks, and to truck-tractors, while seat belt use laws in Oklahoma do not apply to those vehicles.⁷⁹

NHTSA recognizes the benefits of passenger restraint systems in motorcoaches and certain buses, as evidenced by the recent rulemaking on occupant crash protection. The final rulemaking, which will go into effect in 2016, states that all buses meeting the motorcoach or over-the-road bus definition, regardless of the GVWR, must be equipped with lap/shoulder belts at the driver and all passenger seating positions.⁸⁰ Further, all large buses with a GVWR of more than 26,000 pounds must be equipped with lap/shoulder belts at the driver and all passenger seating positions.⁸¹ Unfortunately, however, this rulemaking excludes medium-size buses, such as the one in this crash (which was 1 pound under the GVWR limit).

This rulemaking is based in part on NHTSA research on the effectiveness of seat belts on motorcoaches, which showed that seat belt assemblies installed on motorcoach passenger seats could reduce the risk of fatal injuries in rollover crashes by 77 percent, primarily by preventing ejections.⁸²

2.4.3.2 Previous Recommendations. For more than two decades, the NTSB has advocated legislation requiring the use of seat belts in passenger vehicles. In 1991, the NTSB issued a priority action recommendation to 12 states, which did not have seat belt use laws at that time, to mandate seat belt use in all passenger vehicles regardless of seating position (Safety Recommendation H-91-13; NTSB 1986; 1988). This recommendation is classified “Closed—Acceptable Action” for 11 of these states⁸³ and “Closed—Unacceptable Action” for New Hampshire.

⁷⁸ See *Virginia Traffic Crash Facts*, www.dmv.virginia.gov/safety/crash_data/crash_facts/crash_facts_13.pdf, accessed July 5, 2015.

⁷⁹ (a) See Texas Occupant Restraint Laws, Transportation Code, Chapter 545, www.dps.texas.gov/-director_staff/public_information/seatbelt.htm, accessed July 5, 2015. (b) See Oklahoma Mandatory Seat Belt Use Act, Title 47—Motor Vehicles, www.oklegislature.gov/osStatuesTitle.aspx - Title 47, accessed November 8, 2015.

⁸⁰ According to the final rule, an over-the-road bus is a bus characterized by an elevated passenger deck located over a baggage compartment. See section 3038(a)(3) of the Transportation Equity Act for the 21st Century, cited in section 32702(6) of Subtitle G, Motorcoach Enhanced Safety Act. The requirement for all large buses with GVWRs above 26,000 pounds excludes school buses, transit buses, and prison buses.

⁸¹ See final rulemaking, “Federal Motor Vehicle Safety Standards; Occupant Crash Protection,” at 78 *Federal Register (FR)* 70416, November 25, 2013.

⁸² See 78 *FR* 70416.

⁸³ Alabama, Delaware, Kentucky, Maine, Massachusetts, Nebraska, North Dakota, Rhode Island, South Dakota, Vermont, and West Virginia.

In 1995, as the result of an earlier study on the performance of lap/shoulder belts in motor vehicle crashes, the NTSB issued a recommendation to 41 states and the District of Columbia to enact primary enforcement of mandatory seat belt use laws (Safety Recommendation H-95-13; NTSB 1988). This recommendation was superseded by Safety Recommendation H-97-2, which also called for the imposition of fines for failure to comply with seat belt use laws. It was issued as a result of a forum on air bags and child passenger safety (NTSB 1997):

Enact legislation that provides for primary enforcement of mandatory seatbelt use laws, including provisions such as the imposition of driver license penalty points and appropriate fines. Existing legal provisions that insulate people from the financial consequences of not wearing a seatbelt should be repealed. (H-97-2)

Safety Recommendation H-97-2 has the following classifications:

- “Closed—Acceptable Action” for eight states, two territories, and the District of Columbia.
- “Closed—Acceptable Alternate Action” for 13 states and two territories.
- “Closed—Unacceptable Action” for one state.
- “Open—Acceptable Response” for 12 states and the US Virgin Islands.
- “Open—Acceptable Alternate Response” for 14 states.
- “Open—Unacceptable Response” for two states.

The overall classification of Safety Recommendation H-97-2 is “Open—Acceptable Alternate Response.”

2.4.3.3 Safety Recommendations. The benefits of passenger restraint systems are clear, and the corresponding reduction in fatalities is considerable. However, a passenger restraint system—whether in a passenger vehicle, motorcoach, or medium-size bus—is only effective when used. State laws governing seat belt use pertain only to light vehicles and the driver position in other vehicles. Seat belt use laws with primary enforcement for buses and specialty vehicles such as limousines would have the same effect as they do for passenger cars, sport utility vehicles, and trucks: they would increase the use of restraint systems and reduce fatalities.

The NTSB concludes that extending the mandatory seat belt use laws with primary enforcement to all vehicles in all states for all seating positions would decrease fatalities on the road. Therefore, the NTSB recommends that the 50 states, the District of Columbia, and Puerto Rico enact legislation that provides for primary enforcement of a mandatory seat belt use law for all vehicle seating positions equipped with a passenger restraint system.

The NTSB recognizes the progress that some states have made in the implementation of Safety Recommendation H-97-2; however, the new recommendation is more comprehensive and applies mandatory seat belt use laws to all vehicles and all seating positions. Because of the

considerably broader scope of the new recommendation, the NTSB classifies Safety Recommendation H-97-2 “Closed—Superseded.”⁸⁴

2.5 Crashworthiness of Medium-Size Buses

2.5.1 Overview

Vehicle crashworthiness refers to the capacity of a vehicle to protect its occupants from crash forces. This protection—which is achieved, in part, by vehicle structure—includes maintaining a survivable space around the occupant, retaining the occupant within that space, and reducing the forces applied to the occupant.

Few crashworthiness standards are in place for medium-size buses, such as the accident bus. Seat belts are not required for passengers, only for the driver. No minimum roof or sidewall strength requirements have been established to ensure that a medium-size bus will maintain survival space during a side-impact collision or rollover. Further, advanced window glazing, which could minimize the potential for full ejection of an unbelted passenger or partial ejection of a belted passenger, is not required.

Despite the relative lack of crashworthiness requirements for medium-size buses, Champion Bus designed the model series of the accident bus to meet some *FMVSSs*. For example, this model series was voluntarily equipped with passenger lap belts at all seating positions, and those belts met the standards associated with belt strength and attachment strength (*FMVSSs* 207, 209, and 210). Moreover, the documentation provided by Champion Bus showed that this series met the school bus rollover protection requirements of *FMVSS* 220. However, the series failed the school bus sidewall joint standards (*FMVSS* 221).

The side-impact crash sequence compromised the bus structure. All but one of the windows on the bus were broken out, enabling the ejection of unbelted occupants. In addition, the sidewall joints failed. The sidewalls separated from the lower roof panel along the left side of the bus, which—combined with the lack of seat belt use—exposed the occupants to a greater risk of injury.

2.5.2 Previous Recommendations and Pending Regulations

The NTSB has a long history of investigating crashes involving all types and sizes of buses. In a 1999 investigation of bus crashworthiness, we issued 14 recommendations, two of which asked that NHTSA develop performance standards for motorcoach roof strength to provide maximum survival space for all seating positions—and, once the standards were developed, require newly manufactured motorcoaches to meet them (Safety Recommendations H-99-50 and -51; NTSB 1999).⁸⁵ An additional recommendation asked that NHTSA expand its research on advanced window glazing to prevent motorcoach occupant ejection (Safety

⁸⁴ Safety Recommendation H-97-2, as issued to the US Virgin Islands, is classified “Closed—No Longer Applicable.”

⁸⁵ Nine of the 14 recommendations were specific to school buses and motorcoaches.

Recommendation H-99-49). More than 15 years later, these recommendations are classified “Open—Unacceptable Response.”

NHTSA considers medium-size buses as a separate vehicle class. However, the NTSB recognizes that medium-size buses, regardless of weight, operate in a manner similar to motorcoaches. Thus, following a crash in Dolan Springs, Arizona, in 2009—which resulted in seven fatalities—the NTSB (2010a) expanded the 1999 recommendations beyond motorcoaches and recommended that NHTSA:

In your rulemaking to improve motorcoach roof strength, occupant protection, and window glazing standards, include all buses with a GVWR above 10,000 pounds, other than school buses. (H-10-3)

NHTSA recently published one rule and a proposed rule on motorcoach safety. The rule applies to occupant protection—the requirement for lap/shoulder belts, as described in section 2.4.3.⁸⁶ The proposed rule applies to over-the-road bus rollover structural integrity.⁸⁷ However, based on the definition of a bus in these rulemakings, the new occupant protection and rollover structural integrity standards would not be required for medium-size buses such as the one involved in this crash, despite Safety Recommendation H-10-3—which is currently classified “Open—Unacceptable Response.” In our October 2, 2014, response to the proposed rule, the NTSB expressed overall support, but also a concern that the limited scope would not provide medium-size buses with sufficient structural integrity in the event of a rollover crash.

2.5.3 Safety Recommendations

The Davis crash highlights the risks that medium-size buses may be exposed to during collisions with other large vehicles. Well-designed and accessible occupant protection systems, such as lap/shoulder belts, are critical for keeping the occupant within the vehicle and reducing applied forces. Further, rollover structural integrity—which requires window retention during a roll, among other features—assists in maintaining sufficient survival space around the occupant during a crash sequence and reducing the risk of ejection. Advanced window glazing may further reduce the risk of ejection. The accident bus was not required to meet the standards for occupant protection, nor will newly designed medium-sized buses under 26,001 pounds GVWR be required to meet the standard for rollover structural integrity.

The NTSB concludes that the crashworthiness of medium-size buses can be improved by requiring those vehicles to meet the existing motorcoach occupant protection standards and the proposed rollover structural integrity standard. Therefore, the NTSB reiterates Safety Recommendation H-10-3 to NHTSA.

This model series bus failed the school bus sidewall joint standard (FMVSS 221). However, even if the medium-size bus had met this standard, application of the requirements of

⁸⁶ See 49 *CFR* Part 571, “Federal Motor Vehicle Safety Standards; Occupant Crash Protection,” published at 78 *FR* 70416, November 25, 2013.

⁸⁷ See “Federal Motor Vehicle Safety Standards; Bus Rollover Structural Integrity, Motorcoach Safety Plan; Proposed Rule,” published at 79 *FR* 46090, August 6, 2014.

FMVSS 221 to all buses above 10,000 pounds may not have resulted in the same level of protection. The body panels on school buses are made of corrugated steel, while the body panel materials on medium-size buses vary.⁸⁸ Because the minimal required tensile strength of sidewall joints is dependent on the strength of the body panels (60 percent of the tensile strength of the solid body panel), a vehicle with weak body panels could meet FMVSS 221 requirements but not provide adequate crashworthiness in a real-world side impact or rollover crash.⁸⁹ Thus, for buses that are not constructed in the same manner and of the same material as a school bus, FMVSS 221 may not result in improved crashworthiness.

The initial impact in the Davis crash was a side impact between the truck-tractor and the medium-size bus, during which the sidewall joints of the bus failed, and the sidewall separated from the lower roof panel. As a result of the loss of the sidewall panel, the occupants seated in that area were exposed to a greater risk of injury and ejection because the structure of the bus was no longer present to provide protection. This loss of sidewall panels is especially hazardous for typical medium-size buses, in which the low placement of passenger compartments puts occupants at greater risk from side-impact collisions, particularly from heavy vehicles. In contrast, motorcoaches are built with the passenger compartment over a luggage compartment, providing occupants greater protection due to the higher seating.

The side structure of a bus can be improved by adding energy-absorbing materials in the pillars, subframe rails, and roof. Currently, no federal safety standards require minimum side-impact protection to ensure the integrity of the sidewall structure and maintain sufficient survival space during a side-impact collision.

The NTSB concludes that because of the current lack of side-impact protection standards for medium-size buses, occupants are at risk of injury and ejection during side-impact crashes. Therefore, the NTSB recommends that NHTSA develop, and require compliance with, a side-impact protection standard for all newly manufactured medium-size buses, regardless of weight.

2.6 Dedicated Event Data Recorders

2.6.1 Truck-Tractor and Bus Recorders

The truck-tractor was equipped with multiple modules capable of recording and storing vehicle parameters related to collision events, including the EECU and the Bendix ABS-ESC module. However, the bus was not equipped with any such systems.

Among the data obtained from download of the truck-tractor EECU, only a single diagnostic trouble code for an “incorrect power down” can definitively be attributed to the collision. The system recorded some vehicle parameters; however, the power was insufficient to record vehicle speed and engine speed, or to continue recording for an additional time.

⁸⁸ For example, a medium-size bus of 19,500 pounds GVWR may have a welded steel cage construction but aluminum or fiberglass composite sidewalls.

⁸⁹ See also section 1.5.3 and figures 12 and 13.

Therefore, the NTSB concludes that because of a power loss during the collision sequence, the truck-tractor EECU did not record useful vehicle parameter data.

The Bendix ABS–ESC module began recording at the start of the yaw control event—some time following the impact—but abruptly ended part way through its fourth data recording, storing vehicle parameters for 1.5–2 seconds. The most probable explanation for this incomplete recording is a sudden loss of power to the module, which likely occurred when the truck-tractor struck the trees.

The ABS–ESC module data showed that the accelerator was nearly fully depressed for 1.5–2 seconds following the collision with the bus. Testing revealed that the accelerator pedal would have had to be manually depressed to obtain such a recording. The NTSB thus concludes that the driver of the truck-tractor applied nearly full throttle for 1.5–2 seconds between colliding with the medium-size bus and striking the trees.

2.6.2 Historical Review of Event Data Recorders

The NTSB has a long history of recommendations pertaining to recorders in highway transportation, beginning with their use for monitoring driver and vehicle information (Safety Recommendations H-98-23 and -26; NTSB 1998). More recently, Safety Recommendations H-10-14 and -15, pertaining to recorders in trucks, were issued to NHTSA following a Miami, Oklahoma, crash that resulted in 10 fatalities (NTSB 2010b):

Develop and implement minimum performance standards for event data recorders for trucks with gross vehicle weight ratings over 10,000 pounds that address, at a minimum, the following elements: data parameters to be recorded; data sampling rates; duration of recorded event; standardized or universal data imaging interface; data storage format; and device and data survivability for crush, impact, fluid exposure and immersion, and thermal exposure. The standards should also require that the event data recorder be capable of capturing and preserving data in the case of a power interruption or loss, and of accommodating future requirements and technological advances, such as flashable and/or reprogrammable operating system software and/or firmware updates. (H-10-14)

After establishing performance standards for event data recorders for trucks with gross vehicle weight ratings over 10,000 pounds, require that all such vehicles be equipped with event data recorders meeting the standards. (H-10-15)

In its most recent communication on these recommendations, NHTSA responded that it was working with the Society of Automotive Engineers and planning a regulatory decision by the end of 2011. Due to NHTSA’s continued slow progress in implementing these recommendations and the ongoing need to capture better postcrash vehicle data, these two recommendations are currently classified “Open—Unacceptable Response.”

The NTSB has also made the following recommendations to NHTSA regarding the development of performance standards for onboard recording of crash data (NTSB 1999) and the installation of event data recorders (EDR) in buses (NTSB 2010a). These recommendations were

issued from the bus crashworthiness special investigation and the Dolan Springs, Arizona, investigation of a medium-size bus loss of control and rollover with seven fatalities, respectively:

Develop and implement, in cooperation with other government agencies and industry, standards for on-board recording of bus crash data that address, at a minimum, parameters to be recorded, data sampling rates, duration of recording, interface configurations, data storage format, incorporation of fleet management tools, fluid immersion survivability, impact shock survivability, crush and penetration survivability, fire survivability, independent power supply, and ability to accommodate future requirements and technological advances. (H-99-54)

Require that all buses above 10,000 pounds gross vehicle weight rating be equipped with on-board recording systems that: (1) record vehicle parameters, including, at minimum, lateral acceleration, longitudinal acceleration, vertical acceleration, heading, vehicle speed, engine speed, driver's seat belt status, braking input, steering input, gear selection, turn signal status (left/right), brake light status (on/off), head/tail light status (on/off), passenger door status (open/closed), emergency door status (open/closed), hazard light status (on/off), brake system status (normal/warning), and flashing red light status (on/off; school buses only); (2) record status of additional seat belts, airbag deployment criteria, airbag deployment time, and airbag deployment energy; (3) record data at a sampling rate sufficient to define vehicle dynamics and be capable of preserving data in the event of a vehicle crash or an electrical power loss; and (4) are mounted to the bus body, not the chassis, to ensure recording of the necessary data to define bus body motion. (H-10-7)

Because of NHTSA's continued slow progress in implementing these recommendations and the ongoing need to capture better postcrash vehicle data, Safety Recommendations H-99-54 and H-10-7 are currently classified "Open—Unacceptable Response."

NHTSA has demonstrated limited progress in mandating the installation of EDRs in truck-tractors and buses. However, in 2006, it published a final rulemaking establishing performance standards for voluntarily installed EDRs on passenger vehicles. NHTSA (2012) estimated that 92 percent of new passenger vehicles in 2010 were voluntarily equipped with EDRs. In 2012, NHTSA proposed rulemaking to mandate the installation of EDRs in light vehicles, but as of November 2015, this proposal has not been finalized.

Although the modules in the accident truck-tractor had the potential to record data, they were not EDRs. Vital crash information could have been captured had both the truck-tractor and the bus been equipped with dedicated crash EDRs built to minimum performance standards, which include device and data survivability, as outlined in Safety Recommendation H-10-14 to NHTSA.

Dedicated EDRs are invaluable not only during an investigation but also in research, and their importance has been recognized across transportation modalities. Cockpit voice and flight data recorders have been required on commercial airliners for decades. Since 1993, locomotive

event recorders have also been required on trains. In marine transportation, voyage data recorders are now required on all international passenger and cargo ships.

2.6.3 Safety Recommendations

Dedicated EDRs would not only have been more likely to survive the collision forces and power failure of this crash, but also to yield critical crash data on driver inputs and vehicle dynamics throughout the collision sequence, far beyond the capabilities of a typical EECU. The lack of such data in this collision represents another missed opportunity to better understand the crash—why it happened as well as the crash dynamics between the truck-tractor and the bus.

Although NHTSA has made progress in developing EDR standards for light vehicles, it has not yet developed standards for—nor required the use of—EDRs in heavy vehicles, including motorcoaches, school buses, truck-tractor semitrailer combination units, and medium-size buses.

The NTSB concludes that because of the continued lack of standards and requirements for EDRs in trucks and buses over 10,000 pounds GVWR, data that are crucial to the improved understanding of crashes, as well as to overall vehicle safety, continue to go unrecorded. Therefore, the NTSB reiterates Safety Recommendations H-99-54 and H-10-7, -14, and -15 to NHTSA.

2.7 Median Barriers

2.7.1 Criteria for Median Barrier Installation

This crash occurred at a location where the median was 100 feet wide—a width for which many state departments of transportation would not normally consider a median barrier. On October 28, 2014, ODOT finalized a new version of its internal median cable barrier guidance. Guideline no. 2 addresses the AADT and crash history of a location regardless of median width.

At the request of NTSB investigators, ODOT examined the median crossover crash history in the vicinity of the crash site from 2009 to 2013. This 5-year review covered a 2.64-mile-long area between the first two scenic pullouts in Murray County (south and north of the I-35–US-77 interchange).⁹⁰ The median is 100 feet wide throughout this segment of I-35. Four median crossover crashes were reported—equating to 1.52 crossovers per mile in a 5-year period—which is well in excess of the threshold of 0.23 in guideline no. 2 (see figure 16).⁹¹

⁹⁰ The scenic pullouts were selected because of their proximity to the crash site and the physical presence of on and off ramps.

⁹¹ The formula for calculating the number of median crossover crashes per mile is number of median crossover crashes over 5 years/length of highway segment = 4 crossovers/2.64 miles = 1.52 crossovers per mile.

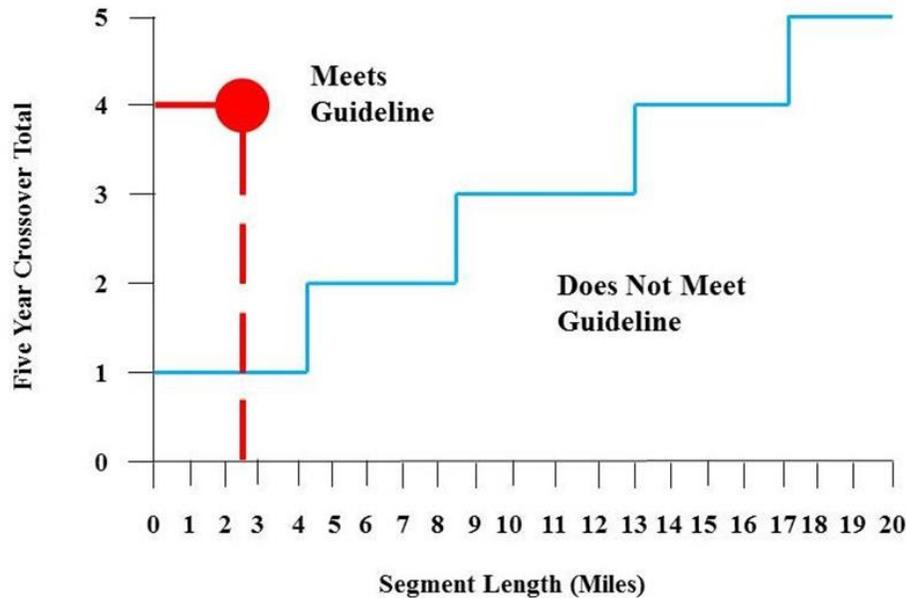


Figure 16. Suitability plot for median cable barrier at crash site, based on ODOT guideline no. 2 (crash rate and AADT).

ODOT acknowledged that this section of I-35 met the criteria of guideline no. 2. ODOT plans to install about 8 miles of longitudinal median cable barrier along I-35 in Carter and Murray Counties, starting at milepost 44 and extending to milepost 52 (the crash occurred near milepost 47). Construction of the barrier began in November 2015, with anticipated completion in January 2016.

ODOT plans to install a test level 4 (TL-4) median cable barrier, which has the capacity to capture vehicles of up to 22,000 pounds GVWR (single-unit trucks).⁹² Although a TL-4 median cable barrier may be effective against combination vehicles in certain circumstances, NTSB investigators were unable to determine whether such a barrier would have made a difference in this crash.⁹³

Based on RDG guidelines, which rely on AADT and median width, the crash site would not normally be considered for a median barrier (AASHTO 2011). Although the RDG provides national guidelines for the installation of median barriers, AASHTO encourages the states to develop their own guidelines to meet their specific needs.

Oklahoma and many other states have developed guidelines for median barrier installation. Like Oklahoma, California also considers crash history when determining the need

⁹² Five of the nine reported median crossovers that occurred in the vicinity of the crash site in the last 7 years involved a single-unit vehicle.

⁹³ The accident semitrailer was empty, which reduced the overall weight of the combination vehicle. Multiple factors can influence the effectiveness of TL-4 median cable barriers, such as angle of impact, point of impact (cable or post pole), speed of vehicle, and overall weight.

for a barrier. However, based on California Department of Transportation guidelines, a median cable barrier would not be warranted at the Davis crash site.⁹⁴

Although there is a lack of uniformity among the states, state guidelines for median barrier installation frequently call for a median barrier at a location that would not be considered under the RDG guidelines. Those states with advanced median barrier guidelines have shown a considerable reduction in the number of median crossover crashes and fatalities. For example, the annual fatality rate in Alabama was reduced by 43 percent (annual average of 47.5 fatalities before implementation of the new guidelines), while Ohio—which had an annual average of 40 fatalities—demonstrated a 100 percent reduction in fatality rate (National Cooperative Highway Research Program [NCHRP] 2012). The NTSB concludes that the advanced state median cable barrier guidelines, which allow for installing barriers at locations where they were not previously considered, can help reduce the frequency of median crossover crashes.

2.7.2 Previous Recommendations and Upcoming Guidelines

As a result of a median crossover crash in Munfordville, Kentucky, which caused 11 fatalities, the NTSB issued four related recommendations—Safety Recommendations H-11-22 and -23 to the Federal Highway Administration (FHWA) and Safety Recommendations H-11-32 and -33 to AASHTO (NTSB 2011):

Work with the American Association of State Highway and Transportation Officials [a] to identify cross-median crash rates that call for special consideration when selecting median barriers (H-11-22); and [b] to define the criteria for median barrier selection, including heavy vehicle traffic volume. (H-11-23)

Work with the Federal Highway Administration [a] to identify cross-median crash rates that call for special consideration when selecting median barriers, and publish the rates in the *Roadside Design Guide* (H-11-32); and [b] to define the criteria for median barrier selection, including heavy vehicle traffic volume, and publish the criteria in the *Roadside Design Guide*. (H-11-33)

These recommendations were issued with the aim of establishing implementation criteria for the selection and installation of TL-4 and -5 median barriers. They are currently classified “Open—Acceptable Response.”

The Transportation Research Board (TRB) has started a project (to be completed in June 2018) to develop guidelines for the selection and placement of TL-2, -3, -4, and -5 median barriers (NCHRP project 22-31). These guidelines are expected to address the four NTSB recommendations from the Munfordville crash—in addition to the selection and placement of TL-5 median barriers capable of redirecting or stopping tractor–van trailers weighing up to 79,300 pounds GVWR. The NTSB encourages this effort to establish comprehensive guidelines for median barrier selection.

⁹⁴ The two states use different units and thresholds when making a determination for a median cable barrier. Based on requirement calculations under the California guidelines, the Davis crash site has a crash rate of 0.30 crossover per mile per year—which is below the threshold of 0.50.

2.7.3 Safety Recommendations

The NTSB communicated the specific circumstances of the Davis crash to the FHWA, the TRB, and AASHTO. We highlighted the advanced guidelines of some states in reducing fatal crossover crashes, as well as the lack of standardization among the states when defining factors such as crash rate history. Based on discussions with the NTSB, the TRB revised the work plan for NCHRP project 22-31 to examine heavy vehicle crossover median crashes by looking at historical crash data and police reports. In addition, the proposed guidelines for the selection and placement of TL-2 through -5 median barriers will consider the frequency of heavy vehicle median crossovers and traffic volume.

NCHRP project 22-31 represents an opportunity, over the next 3 years, to collect valuable data for revising the RDG, while also meeting the requirements of the four related recommendations from the Munfordville investigation (NTSB 2011). However, the project will not be completed until June 2018. This nearly 3-year wait time for guidelines that could save lives is a long period, particularly for the states that are currently considering developing specific median cable barrier guidelines. However, an interim solution may be possible. The findings of NCHRP project 22-31 are not expected to contradict any of the findings from this crash or the ODOT guideline for median cable barrier installation. Rather, it is anticipated that the project will provide expanded guidelines for the installation of all types of median barriers. The NTSB concludes that the circumstances of the median crossover crash in Davis, together with the ODOT median cable barrier guidelines, could provide state departments of transportation with critical information to take provisional steps before the completion of NCHRP project 22-31. Therefore, the NTSB recommends that the FHWA disseminate information to the state departments of transportation about the circumstances of the Davis crash and the ODOT revised median cable barrier guidelines that resulted in the installation of a median cable barrier at the crash site.

Although NCHRP project 22-31 presents an opportunity to address the four recommendations from the Munfordville investigation, it will not be completed until 2018. Furthermore, the circumstances of this crash and the actions taken by ODOT indicate that the issues raised in the Munfordville recommendations, such as crash rate history, are still relevant. Therefore, the NTSB reiterates Safety Recommendations H-11-22, -23, -32, and -33 to the FHWA and AASHTO, respectively.

3 Conclusions

3.1 Findings

1. None of the following were primary or contributory factors in the crash: (1) truck or bus driver licensing and driving experience; (2) bus driver distraction due to cell phone use, fatigue, substance abuse, or medical conditions; (3) motor carrier operations; (4) mechanical condition of either vehicle; (5) traffic hazards; or (6) weather conditions.
2. Although the emergency response deviated from National Incident Management System and incident command system protocols in some instances, and there was a delay in the transportation of one injured passenger, these circumstances did not affect the extent of injuries to the occupants of either vehicle.
3. The truck driver's claim that he was reaching for a soft drink cannot account for his lack of corrective action following the roadway departure.
4. The lack of any type of evasive steering or braking by the truck driver while traveling across the median for more than 10 seconds—and the full throttle following impact with the medium-size bus—are inconsistent with a fatigue-related crash.
5. The truck driver's lack of corrective actions following the roadway departure was due to incapacitation, likely from the use of synthetic cannabinoids.
6. There is a disconnect in the regulations between the drug prohibitions for commercial motor vehicle drivers, found at 49 *Code of Federal Regulations (CFR)* 392.4, and the substances for which they are screened, found at 40 *CFR* 40.85.
7. Research is needed on the extent to which commercial motor vehicle drivers use impairing substances, particularly synthetic cannabinoids and other substances not tested for under 49 *Code of Federal Regulations* 40.85.
8. The incongruity between the trained visual detection of impairment and the results of drug and alcohol tests indicates a need for improved methods of addressing driver impairment.
9. To reduce the likelihood of drug-impaired driving, motor carriers should educate their drivers about the dangers of synthetic drugs.
10. The lack of seat belt use likely exacerbated the injuries of passengers in the medium-size bus.
11. Although North Central Texas College had a policy requiring that drivers operate vehicles only if all passengers were wearing their seat belts, the accident driver did not ensure that his passengers were wearing the available seat belts; and the college had no procedure in place to ensure that its drivers complied with the policy.

12. Junior colleges can improve transportation safety by following the travel policy guidelines developed by the National Collegiate Athletic Association.
13. Extending the mandatory seat belt use laws with primary enforcement to all vehicles in all states for all seating positions would decrease fatalities on the road.
14. The crashworthiness of medium-size buses can be improved by requiring those vehicles to meet the existing motorcoach occupant protection standards and the proposed rollover structural integrity standard.
15. Because of the current lack of side-impact protection standards for medium-size buses, occupants are at risk of injury and ejection during side-impact crashes.
16. Because of a power loss during the collision sequence, the truck-tractor engine electronic control unit did not record useful vehicle parameter data.
17. The driver of the truck-tractor applied nearly full throttle for 1.5–2 seconds between colliding with the medium-size bus and striking the trees.
18. Because of the continued lack of standards and requirements for event data recorders in trucks and buses over 10,000 pounds gross vehicle weight rating, data that are crucial to the improved understanding of crashes, as well as to overall vehicle safety, continue to go unrecorded.
19. The advanced state median cable barrier guidelines, which allow for installing barriers at locations where they were not previously considered, can help reduce the frequency of median crossover crashes.
20. The circumstances of the median crossover crash in Davis, Oklahoma, together with the Oklahoma Department of Transportation median cable barrier guidelines, could provide state departments of transportation with critical information to take provisional steps before the completion of National Cooperative Highway Research Program project 22-31.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the Davis, Oklahoma, crash was the failure of the truck-tractor driver to control his vehicle due to incapacitation likely stemming from his use of synthetic cannabinoids. Contributing to the severity of injuries were the lack of restraint use by the bus passengers and the lack of appropriate crashworthiness standards for medium-size buses.

4 Recommendations

4.1 New Recommendations

As a result of its investigation, the National Transportation Safety Board makes the following new safety recommendations:

To the Federal Motor Carrier Safety Administration:

Determine the prevalence of commercial motor vehicle driver use of impairing substances, particularly synthetic cannabinoids, and develop a plan to reduce the use of such substances. (H-15-38)

Work with motor carrier industry stakeholders to develop a plan to aid motor carriers in addressing commercial motor vehicle driver use of impairing substances, particularly those not covered under current drug-testing regulations—such as by promoting best practices by carriers, expanding impairment detection training and authority, and developing performance-based methods of evaluation. (H-15-39)

To the National Highway Traffic Safety Administration:

Develop, and require compliance with, a side-impact protection standard for all newly manufactured medium-size buses, regardless of weight. (H-15-40)

To the Federal Highway Administration:

Disseminate information to the state departments of transportation about the circumstances of the Davis, Oklahoma, crash and the Oklahoma Department of Transportation revised median cable barrier guidelines that resulted in the installation of a median cable barrier at the crash site. (H-15-41)

To the 50 states, the District of Columbia, and Puerto Rico:

Enact legislation that provides for primary enforcement of a mandatory seat belt use law for all vehicle seating positions equipped with a passenger restraint system. (H-15-42) (Supersedes Safety Recommendation H-97-2)

To the American Trucking Associations, American Bus Association, United Motorcoach Association, Owner-Operator Independent Drivers Association, and Commercial Vehicle Safety Alliance:

Inform your members about the dangers of driver use of synthetic drugs and encourage them to take steps to prevent drivers from using these substances. (H-15-43)

To the American Association of Community Colleges:

Urge your members to adopt and follow the National Collegiate Athletic Association's *Safety in Student Transportation: A Resource Guide for Colleges and Universities*. (H-15-44)

4.2 Reiterated Recommendations

The National Transportation Safety Board also reiterates the following safety recommendations:

To the National Highway Traffic Safety Administration:

Develop and implement, in cooperation with other government agencies and industry, standards for on-board recording of bus crash data that address, at a minimum, parameters to be recorded, data sampling rates, duration of recording, interface configurations, data storage format, incorporation of fleet management tools, fluid immersion survivability, impact shock survivability, crush and penetration survivability, fire survivability, independent power supply, and ability to accommodate future requirements and technological advances. (H-99-54)

In your rulemaking to improve motorcoach roof strength, occupant protection, and window glazing standards, include all buses with a gross vehicle weight rating above 10,000 pounds, other than school buses. (H-10-3)

Require that all buses above 10,000 pounds gross vehicle weight rating be equipped with on-board recording systems that: (1) record vehicle parameters, including, at minimum, lateral acceleration, longitudinal acceleration, vertical acceleration, heading, vehicle speed, engine speed, driver's seat belt status, braking input, steering input, gear selection, turn signal status (left/right), brake light status (on/off), head/tail light status (on/off), passenger door status (open/closed), emergency door status (open/closed), hazard light status (on/off), brake system status (normal/warning), and flashing red light status (on/off; school buses only); (2) record status of additional seat belts, airbag deployment criteria, airbag deployment time, and airbag deployment energy; (3) record data at a sampling rate sufficient to define vehicle dynamics and be capable of preserving data in the event of a vehicle crash or an electrical power loss; and (4) are

mounted to the bus body, not the chassis, to ensure recording of the necessary data to define bus body motion. (H-10-7)

Develop and implement minimum performance standards for event data recorders for trucks with gross vehicle weight ratings over 10,000 pounds that address, at a minimum, the following elements: data parameters to be recorded; data sampling rates; duration of recorded event; standardized or universal data imaging interface; data storage format; and device and data survivability for crush, impact, fluid exposure and immersion, and thermal exposure. The standards should also require that the event data recorder be capable of capturing and preserving data in the case of a power interruption or loss, and of accommodating future requirements and technological advances, such as flashable and/or reprogrammable operating system software and/or firmware updates. (H-10-14)

After establishing performance standards for event data recorders for trucks with gross vehicle weight ratings over 10,000 pounds, require that all such vehicles be equipped with event data recorders meeting the standards. (H-10-15)

To the Federal Highway Administration:

Work with the American Association of State Highway and Transportation Officials to identify cross-median crash rates that call for special consideration when selecting median barriers. (H-11-22)

Work with the American Association of State Highway and Transportation Officials to define the criteria for median barrier selection, including heavy vehicle traffic volume. (H-11-23)

To the American Association of State Highway and Transportation Officials:

Work with the Federal Highway Administration to identify cross-median crash rates that call for special consideration when selecting median barriers, and publish the rates in the *Roadside Design Guide*. (H-11-32)

Work with the Federal Highway Administration to define the criteria for median barrier selection, including heavy vehicle traffic volume, and publish the criteria in the *Roadside Design Guide*. (H-11-33)

4.3 Previously Issued Recommendation Reclassified in This Report

The National Transportation Safety Board reclassifies Safety Recommendation H-97-2 from its current classification of “Open—Acceptable Alternate Response” to “Closed—Superseded” in section 2.4.3, “State Level Seat Belt Use Laws,” of this report (superseded by Safety Recommendation H-15-42).

To the governors and legislatures of the 50 states, the US Territories, and the District of Columbia:

Enact legislation that provides for primary enforcement of mandatory seatbelt use laws, including provisions such as the imposition of driver license penalty points and appropriate fines. Existing legal provisions that insulate people from the financial consequences of not wearing a seatbelt should be repealed. (H-97-2)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

CHRISTOPHER A. HART
Chairman

ROBERT L. SUMWALT
Member

T. BELLA DINH-ZARR
Vice Chairman

EARL F. WEENER
Member

Adopted: November 17, 2015

Appendix A: Investigation

The National Transportation Safety Board was notified of the Davis, Oklahoma, crash on September 26, 2014, and an investigative team was dispatched. Groups were established to investigate human performance; motor carrier operations; and highway, survival, and vehicle factors. Member Robert L. Sumwalt, accompanied by Special Assistant Sean Dalton, was the spokesperson on scene.

Parties to the investigation were representatives from the Federal Motor Carrier Safety Administration, Oklahoma Highway Patrol, Oklahoma Department of Transportation, Quickway Transportation Inc., and PACCAR Inc.

No depositions were taken, and no investigative hearing was held.

Appendix B: *Federal Motor Vehicle Safety Standards Requirements for Buses*

Table B-1 is based on 49 *Code of Federal Regulations* Part 571; the School Bus Manufacturers Technical Council *School Bus Technical Reference*; the National Association of State Directors of Pupil Transportation Services *School Transportation News*, August 2001; and the National Highway Traffic Safety Administration *Federal Motor Vehicle Safety Standards (FMVSS)* for school buses and transit buses.

Table B-1. Required crashworthiness *FMVSSs* for passenger compartments of various bus types.

49 CFR Part 571 FMVSS Number	Small School Bus (GVWR ≤ 10,000 lb)	Large School Bus (GVWR > 10,000 lb)	Small-Size Bus (GVWR ≤ 10,000 lb)	Medium-Size Bus (GVWR 10,000 – 26,000 lb)	Large-Size Bus (GVWR > 26,000 lb)	Motorcoach (over-the-road bus)	Transit Bus
201 Occupant Protection in Interior Impact	•		•				
205 Glazing Materials	•	•	•	•	•	•	•
207 Seating Systems	• ^a				• ^b	• ^b	
208 Occupant Crash Protection	•	• ^c	•		• ^b	• ^b	
209 Seat Belt Assemblies	•	• ^c	•		• ^b	• ^b	
210 Seat Belt Assembly Anchorages	•	• ^c	•		• ^b	• ^b	
213 Child Restraint Systems ^d	•	•	•	•	•	•	•
214 Side-Impact Protection	•		•				
216 Roof Crush Resistance			• ^e				
217 Bus Emergency Exits and Window Retention	•	•	•	•	•	•	•
220 School Bus Rollover Protection	•	•					
221 School Bus Body Joint Strength	•	•					
222 School Bus Seating and Crash Protection	•	•					
225 Child Restraint Anchorage Systems	•		• ^f				
227 <i>Proposed Bus Rollover Structural Integrity</i>					• ^g	• ^g	

^a Applies to small school buses (gross vehicle weight rating [GVWR] of 10,000 pounds or less) manufactured after October 21, 2011.

^b Effective November 28, 2016.

^c Applies to large school buses if voluntarily equipped with seat belts.

^d If equipped with a built-in child restraint system.

^e Based on the April 2009 Final Rule, the phase-in schedule for vehicles with a GVWR greater than 6,000 pounds began in September 2012.

^f Except shuttle buses, defined in FMVSS 225 as a bus with only one row of forward-facing seating positions rearward of the driver's seat.

^g Proposed Rule, 79 *Federal Register* 151, August 6, 2014.

Appendix C: Truck Driver's Occupational History of Drug Use

During the course of this crash investigation, a supervisor with Big Star Trucking, LLC, in Fort Worth, Texas, contacted the NTSB with information pertaining to the truck driver involved in the Davis crash. Big Star was the truck driver's previous employer.

A National Transportation Safety Board (NTSB) investigator interviewed the caller, who stated that the truck driver began showing signs of declining work performance, such as missing work, tardiness, and poor work habits. The supervisor stated that he attempted to counsel the truck driver, who said that he was having extremely difficult personal problems and smoked "K2" (a synthetic cannabinoid) as a way of dealing with stress. The supervisor stated that he was not familiar with "K2." The accident driver had described it as "legal marijuana" and said that it could not be detected by US Department of Transportation drug testing. Concerned by the truck driver's behavior and decline in job performance, the supervisor reported this information to his manager.

NTSB investigators visited the Big Star operations in Fort Worth and interviewed the terminal manager. The manager was familiar with the truck driver and his circumstances. According to the manager, he became aware of the driver's potential drug abuse on September 17, 2013, based on information from one of the employees (the supervisor who called the NTSB hotline), who had reported that the driver was potentially using "K2" during work hours. To address the situation, the manager stated that the next day he went to the Rhome, Texas, yard at 5:00 a.m., where all truck drivers, including the accident driver, reported for duty.

The terminal manager confronted the accident driver concerning these allegations. The driver admitted that he had smoked "K2" before he started employment at Big Star, but said he had not used it since then. The manager, who was trained in reasonable suspicion testing, examined the driver for dilated pupils, slurring of words, swaying, or attention problems. The manager stated that he did not see any symptoms of drug use and documented his findings on September 18, 2013. On September 20, the manager again showed up at the driver's reporting location, early in the morning, to "catch the driver in the act," but he found no symptoms of impairment. The manager stated that he reported these findings to his superiors. He further stated that, while the accident driver was employed at Big Star, he had never witnessed him behaving in a manner that would call for reasonable suspicion drug testing.

According to the Big Star corporate safety manager, the company was very concerned about the accident driver and, as a result of this situation, amended its drug testing policy. In the new policy, the carrier reserves the right to test for synthetic cannabinoids, bath salts, and a hallucinogenic herb (*salvia divinorum*). Big Star provided the NTSB with the results of its drug and alcohol testing, as well as its random testing program for 2013. This program met or exceeded the requirements under 49 *Code of Federal Regulations (CFR)* 382.305. Big Star also provided the NTSB with the driver qualification file for the accident driver. According to these documents, the carrier had complied with 49 *CFR* Part 391 requirements.

Appendix D: Oklahoma Median Cable Barrier Guidelines

The Oklahoma Department of Transportation adopted its median cable barrier guidelines on October 28, 2014. The first stage contains the following seven requirements, each of which should be met to begin considering a median cable barrier at a particular location:

- Posted speed limit of 55 mph or greater.
- At least two through travel lanes in each direction of travel.
- No existing barrier in the median, except short overlaps at transitions or where the existing barrier protects a fixed object.
- All cable barrier median openings located not less than 0.4 mile from each other and from any interchange overpass or underpass.
- No uninterrupted length of cable barrier longer than 2 miles without a median opening or interchange overpass or underpass permitting crossing of the median by emergency vehicles.
- An achievable 6:1 median cross slope, unless cable barrier is to be placed on both sides of the median.
- At least 0.2-mile uninterrupted length of any median cable barrier installation.

The second stage of requirements consists of four primary guidelines:

- **Guideline 1 (Controlled Access):** (1) All fully controlled access highways with a median width of 80 feet or less; (2) all partially controlled access highways with annual average daily traffic (AADT) of 3,500 vehicles or greater and a median width of 80 feet or less.
- **Guideline 2 (Crash History and AADT):** The entirety of any portion of a highway, not less than 1 mile, with substantially similar characteristics of traffic flow, speed, median width, access density, terrain, and geometrics, within which 0.23 or more crossovers per mile have occurred within a 5-year period, and having an average AADT of 10,500 vehicles or greater.
- **Guideline 3 (High Speed, Narrow Median):** Any highway with a speed limit of 65 mph or greater, AADT of 3,500 vehicles or greater, and median width less than 35 feet.
- **Guideline 4 (Gaps):** Any portion of highway up to 1 mile long, adjacent to a portion of the same highway that is provided with median cable barrier, which has

substantially similar characteristics of traffic flow, speed, median width, access density, terrain, and geometrics.

Meeting any one of these second-stage requirements could justify the installation of a median cable barrier as long as that highway segment also meets *all* of the first-stage requirements.

References

- AASHTO (American Association of State Highway and Transportation Officials). 2011. *Roadside Design Guide*, 4th edition. Washington, DC: AASHTO.
- Beck, L. F., and B. A. West. 2011. *Vital Signs: Motor Vehicle Occupant Nonfatal Injuries (2009) and Seat Belt Use (2008) Among Adults—United States*. Atlanta, Georgia: Centers for Disease Control and Prevention.
- Castaneto, M. S., D. A. Gorelick, N. A. Desrosiers, R. L. Hartman, S. Pirard, and M. A. Huestis. 2014. “Synthetic Cannabinoids: Epidemiology, Pharmacodynamics, and Clinical Implication,” *Drug and Alcohol Dependence* 144: 12–41.
- CDC (Centers for Disease Control and Prevention). 2015a. “Morbidity and Mortality Weekly Report,” www.cdc.gov/mmwr/preview/mmwrhtml/mm6422a5.htm?s_cid=mm6422a5_x, accessed June 12, 2015.
- _____. 2015b. “Motor Vehicle Prioritizing Interventions and Cost Calculator for States,” www.cdc.gov/motorvehiclesafety/calculator/index/html, accessed June 5, 2015.
- Chen, Y. Y. 2015. *Seat Belt Use in 2014, Use Rates in the States and Territories*, DOT HS 812 149. Washington, DC: National Highway Traffic Safety Administration.
- CVSA (Commercial Vehicle Safety Alliance). 2015. *North American Standard Out-of-Service Criteria Handbook and Pictorial*. Greenbelt, Maryland: CVSA.
- DEA (Drug Enforcement Administration). 2015. “Title 21 United States Code (USC) Controlled Substances Act,” www.deadiversion.usdoj.gov/21cfr/21usc/811.htm, accessed January 2, 2015.
- Douma, F., and Tilahun, N. 2012. *Impacts of Minnesota’s Primary Seat Belt Law*. Minneapolis, Minnesota: Center for Excellence in Rural Safety.
- Farmer, C., and A. Williams. 2004. *Effect on Fatality Risk of Changing From Secondary to Primary Seat Belt Enforcement*. Ruckersville, Virginia: Insurance Institute for Highway Safety.
- FMCSA (Federal Motor Carrier Safety Administration). 2014. *Results From the 2011 Drug and Alcohol Testing Survey*, Analysis Brief. Washington, DC: FMCSA.
- GHSA (Governors Highway Safety Association). 2015. “Seat Belt Laws,” www.ghsa.org/html/-stateinfo/laws/-seatbelt_laws.html.
- Johnston, L. D., P. M. O’Malley, R. A. Miech, J. G. Bachman, and J. E. Schulenberg. 2014a. *Monitoring the Future National Results on Drug Use: 1975–2013, Overview, Key Findings on Adolescent Drug Use*. Ann Arbor, Michigan: Institute for Social Research.

- _____. 2014b. *Monitoring the Future National Results on Drug Use: 1975–2013, Volume 2, College Students and Adults Ages 19–55*. Ann Arbor, Michigan: Institute for Social Research.
- Musshoff, F., B. Madea, G. Kernbach-Wighton, W. Bicker, S. Kneisel, M. Hutter, and V. Auwärter. 2014. “Driving Under the Influence of Synthetic Cannabinoids (‘Spice’): A Case Series,” *International Journal of Legal Medicine* 128 (1): 59–64.
- NCHRP (National Cooperative Highway Research Program). 2012. *Guidance for the Selection, Use and Maintenance of Cable Barrier Systems*, Report 711. Washington, DC: Transportation Research Board.
- NCTC (North Central Texas College). 2013. “Vehicle Use Policy,” *Administrative Procedure Manual*.
- NHTSA (National Highway Traffic Safety Administration). 2012. *Notice of Proposed Rulemaking: Federal Motor Vehicle Safety Standards: Event Data Recorders*, NHTSA-2012-0177-0001. Washington, DC: NHTSA.
- _____. 2009. “Occupant Protection,” *Traffic Safety Facts*, DOT HS 811 160. Washington, DC: NHTSA.
- _____. 1984. *Final Regulatory Impact Analysis Amendment to Federal Motor Vehicle Safety Standard 208, Passenger Car Front Seat Occupant Protection*, DOT HS 806 572. Washington, DC: NHTSA.
- NTSB (National Transportation Safety Board). 2011. *Truck-Tractor Semitrailer Median Crossover Collision With 15-Passenger Van, Munfordville, Kentucky, March 26, 2010*, NTSB/HAR-11/02. Washington, DC: NTSB.
- _____. 2010a. *Bus Loss of Control and Rollover, Dolan Springs, Arizona, January 30, 2009*, NTSB/HAR-10/01. Washington, DC: NTSB.
- _____. 2010b. *Truck-Tractor Semitrailer Rear-End Collision Into Passenger Vehicles on Interstate 44 Near Miami, Oklahoma, June 26, 2009*, NTSB/HAR-10/02. Washington, DC: NTSB.
- _____. 2003. *In-Flight Electrical System Failure and Loss of Control, Jet Express Services, Raytheon (Beechcraft) Super King Air 200, N81PF, Near Strasburg, Colorado, January 27, 2001*, NTSB/AAR-03-01. Washington, DC: NTSB.
- _____. 1999. *Bus Crashworthiness*, NTSB/SIR-99/04. Washington, DC: NTSB.
- _____. 1998. *Multiple Vehicle Crossover Accident, Slinger, Wisconsin, February 12, 1997*, NTSB/HAR-98/01. Washington, DC: NTSB.

- _____. 1997. *Proceedings of the National Transportation Safety Board Public Forum on Air Bags and Child Passenger Safety, March 17–20, 1997*, NTSB/RP-97/01. Washington, DC: NTSB.
- _____. 1988. *Performance of Lap/Shoulder Belts in 167 Motor Vehicle Crashes, Volume 1*, NTSB/SS-88/02. Washington, DC: NTSB.
- _____. 1986. *Performance of Lap Belts in 26 Frontal Crashes*, NTSB/SS-86/03. Washington, DC: NTSB.
- NYT (New York Times). 2015. “Potent ‘Spice’ Drug Fuels Rise in Visits to Emergency Room,” www.nytimes.com/2015/04/25/health/surge-in-hospital-visits-linked-to-a-drug-called-spice-alarms-health-officials.html?_r=1, accessed May 1, 2015.
- ODOT (Oklahoma Department of Transportation). 1992. *Roadway Design Manual*. Oklahoma City, Oklahoma: ODOT.
- Progressive Engineering, Inc. 1999. *Champion Bus FMVSS 221 Test on Galvanized and Fiberglass Body Panel Joints*, Test Report 99-498. Goshen, Indiana.
- Seely, K. A., J. Lapoint, J. H. Moran, and L. Fattore. 2012. “Spice Drugs are More Than Harmless Herbal Blends: A Review of the Pharmacology and Toxicology of Synthetic Cannabinoids,” *Progress in Neuro-Psychopharmacology & Biological Psychiatry* 39: 234–243.
- Spaderna, M., P. Addy, and D. D’Souza. 2013. “Spicing Things Up: Synthetic Cannabinoids,” *Psychopharmacology* 228: 525–540.
- US Army. 2014. “Expansion of Synthetic Cannabinoids to Military Urinalysis Testing,” acsap.army.mil/Pdf/ALARACT%20310-2013.pdf, accessed December 29, 2014.
- Wish, E. D., E. E. Artigiani, and A. S. Billing. 2013. “Community Drug Early Warning System: The CDEWS Pilot Project,” www.whitehouse.gov/sites/default/files/finalreport_with_cover_09172013.pdf, accessed October 20, 2015. Washington, DC: Executive Office of the President, Office of National Drug Control Policy.
- Yeakel, J. K., and B. K. Logan. 2013. “Blood Synthetic Cannabinoid Concentrations in Cases of Suspected Impaired Driving,” *Journal of Analytical Toxicology* 37 (8): 547–551.