Motorcoach Run-Off-the-Road and Overturn
US Highway 83
Laredo, Texas
May 14, 2016

Accident Report

NTSB/HAR-18/03
PB2019-100083

National
Transportation
Safety Board

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Notation 57900
Adopted November 7, 2018

Highway Accident Report

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National
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Safety Board

490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2018. ***Motorcoach Run-Off-the-Road and Overturn, US Highway 83, Laredo, Texas, May 14, 2016*****. Highway Accident Report NTSB/HAR-18/03. Washington, DC.**

Abstract: On Saturday, May 14, 2016, shortly before 11:24 a.m., central daylight time, a 1998 Van Hool 49-passenger motorcoach, operated by OGA Charters LLC of San Juan, Texas, was traveling northbound on US Highway 83 near Laredo, Texas. The motorcoach entered a horizontal curve to the right, and, as it moved through the curve, it drifted from its lane to the left. After the motorcoach drifted left, the driver steered to the right and applied the brakes, which resulted in the vehicle's loss of control, so that it slid and yawed clockwise. The motorcoach departed the right, or east, side of the highway and, after entering the earthen right-of-way, overturned onto its left side. Nine passengers died, 36 passengers experienced minor-to-serious injuries, and the motorcoach driver and trip coordinator were treated for minor injuries. The injury severity for five passengers could not be determined.

The investigation focused on the following safety issues: inadequate federal oversight and guidance for commercial drivers with diabetes treated without insulin; inaccurate and incomplete highway maintenance recordkeeping by the Texas Department of Transportation (TxDOT); need for improved training for TxDOT maintenance workers; need for increased motorcoach crashworthiness through improvements to window glazing and retention; driver fatigue resulting from poor safety management by OGA Charters and inadequate federal safety ratings for passenger motor carriers with repetitive safety violations in the area of driver performance.

As a result of this investigation, the National Transportation Safety Board (NTSB) makes new safety recommendations to Federal Motor Carrier Safety Administration (FMCSA) and TxDOT. The NTSB also reiterates two recommendations to the FMCSA and one recommendation to the National Highway Traffic Safety Administration.

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Figures and Tables

Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ABS	antilock braking system
AME	aviation medical examiner
ASTM	American Society for Testing and Materials International
BASIC	behavior analysis safety improvement category [FMCSA]
BMI	body mass index
CBP	US Customs and Border Protection
CDC	Centers for Disease Control and Prevention
CDL	commercial driver's license
CFR	*Code of Federal Regulations*
CME	certified medical examiner
CSMS	Carrier Safety Measurement System [FMCSA]
DAR	daily activity report [TxDOT]
DOT	US Department of Transportation
EMS	emergency medical service
EMT	emergency medical technician
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMCSRs	*Federal Motor Carrier Safety Regulations*
GVWR	gross vehicle weight rating
ISD	Independent School District
kg/m^2	kilograms per square meter
MAP-21	Moving Ahead for Progress in the 21st Century Act
mg/dl	milligrams per deciliter
MM	mile marker

NHTSA	National Highway Traffic Safety Administration
NPRM	notice of proposed rulemaking
NTSB	National Transportation Safety Board
NVIC	Navigation and Vessel Inspection Circular
PMS	pavement management system
PSAP	[Webb County] Public Service Answering Point
psi	pounds per square inch
RM	mile marker (alternative abbreviation)
SFD	safety fitness determination [FMCSA]
TFHRC	Turner-Fairbank Highway Research Center [FHWA]
TxDOT	Texas Department of Transportation
TxDPS	Texas Department of Public Safety
US-83	US Highway 83

Executive Summary

Investigation Synopsis

On Saturday, May 14, 2016, shortly before 11:24 a.m., central daylight time, a 1998 Van Hool 49-passenger motorcoach, operated by OGA Charters LLC of San Juan, Texas, was traveling northbound on US Highway 83 near Laredo, Texas. The motorcoach entered a horizontal curve to the right, and, as it moved through the curve, it drifted from its lane to the left. After the motorcoach drifted left, the driver steered to the right and applied the brakes, which resulted in the vehicle's loss of control, so that it slid and yawed clockwise. The motorcoach departed the right, or east, side of the highway and, after entering the earthen right-of-way, overturned onto its left side. Nine passengers died, 36 passengers experienced minor-to-serious injuries, and the motorcoach driver and trip coordinator were treated for minor injuries. The injury severity for five passengers could not be determined.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the Laredo, Texas, crash was the driver's failure to maintain the motorcoach fully within the northbound travel lane, due to a combination of fatigue from an acute sleep deficit and blurred distance vision due to hyperglycemia resulting from poorly controlled diabetes; then, as the motorcoach drifted left from the travel lane, the driver abruptly steered to the right and braked, causing the vehicle to leave the highway and roll over. Contributing to the driver's inability to regain control of the motorcoach was the low friction value of the wet pavement and the inoperable antilock braking system. Contributing to the severity of the passenger injuries was the failure of the left side passenger windows to keep passengers within the motorcoach.

Safety Issues

The crash investigation focused on the following safety issues:

- Inadequate federal oversight and guidance for commercial drivers with diabetes treated without insulin.
- Inaccurate and incomplete highway maintenance recordkeeping by the Texas Department of Transportation (TxDOT), leading to deficiencies in conducting safety-critical highway maintenance.
- Need for improved training for TxDOT maintenance workers to ensure that roadway maintenance operations result in acceptable levels of surface friction.
- Need for increased motorcoach crashworthiness through improvements to window glazing and retention.

- Driver fatigue resulting from poor safety management by OGA Charters and inadequate federal safety ratings for passenger motor carriers with repetitive safety violations in the area of driver performance.

Recommendations

As a result of this investigation, the National Transportation Safety Board (NTSB) makes new safety recommendations to the Federal Motor Carrier Safety Administration (FMCSA) and TxDOT. The NTSB also reiterates two recommendations to the FMCSA and one recommendation to the National Highway Traffic Safety Administration.

1 Factual Information

1.1 Crash Narrative

Shortly before 11:24 a.m., central daylight time, on May 14, 2016, a 1998 Van Hool 49-passenger motorcoach, operated by OGA Charters LLC of San Juan, Texas (OGA Charters), was traveling northbound on US Highway 83 (US-83) near the city of Laredo, in Webb County, Texas.[1] (See figure 1.) The motorcoach, occupied by the driver, a trip coordinator, and 50 passengers, was en route from Brownsville, Texas, to the Kickapoo Lucky Eagle Casino Hotel in Eagle Pass, Texas.[2] During the trip, rain showers were encountered, and the pavement was wet.

Figure 1. Route map for OGA Charters motorcoach for May 14, 2016, trip.

[1] Unless otherwise specified, all times in this report are central daylight time.

[2] In addition to its 49 passenger seats, the motorcoach had a jump seat in the loading door area. The tour coordinator did not have a seat available to her; during the trip, she stood in the vehicle's center aisle.

In the vicinity of mile marker (MM) 670.7, the northbound motorcoach entered a horizontal curve to the right. Roadway evidence and postcrash simulations (discussed in section 1.9) suggest that, while in the curve, the motorcoach drifted out of its lane to the left, and the driver made sudden steering and braking input to correct the drift. During a postcrash interview, the motorcoach driver said that he recalled applying the brakes and feeling the bus slide before going off the road. Near the end of the curve, the motorcoach departed the right, or east, side of the highway. The vehicle overturned 90 degrees onto its left side. The motorcoach continued to yaw clockwise and came to rest with its front end partially on the eastern edge of the northbound roadway. (See figures 2, 3, and 4.)

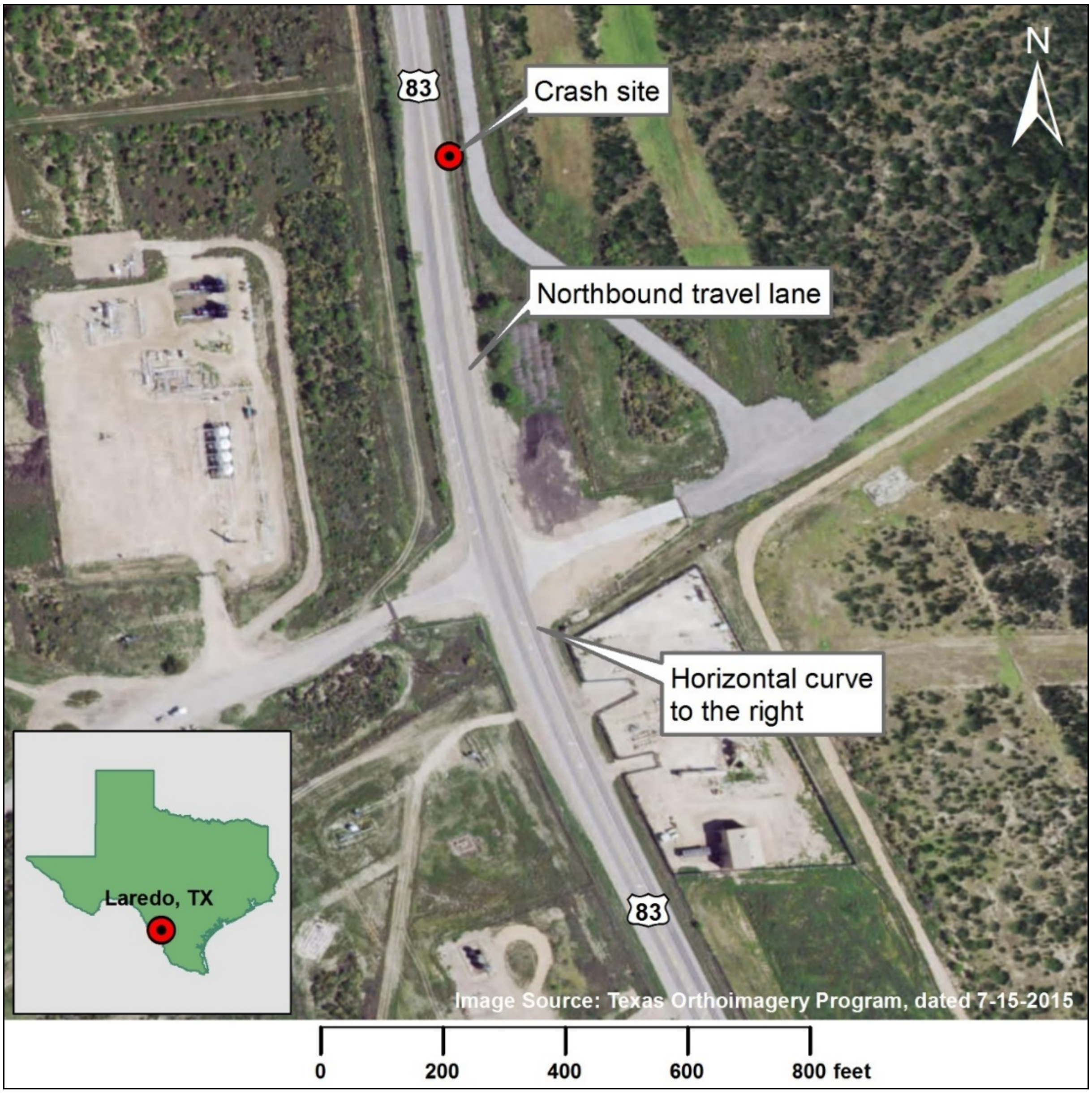

Figure 2. Approach to crash site on US-83, Laredo, Texas.

Figure 3. View of front left of motorcoach at its approximate final rest position. The left side of the vehicle has been partially raised and supported to facilitate extrication of the occupants. (Source: Texas Department of Public Safety)

Figure 4. View of left side of motorcoach after the vehicle was uprighted from its final rest position. (Source: Texas Department of Public Safety)

1.2 Injuries

Nine passengers died as a result of this crash. Of those nine passengers, seven died at the crash scene, one died after being transported to the hospital, and one died in the hospital 6 days after the crash. Autopsy reports from the Webb County medical examiner show that eight deaths were caused by multiple blunt force injuries, and one death resulted from a neck fracture. Thirty-six passengers suffered injuries of varying degrees; serious injuries included internal blunt force trauma, rib fractures, and extremity fractures. Medical records and related injury information for five passengers could not be obtained due to incomplete personal information. The driver and trip coordinator had minor injuries. Occupants were transported to three local hospitals for treatment. (See table 1.)

Table 1. Injuries.

Injury Severity[a]	Fatal	Serious	Minor	Unknown	TOTAL
Motorcoach driver	0	0	1	0	1
Motorcoach trip coordinator	0	0	1	0	1
Motorcoach passengers	9	20	16	5	50
TOTAL	9	20	18	5	52

[a] Although 49 *Code of Federal Regulations* (CFR) Part 830 pertains to the reporting of aircraft accidents and incidents to the National Transportation Safety Boad (NTSB), section 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.

1.3 Emergency Response

The crash location was under the jurisdiction of the Texas Department of Public Safety (TxDPS), and officers from the Laredo office were responsible for the primary response to the crash. However, two agents from US Customs and Border Protection (CBP) were the initial first responders. The CBP agents had been on patrol in the area when they encountered the crash shortly after it occurred. TxDPS dispatch records documented two phone calls from CBP agents reporting the crash; one was made at 11:24 a.m. and a second at 11:25 a.m. The TxDPS dispatcher and the Webb County Public Service Answering Point (PSAP) received three additional calls about the crash between 11:26 a.m. and 11:28 a.m. A Webb County sheriff’s deputy, who had originally been dispatched to another collision before the crash, was in the vicinity and was redirected to the motorcoach crash. The deputy, with another nearby CBP agent, arrived within 10 minutes of the crash. Both officers were trained emergency medical technicians (EMTs), and they began assisting the injured. The Webb County PSAP dispatched emergency medical services (EMS) and fire/rescue services. Angel Care Ambulance was the contracted EMS provider, and its units were en route by 11:27 a.m. The Webb County Fire Department had fire/rescue jurisdiction, and its first units were en route by 11:30 a.m. TxDPS officers were en route to the crash by 11:31 a.m.

After the first four officers arrived, additional CBP agents who were nearby also responded. The CBP agents and the Webb County sheriff’s deputy performed initial triage and evacuation activities while medical assistance was en route. Civilian personnel working near the crash also helped. The sheriff's deputy worked part time at Angel Care, and he communicated pertinent injury information to Angel Care by telephone. Mutual aid EMS and fire/rescue services were assigned by 11:30 a.m. Angel Care also contacted neighboring jurisdictions for mutual aid EMS support. Mutual aid services responding included agencies from the neighboring LaSalle and Dimmit Counties, including Bronze Star Ambulance, Cotulla Fire and EMS, and Camino Real Ambulance, as well as the City of Laredo Fire Department and EMS. Air evacuation services were requested, but at 11:47 a.m., and again at 12:35 p.m., the Webb County PSAP was advised that weather conditions precluded airborne evacuation.

Because of the severity of the crash, the CBP dispatched additional agents to assist with the injured, secure the scene, and provide traffic control. The CBP had been operating a traffic checkpoint on US-83, about 10 miles south of the crash. About 11:43 a.m. the CBP closed the checkpoint, freeing additional CBP agents to assist with the crash. At that same time, agents set up traffic control at the intersection of US-83 and State Highway 44, restricting northbound traffic on US-83 to emergency vehicles only. A CBP supervisor also responded to the crash and assumed incident command. He initiated a mass casualty incident, which brought aid from all local jurisdictions. In all, 25 CBP agents, 6 of whom were EMTs, assisted with the crash. Once Webb County Fire Department personnel arrived, the CBP transferred incident command duties to them. The CBP agents departed the scene about 20 minutes later.

The TxDPS dispatcher logged the arrival of its first officer at the crash site at 11:54 a.m. At 11:59 a.m., the dispatcher was notified that the crash involved severely injured passengers, some of whom were trapped in and under the motorcoach, and that some might have been fatally injured. The Webb County medical examiner's office was notified at 12:02 p.m. The first fire/rescue units were reported on the scene at 12:05 p.m., and by 12:14 p.m., three ambulances were on scene and an additional nine were reported to be en route.

A telescopic handler to lift the motorcoach and assist with extricating trapped passengers was brought on scene by about 12:14 p.m., and fire/rescue responders took control of the rescue operations.[3] Postcrash interviews with first responders and passengers indicated that some passengers had been partially or fully ejected out of the motorcoach's left side windows and that some were trapped under the left side of the vehicle.[4] Forty-four passengers were transported by seven EMS agencies to three hospitals. Patient care reports logged the arrival times of patients at the hospitals as between 12:54 p.m. and 2:55 p.m.

1.4 Driver Information

1.4.1 Certification, License, and Driving History

The 29-year-old motorcoach driver held a Texas class A commercial driver's license (CDL) with endorsements allowing him to engage in operations involving passenger

[3] A telescopic handler, also referred to as a telehandler, teleporter, or boom lift, is a machine that shares characteristics with a heavy-duty forklift. These machines are intended for outdoor use and are widely used in agriculture and industry.

[4] The exact number of partially ejected, ejected, and trapped passengers could not be determined.

transportation, school buses, cargo tanks, and double or triple trailers.[5] The driver's license included a restriction requiring that he wear corrective lenses while operating a vehicle. (He was wearing glasses at the time of the crash.) The license was issued in August 2015 and would expire in February 2021. His most recent medical certificate was issued in February 2016 and would expire in February 2017.

The driver first obtained a Texas CDL in 2010, following successful completion of a 6-week CDL course at South Texas College in McAllen, Texas. At the end of the course, the driver was qualified for a class A CDL with endorsements for both cargo tank and double or triple trailer operations. After obtaining his CDL, the driver trained at a trucking company to become an over-the-road freight driver; however, he reported that, during this training, he found that he did not enjoy that type of work and left after only a couple of days. Later in 2010, he began employment as a driver for the Valley View Independent School District (ISD) in Pharr, Texas. While employed there, he received additional training and obtained endorsements for school bus and passenger operations.

NTSB investigators examined the driver's Commercial Driver's License Information System record, which showed no convictions for traffic violations or crashes. During an interview with investigators, the driver stated that, in October 2015, he had been issued a citation in Georgia for an improper lane change. (No record of the citation was found.)

1.4.2 Employment Background

The driver began working as a commercial bus driver in 2010, operating school buses and motorcoaches for the Valley View ISD. In 2012, the driver left the Valley View ISD and began driving school buses for the McAllen ISD. Beginning in March 2015, in addition to his full-time employment as a school bus driver, he began working as an occasional driver for two Texas charter bus companies—Santa Rosa Express, located in McAllen, and the carrier he was driving for when the crash occurred, OGA Charters, located in San Juan. In April 2015, the driver also started driving on an as-needed basis for Escamilla Tour Bus, located in McAllen.

1.4.3 Precrash Activities

NTSB investigators determined the motorcoach driver's activities for the 5 days preceding the crash using information from a postcrash interview, as well as his personal cell phone records, employment records, and hours-of-service logs. The driver's primary employment involved driving a school bus for the McAllen ISD, where he typically worked a split shift. His morning shift was from 6:00 a.m. to 9:00 a.m. and his afternoon shift was from 3:00 p.m. to 6:00 p.m. In the week before the crash, the driver worked this schedule Monday through Thursday.

On Friday, May 13, the day before the crash, the driver took the day off from his school bus driving job and chose instead to drive a chartered trip for OGA Charters. The driver went on duty that morning at 3:45 a.m. and an hour later picked up passengers in Weslaco, Texas. The trip destination was an amusement park in San Antonio, Texas, a distance of about 248 miles. After dropping off the passengers at the amusement park, the driver parked the motorcoach on the

[5] A Texas class A commercial driver's license is required to operate vehicles with a gross combination weight rating of 26,001 pounds or more, including a towed vehicle heavier than 10,000 pounds.

premises and remained onboard the vehicle, going off duty at 10:30 a.m. The driver told investigators that he kept the bus running so that the air conditioner would stay on, and he lay down across seats at the back of the vehicle to rest and sleep. The driver said he thought he fell asleep sometime between 10:30 a.m. and 11:00 a.m. and remained asleep until 5:00 p.m., when he woke up and got something to eat. The driver's cell phone records indicate that during the time that he reported that he had been asleep or resting, he used his cell phone on five separate occasions, making his first call at 11:24 a.m. and receiving the fifth call at 4:53 p.m.[6] The driver made three additional phone calls before going back on duty at 6:15 p.m., at which time he loaded the passengers and began the trip back to Weslaco. The driver dropped the passengers off in Weslaco at 10:30 p.m., drove back to his residence—where he kept the OGA Charters motorcoach—and went off duty an hour later at 11:30 p.m.

On Saturday, May 14, the day of the crash, the driver made two brief calls on his cell phone, one at 12:07 a.m. and another at 12:27 a.m. before going to sleep. The driver reported that he woke up at 2:30 a.m. (to take medication) and prepared for the day, during which he would be driving another trip for OGA Charters. He went on duty at 3:30 a.m., when he left his residence en route to Brownsville, Texas, to pick up passengers. After driving about 54 miles, he arrived in Brownsville at 5:00 a.m. and picked up the majority of his passengers. The destination for the chartered trip was the Kickapoo Lucky Eagle Casino Hotel in Eagle Pass, Texas, about 330 miles northwest of Brownsville.

After departing Brownsville, the driver traveled west and made several brief stops to pick up additional passengers in the Harlingen and McAllen areas. The final passengers were picked up in Palmview, Texas, after which the motorcoach was filled to capacity, including one passenger occupying the jump seat at the front of the motorcoach. The tour coordinator did not have a seat available to her; during the trip, she led the passengers in games and activities while standing in the vehicle's center aisle. Following the final pickup stop in Palmview, the driver continued driving for 82 miles before stopping in Zapata, Texas, at 9:00 a.m.

In Zapata, the driver allowed passengers to leave the vehicle, so they could eat and use the restroom while he refueled the bus. The motorcoach departed Zapata at 9:30 a.m. and continued northbound on US-83. It was stopped at a CBP checkpoint on US-83 near the intersection with State Highway 44. CBP agents boarded the bus and verified passengers' residency information before allowing the driver to continue the trip. After departing the CBP checkpoint, the motorcoach traveled an additional 10 miles north on US-83; the crash occurred a short time later, just before 11:24 a.m.

Cell phone records indicate that the driver sent four text messages between 10:30 a.m. and 10:42 a.m., but he was not using a cell phone at the time of the crash. (See figure 5 for a chart that summarizes the driver's on-duty time, sleep opportunities, and cell phone usage from May 9 until the crash on May 14.)

[6] (a) NTSB investigators found that the driver had used two different cell phones during the precrash period. (b) Between the two calls cited, the driver also made one call at 12:43 p.m., made another at 2:46 p.m., and received a call at 3:49 p.m.

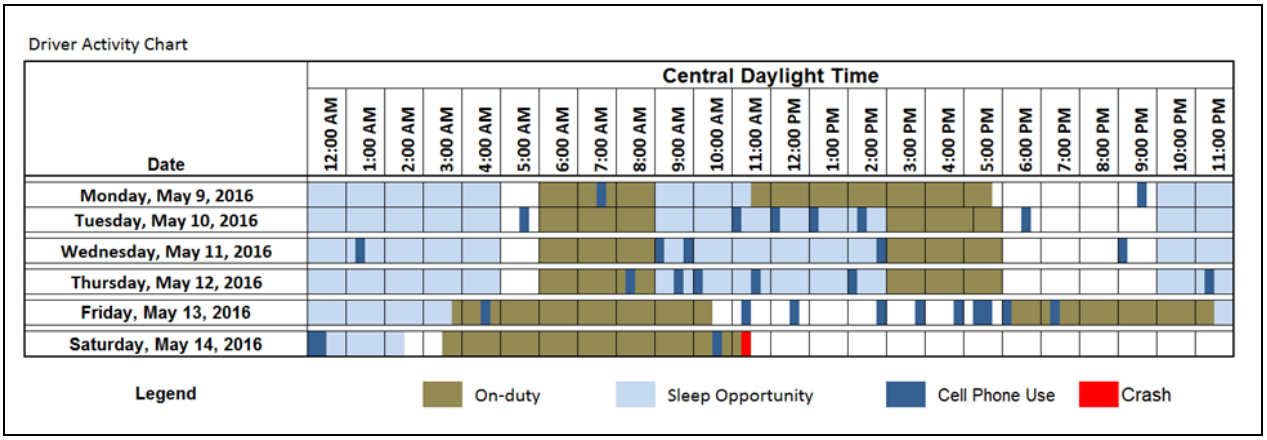

Figure 5. Driver's work/sleep history and cell phone use in the days preceding the crash.

1.4.4 Medical History and Toxicology

The driver's medical history was examined using information from his two most recent CDL medical certification exams, postcrash emergency care records, and postcrash toxicology results. An NTSB medical investigator also reviewed records maintained by the driver's primary care physician from January 2014 through February 2016.

Information from the driver's February 24, 2016, commercial driver medical exam showed the 29-year-old driver's height to be 69 inches (5 feet 9 inches) and his weight to be 233 pounds, resulting in a body mass index (BMI) of 34 kilograms per square meter (kg/m^2).[7] The driver self-reported that he had hypertension and type 2 diabetes and was taking lisinopril and dapagliflozin for those conditions. The certified medical examiner (CME) noted that hypertension and diabetes had been diagnosed in 2015. The driver's blood pressure was 138/80, his pulse was 72, and the record indicated that an "FBS" was measured at 95.[8] The driver's urine dip test had specific gravity of 1.015, was negative for blood and protein, and was positive for "500" glucose.[9] His corrected vision in each eye was reported as 20/20; his uncorrected vision was not reported.[10] No abnormalities were noted on the physical exam, and the driver was certified for 1 year with a requirement that he wear corrective lenses when driving.

The results from the driver's earlier August 27, 2015, medical examination differed in some ways from the February 2016 exam results. During the 2015 exam, the driver reported having hypertension and type 2 diabetes treated with lisinopril and a combination product containing

[7] BMI is calculated by dividing the weight of the person by the square of their body surface area. BMI results between 25 and 30 indicate that the person is overweight; results above 30 indicate obesity. BMI is universally expressed in units of kg/m^2.

[8] The report was unclear whether "FBS" was intended to indicate "fasting blood sugar" or "fingerstick blood sugar." No units or other descriptors were given, but blood glucose is typically measured in milligrams per deciliter (mg/dl) in the United States. Normal fasting numbers are considered between 70 and 99 mg/dl. Fasting levels above 126 mg/dl indicate diabetes.

[9] (a) Specific gravity is a measure of the concentration of the urine. (b) Normal urine results are negative for blood, protein, and glucose. No glucose units were given in this result, but they are typically provided in mg/dl. Glucose begins to spill into urine when blood glucose levels are above about 180 mg/dl. Use of dapagliflozin may increase urine glucose.

[10] Medical information concerning the driver's vision was limited because he obtained vision care in Mexico.

metformin and saxagliptin. During this examination, his height was recorded as 68 inches (5 feet 8 inches) and his weight was recorded as 268 pounds, resulting in a BMI of 36.3 kg/m^2. The driver's urine dip test had a specific gravity of greater than or equal to 1.030, and his urine was negative for blood, protein, and glucose. The physician who performed the exam noted "Hgb A1C 10.2 percent."[11] His corrected vision in each eye was reported as 20/20; his uncorrected vision was not reported. No abnormalities were noted on the physical exam, and the driver was certified for 6 months with a requirement that he use corrective lenses when driving.

About 3 hours after the Laredo crash, the driver arrived at the hospital. His urinalysis demonstrated a specific gravity of 1.005 and was positive for 4+ glucose and 3+ ketones.[12] A blood sample drawn at 3:13 p.m. had a blood glucose of 373 mg/dl; the remainder of his blood count and chemistries were normal.[13] According to a note in the hospital lab records, this blood glucose value was considered critically high, and lab personnel verbally reported it to emergency department personnel. However, nothing in the emergency department records indicated any action taken by the treating providers to address the driver's glucose level. The emergency physician who was treating the driver gave a final diagnosis of multiple contusions and discharged him from the emergency department later that day.

An initial clinical screen of the driver's urine by the hospital was negative for amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine, methadone, opiates, and phencyclidine. The results of toxicology testing of the driver's urine, performed in compliance with Federal Motor Carrier Safety Administration (FMCSA) postcrash drug test requirements, were negative.[14] Remaining samples of the driver's blood and urine were provided to the Federal Aviation Administration (FAA) Bioaeronautical Sciences Research Laboratory for toxicology testing. The results were negative for alcohol and other drugs.[15] Clinical testing of the blood revealed 2 mg/dl of acetone. Clinical testing of the urine revealed 5,247 mg/dl of glucose, 12 mg/dl of acetone, and the presence of salicylate.[16] The hemoglobin A1C was measured at 12.7 percent.[17]

[11] "Hgb A1C" is medical shorthand for hemoglobin A1C. The level of 10.2 percent indicates poor diabetes control with average glucose about 250–270 mg/dl. The source of this information is unclear from the exam form.

[12] Glucose and ketones are typical findings from dip urine results. These results are categorized as 0 (normal), trace, and 1+ to 4+ in reference to the degree of color change.

[13] Normal random glucose values range between 70 and 150 mg/dl.

[14] Testing was conducted through Genesis Drug Testing, located in Laredo. The testing was limited to identifying urinary metabolites of amphetamine, methamphetamine, cocaine, codeine, morphine, heroin, phencyclidine, methylenedioxymethamphetamine, methylenedioxyamphetamine, methylenedioxyethylamphetamine, and tetrahydrocannabinol.

[15] Toxicological testing included more than 1,300 substances; see the FAA WebDrugs website for a complete listing, accessed July 5, 2018.

[16] Acetone is a byproduct of the metabolic distortion caused by uncontrolled diabetes. Salicylate is a metabolite of aspirin, an over-the-counter anti-inflammatory drug used to treat fever, pain, or inflammation that also has platelet-inhibiting effects, for which it may be used to prevent recurrent heart attacks.

[17] This level of hemoglobin A1C (12.7 percent) indicates that the driver's blood glucose had averaged about 318 mg/dl over the preceding several weeks (Nathan and others 2008).

1.5 Vehicle Information

1.5.1. General

The 49-passenger 1998 Van Hool model T2140 motorcoach was manufactured in October 1997 and was equipped with a Detroit Diesel Corporation Series 60 six-cylinder electronically controlled diesel engine and an Allison B500 six-speed automatic transmission. Engine management functions were performed by a Detroit Diesel Electronic Controls Series III engine control module. The motorcoach was also equipped with a WABCO 2P/1E antilock braking system (ABS) designed to control a combination of disc and drum-type brakes.

As manufactured, the motorcoach was 40 feet long and had a gross vehicle weight rating (GVWR) of 45,650 pounds.[18] The motorcoach was equipped with 315/80R22.5 tires mounted on 22.5 X 8.25 steel wheels. The brakes on the first and third axles were pneumatically operated disc brakes; the second axle was equipped with pneumatic drum brakes.[19] The odometer reading at the time of the crash was 919,354 miles. The motorcoach's most recent annual inspection occurred on February 4, 2016.[20]

1.5.2 Postcrash Inspections

Following the crash, investigators examined the tires on the motorcoach and found no evidence of tire failure. All tires were found to be inflated. According to federal regulations, the minimum tread depth for tires on the motorcoach steer axle is 4/32 inch; for tires on the remaining two axles, the minimum depth is 2/32 inch.[21] Table 2 provides the inflation values and minimum tire tread depths recorded by investigators during the postcrash inspection.

Table 2. Vehicle tire information.

Tire Location	Pressure (pounds per square inch [psi])	Average Tread Depth
Axle I (steer axle) – left side	108 psi	20/32 inch
Axle I (steer axle) – right side	108 psi	19/32 inch
Axle II – left side (inboard)	110 psi	16/32 inch
Axle II – left side (outboard)	106 psi	16/32 inch
Axle II – right side (inboard)	120 psi	8/32 inch

[18] The GVWR is the total maximum weight that a vehicle is designed to carry when loaded, including the weight of the vehicle itself plus fuel, passengers, and cargo.

[19] The first or front axle is also referred to as the steer axle. It relays driver steering inputs to the wheels. The second axle is referred to as the drive axle, and it connects engine power to the wheels. The third axle is referred to as the tag axle and is used to support a portion of the vehicle's weight.

[20] Title 49 CFR 396.17 specifies that every commercial motor vehicle shall be inspected at least once during each 12-month period and that all vehicle parts and accessories must meet the minimum requirements in appendix G of the section's subchapter.

[21] Title 49 CFR 393.75 specifies that tread depth shall be measured in a major groove at any location on the tire and not where tie bars, humps, or fillets are located.

Tire Location	Pressure (pounds per square inch [psi])	Average Tread Depth
Axle II – right side (outboard)	102 psi	7/32 inch
Axle III – left side	96 psi	6/32 inch
Axle III – right side	100 psi	5/32 inch

Excluding the inboard tire on the dual wheel assembly for axle II, all of the tire positions on the left side of the motorcoach were found to have dirt and vegetation embedded between the tire bead and outboard wheel flange. Additionally, excluding those tires on the right side of axle I, all tire treads exhibited patches of roadway abrasion.

The motorcoach was equipped with type 24 long-stroke brake chambers actuating the disc brakes on axle I, type 36 brake chambers for both the service and parking brakes on axle II's drum brakes, and type 20 brake chambers for the disc brakes on axle III. The brake discs, drums, and brake linings on all axles were visually inspected. Investigators measured the brake linings, and all were found to exceed minimum thickness requirements.[22]

Engine damage from the crash required that postcrash testing of the brake system use an external source of air. Pressurized air regulated to 95 psi was applied to the vehicle's air brake system to verify that check valves within the system were working as designed. The testing found that the audible and visual warnings for low air pressure were operational on both the primary and secondary air systems. To evaluate the vehicle's brake adjustments, pressure for the external air source was reset to 90 psi, and measurements were taken at each brake assembly. The brake stroke adjustment for the left drum brake on axle II was found to be 2.5 inches, while the stroke on the right brake was measured at 3 inches. Both brakes were out of adjustment and exceeded the maximum stroke limit of 2.25 inches.[23]

Although at the time of the motorcoach's manufacture, an ABS was not required equipment, the motorcoach was equipped with an optional Wabco ABS and had sensors and modulators at all six wheel positions.[24] During the postcrash inspection, the ABS was found to be nonoperational due to broken and disconnected wires, as well as a missing ABS sensor on the left side of axle II. The broken ABS wiring at the axle's end showed signs of corrosion, and it was covered with road grime, as would be expected for a condition existing over a prolonged period.

When the vehicle's required annual inspection took place on February 4, 2016, the inspection requirements addressed only the functionality of a vehicle's basic brake system and not the operability of its ABS, if so equipped. However, on July 22, 2016, the inspection requirements were revised so that, among other things, if a commercial motor vehicle that was required to be equipped with ABS had missing or inoperative ABS components, the vehicle would not pass its

[22] Title 49 CFR 393.47(d)(2) prescribes a 0.25-inch minimum lining thickness for brakes on air-braked nonsteering axles, and a 0.0625-inch minimum lining thickness for brakes on an air-braked front steering axle.

[23] Based on the April 1, 2016, Commercial Vehicle Safety Alliance North American Standard Out-of-Service Criteria for clamp-type pneumatic brakes, the brakes were out of adjustment.

[24] Had the motorcoach been manufactured after March 1, 1998, it would have been required to be equipped with ABS (63 *Federal Register* 24454). Final assembly of this motorcoach occurred on October 10, 1997.

annual inspection and would not be permitted to continue to operate (81 *Federal Register* 47722–47732).

1.5.3 Exterior Damage

Exterior damage was observed primarily along the motorcoach's left side. Parallel scrapes and scratches extended the entire length of the left side, and various body panel seams and openings had grass and soil embedded in them. There was a small area of impact damage on an access door forward of the front wheel opening. The left rear corner of the vehicle also had impact damage. The damage was concentrated at the lower portion of the corner and extended up to the area of the rearmost passenger window.

The left side of the motorcoach had one multipane driver's window adjacent to the driver's seating position and five passenger windows. The upper pane of the driver's window was broken, and the remaining panes of the driver's window were soiled with mud and dirt. The forwardmost passenger window was 78 inches wide and tapered in height; it measured 44 inches high at the front and 36 inches high at the rear. Passenger windows two through four were the same size, measuring 74.5 inches wide and 32 inches high. The rearmost passenger window was 44 inches wide and 32 inches high. The glazing for all five passenger windows on the left side was broken and missing. Additionally, the window retention frame for passenger window two was displaced at the bottom, having a 2-inch-wide opening between the frame and the vehicle body. The frame for passenger window three was completely missing. Passenger windows two through five were configured for use as emergency exits. (See figure 6 for a postcrash view of the left side of the motorcoach.)

Figure 6. View of motorcoach's left side, showing missing window panes and impact damage to the front and rear of the vehicle.

Five passenger windows, similar to those on the left side, were located along the right side of the motorcoach; windows two through five were configured as emergency exits. The glazing for the five passenger windows on the right side was intact, and those windows designed to be used as emergency exits were functional.

The right side and front of the motorcoach showed no signs of impact damage. The three laminated glass panes comprising the front windshield were missing. The passenger loading door area was intact and did not have significant damage. (See figure 7 for a postcrash view of the right side of the motorcoach.)

Figure 7. View of motorcoach's right side, showing intact window panes and minimal vehicle damage.

1.5.4 Interior Configuration and Damage

The motorcoach was configured with 13 rows of passenger seats on the driver's, or left, side of the vehicle and 11 rows on the right side. In addition to the 49 passenger seats, a folding jump seat was mounted adjacent to the passenger stairwell. Including the driver's seat, seven seat positions were fitted with lap belts. These positions were as follows: the jump seat, the four seats in row one, and a single seat positioned in the last row at the end of the center aisle, in the vehicle's rearmost row.[25] Overhead luggage bins equipped with passenger control units, which were

[25] The vehicle manufacturer installed lap belts at each of these seating positions because the absence of a seat in front of these locations made the occupant more vulnerable in the event of a crash. When this motorcoach was manufactured in 1998 (final assembly in October 1997), US motorcoaches were not required to be equipped with passenger seat belts. However, Van Hool chose to follow European standards in its motorcoach manufactures. European directive 90/629/EEC, which became effective July 1, 1992, mandated the installation of lap seat belts on motorcoaches for "exposed" seating positions only. As indicated above, under this directive, an exposed seating position is essentially one with nothing in front of the seat.

designed to provide individual control of lighting and ventilation, ran the length of the passenger compartment above both rows of seats.

With the exception of the three seats in the last row, the passenger seats consisted of double seat assemblies, each incorporating two 16-inch-long by 18-inch-wide cushions. The seatbacks were 30.5 inches tall and 16 inches wide at their widest points. Individual armrests were located at the outside and center of each seat assembly. On the right side of the vehicle, the center armrests at rows two and nine were broken off and the center armrest at row eight was missing. Several aisle-side armrests on both the left and right sides were deformed and displaced about 1 to 3 inches toward the left side of the motorcoach.

The overhead luggage bins on the right side had pulled away from the support frame adjacent to the passenger windows. The displacement extended from the front of the vehicle to about row eight. Several of the overhead passenger control units on the left side were displaced, and they hung by electrical wires from their mounting locations.

1.6 Highway Information

1.6.1 General

The crash occurred about 45 miles north of Laredo, in the northbound travel lane of US-83 near MM 670.7. At this location, US-83, as oriented from the motorcoach's direction of travel, has a compound curve to the right, and the road configuration changes from two travel lanes in each direction to a multilane, channelized road with a painted center median that is delineated from the travel lanes by yellow-painted lines.[26] The loss-of-control event that preceded the motorcoach crash originated in the curve. The 2-degree horizontal curve is about 881 feet long and has a super-elevation of about 4 percent.[27] The crest of the vertical curve is near the midpoint of the horizontal curve. Three private driveways are located within the curve along the east side of the roadway, and a single driveway to a gas and oil facility is located near the midpoint of the curve on the west side. (See figure 8 for a diagram of the crash scene curve.)

[26] A compound curve consists of horizontal and vertical elements.

[27] (a) The 2-degree curve has a radius of about 2,925 feet. (b) The super-elevation or cross slope of a roadway is used to help offset the centripetal forces that develop as a vehicle travels around a curve. In addition to providing a level of motorist comfort, super-elevation increases the potential speed at which a horizontal curve may be traversed.

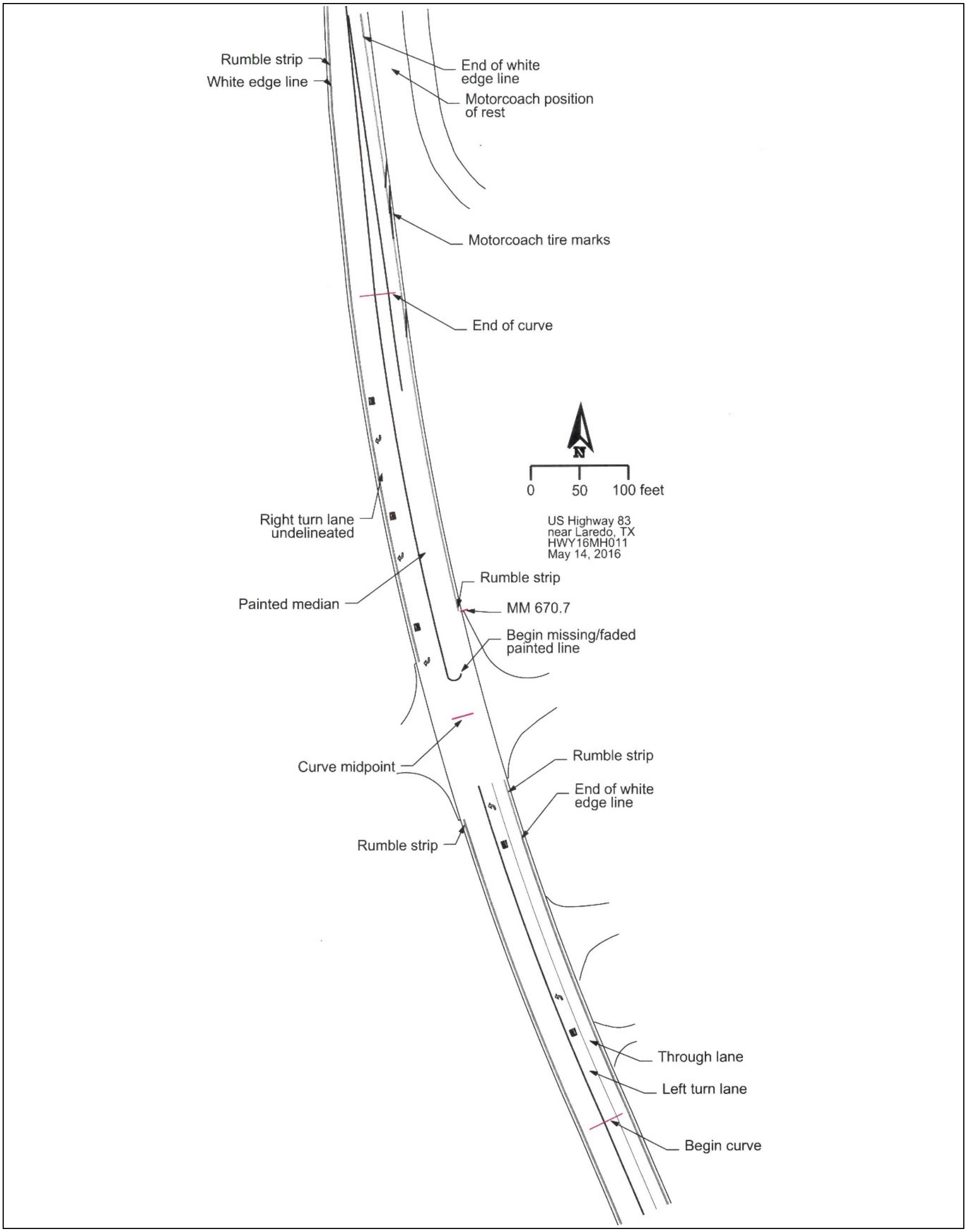

Figure 8. Crash scene diagram.

At the beginning of the right horizontal curve, northbound US-83 consists of a 12-foot-wide travel lane and a 12-foot-wide left turn lane. A 5-foot-wide paved shoulder is located adjacent to the travel lane. Southbound US-83 consists of a single tapered travel lane bordered by a 5-foot-wide paved shoulder.[28] To facilitate access to the gas and oil facility's driveway on the west side of the highway, a northbound left turn lane was added in March 2013.[29]

The cross section for US-83 changes immediately north of the curve's midpoint, and the travel lanes are channelized by an approximately 14-foot-wide painted median.[30] A single travel lane is used for northbound traffic, while the southbound portion of the highway includes a 12-foot-wide travel lane and a 12-foot-wide right turn lane. The 5-foot-wide paved shoulders continue along this section of highway. As with the previously described northbound left turn lane, the southbound right turn lane was added to accommodate traffic access to the gas and oil facility's driveway on the west side of the highway.

On each approach to the curve where the crash occurred, the northbound and southbound travel lanes are separated by a combination of painted lines and rumble strips. The grooved rumble strips are about 16 inches wide and are milled to a depth of about 0.5 inch. Yellow 6-inch-wide lane lines are painted along each side of the rumble strips.[31] The travel lanes on the approaches, as well as within the curve, are delineated from the paved shoulders by 6-inch-wide painted white edge lines adjacent to milled rumble strips.

Within the curve, the turn lanes are delineated from the painted center median by 6-inch-wide painted lines. At the time of the crash, the double 6-inch-wide yellow lines that separate the northbound travel lane from the center median were worn and faded. Beginning at about the curve midpoint, the white edge line intended to separate the northbound travel lane from the paved shoulder was so faded as to be not visible. (See figure 9.)

[28] The lane tapered from 24 feet to 12 feet wide. The tapering was part of a 2014 roadway modification to facilitate the movement of commercial vehicles from the adjacent property.

[29] The work was documented in TxDOT Minute Order Number 113363, which was approved on November 15, 2012, by the Texas Transportation Commission. The work had an estimated cost of $2.2 million.

[30] According to the American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets*, "channelization" is the separation or regulation of conflicting traffic movements into definite paths of travel by traffic islands or pavement marking to facilitate the safe and orderly movements of both vehicles and pedestrians (AASHTO 2011).

[31] The centerline rumble strips did not continue into the curved section of the highway.

Figure 9. Northbound view of US-83, showing the degraded condition of lane striping within the curve.

1.6.2 Speed Limit and Crash History

The posted speed limit for US-83 in the area of the crash is 75 mph.[32] The nearest speed limit sign to the crash site for northbound traffic is about 8 miles south of the site. No warning signs or advisory plaques indicate a speed reduction within the curve.[33]

For 2010–2015 on US-83 near the crash location, a total of 50 crashes occurred, 3 of which resulted in a vehicle occupant death.[34] The crash reports for these fatal crashes showed that one each occurred in 2011, 2012, and 2015. The mile markers where the crashes occurred were identified as 676.1, 668.7, and 673.0, respectively. (The subject crash occurred at MM 670.7.) None of the fatal crashes occurred during wet pavement surface conditions.

[32] Two informal speed surveys, one conducted on May 21, 2016, and the other on June 25, 2016, found that the 85th percentile speed for this location was about 75–77 mph.

[33] Chapter 2C of the *Manual on Uniform Traffic Control Devices for Streets and Highways* specifies how warning signs and advisory speed plaques should be placed and used. Warning sign usage includes situations to alert road users to conditions that might call for a reduction of speed. The manual also states that, in addition to warning signs, an advisory speed plaque shall be used where an engineering study indicates a need to advise road users of the advisory speed for other roadway conditions (Federal Highway Administration [FHWA] 2009, Section 2C.08 Advisory Speed Plaque).

[34] Centering upon the crash location of MM 670.7, NTSB investigators obtained from the Texas Department of Transportation (TxDOT) a list of reportable crashes occurring within 5 miles in each direction on US-83.

1.6.3 Wet Weather Crashes

TxDOT monitors and evaluates Texas roadways to ensure that surface conditions allow for safe operation by motorists; this includes operating vehicles on roadways during wet weather. The agency uses its *Wet Surface Crash Reduction Program Guidelines*, which are implemented and maintained by the TxDOT Construction Division's Materials and Pavements Section. The guidelines specify that, for a segment of rural roadway to be identified as a wet surface crash location, the minimum threshold is for three or more wet surface crashes to occur on it within the most recent complete calendar year. The *2016 District Rural Wet Surface Crash Reduction Program Location Report* for the Laredo District identified the crash location on US-83 as a wet surface crash location, referencing six wet pavement crashes.

Three of the wet weather crashes referenced in the 2016 report occurred in November 2015 and originated in the northbound part of the US-83 curve where the motorcoach crash took place. Another wet weather crash originating in the northbound curve occurred on May 18, 2016—4 days after the motorcoach crash. All four of these wet weather crashes involved truck-tractors in combination with semitrailers, and all resulted in vehicles' jackknifing.[35] Each crash involved only the combination vehicle and did not result in injuries or fatalities. In three of the crash reports, the investigating officer listed "unsafe speed" as a contributing factor; in two of those crashes, the driver was cited for unsafe speed. The report for the fourth wet weather crash listed "other (explain in narrative)" and "faulty evasive action" as contributing factors. The officer's narrative of the crash described the road surface as being wet because of rainfall and oily due to the heavy oilfield traffic. The report also listed "unsafe speed" as a factor that might have contributed. No citations were issued for this crash.

1.6.4 Roadway Maintenance

At the request of NTSB investigators, TxDOT personnel provided the daily activity reports (DARs) used by the department to document the maintenance activities on US-83 in the area of the crash. These reports are intended to capture, on a daily basis, the type of work being performed, the personnel involved, the equipment and materials used, and the location where the work is performed. Sixteen DARs were received. They covered the period from September 28 through November 5, 2015.

The DARs showed that several maintenance activities had taken place to address pavement surface issues in this area of US-83. The TxDOT DAR for October 21, 2015, indicated that a "full-width" chip seal had been applied to US-83.[36] Chip sealing is a common pavement maintenance practice in which a thin layer of heated asphalt emulsion is sprayed on the road surface, followed by the spreading of small pieces of aggregate (known as "chips"). The chips are then compacted for maximum adherence to the asphalt, and any excess aggregate is swept from the road surface.

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[35] A jackknife is a spinout event involving an articulated vehicle, such as a truck-tractor in combination with a semitrailer. As the spinout progresses, the front portion of the articulated vehicle becomes perpendicular to the trailing or towed section.

[36] In this context, the term "full width" refers to the application of asphalt followed by aggregate over the entire width of any lane (or lanes) to which the chip seal is applied. It does not refer to an application covering the full width of the highway.

The DAR for October 21, 2015, did not state whether the chip seal was applied to the full width of the northbound travel lane, the southbound travel lane, or both lanes. The DAR indicated that about 1,518 gallons of asphalt emulsion and 96 tons of aggregate were applied in the areas from MM 664 to MM 698, a distance of 34 miles. Based on their own recollections, TxDOT personnel told NTSB investigators that the chip seal was applied in the northbound travel lane near MM 670.7 (in the vicinity of the crash); however, the DAR does not indicate any more specific location information than within the 34-mile-long section.

The following bullets summarize the pavement maintenance activities that took place in the crash area before the May 14, 2016, crash, as reported to NTSB investigators by TxDOT maintenance personnel:

- On August 5, 2011, a TxDOT contractor began a countywide 1.5-inch overlay project for the north- and southbound travel lanes of US-83 within Webb County. TxDOT accepted the work as completed on January 10, 2012.

- In November 2012, an oil company contractor began work on US-83 to add turn lanes and driveways to permit access to the company's property adjacent to the highway. The pavement edge along the west side was extended outward by 15 feet to provide space for the turn lanes, and the grade and super-elevation of the extension were matched to the existing surface conditions. No changes were made to the pavement overlay of the north- and southbound travel lanes.

- On October 1, 2015, TxDOT maintenance crews began work in the southbound travel lane to address cracking and minor rutting.[37] No maintenance work was performed in the northbound travel lane.

- On October 21, 2015 (as noted above), TxDOT maintenance crews applied a chip seal—as a preventive measure to extend the life of the pavement surface—to the northbound travel lane. TxDOT subsequently reported that the aggregate did not adhere properly to the top layer of asphalt emulsion on the roadway and became displaced from the road surface.

- On October 26, 2015, to address the low-friction issues caused by the failed chip seal operation of October 21, TxDOT maintenance crews began milling operations to provide texture and increased surface friction in the northbound travel lane. The operation removed about 0.25 inch of pavement from the road surface.

No additional precrash surface treatments were performed after the October 26, 2015, milling operations. Another chip seal project had been scheduled to take place on April 25, 2016, to remedy the failed October 21, 2015, chip seal operation. However, on April 21, 2016, TxDOT's contractor reported that the aggregate for the chip seal project was not available for delivery and would be delayed. The contractor provided TxDOT with a tentative project start date of June 6, 2016.

[37] Rutting occurs when depressions or grooves are worn into the road by tire travel. Ruts form through the deformation of the asphalt pavement.

On May 18, 2016—4 days after the May 14, 2016, crash—TxDOT began a 1,030-foot-long pavement milling project to add texture to the pavement surface to restore skid resistance. The project encompassed the entire length of the horizontal curve at the motorcoach crash location, and it was conducted to address safety concerns related to low pavement friction.[38] The milling was completed on May 20, 2016. TxDOT reported that it experienced equipment problems during this postcrash milling operation, which left gouges and continuous longitudinal grooves in the pavement. These results were contrary to specifications in TxDOT's *Planing and Texturing Pavement Specifications*, which states that the "Surface should be free from gouges, continuous longitudinal grooves, ridges, oil films, and other imperfections of workmanship" (TxDOT 2004, p. 377).

On May 27, 2016, the contractor for the chip seal operation notified TxDOT that its material supplier was again unable to deliver the aggregate and asked for a further delay, with a tentative project start date of no later than September 5, 2016.[39]

1.6.5 Pavement Evaluation

Several days after the crash, at the request of the NTSB, personnel from the TxDOT Maintenance Division's Pavements Preservation Branch performed a series of skid resistance tests to determine the pavement friction in the northbound travel lane of US-83. The tests were performed along the entire length of the crash curve, including the crash location. Following the methods established by ASTM International (ASTM) Standard E-274, testing was performed using a trailer-mounted friction-testing device towed behind a vehicle.[40] Detailed results from the skid testing can be found in appendix B of this report.

Table 3 is a summary of the skid numbers that TxDOT provided to the NTSB as related to the 66,615 lane miles it maintained in fiscal year 2015. Skid numbers represent the frictional properties of the pavement and are used to evaluate the pavement's skid resistance relative to other pavements and/or to evaluate changes in a pavement's skid resistance over time. The higher the skid numbers, the higher the friction level of the tested pavement. TxDOT uses a five-color code to categorize skid numbers, with the "Blue" category containing the lane miles having the highest friction levels and the "Red" category those with the lowest friction levels.

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[38] TxDOT personnel reported that the milling was initiated because of the low skid numbers obtained from their postcrash skid testing and because of two recent crashes; the one involving the motorcoach on May 14 and another involving a combination vehicle on May 18. Overall, the milling was intended to improve the pavement's friction.

[39] After the May 2016 crash, personnel from the TxDOT Laredo District notified the NTSB of their intent to begin the chip seal operation on August 17, 2016. However, wet weather delayed the operation until August 23, 2016. The project was completed 4 days later, on August 27, 2016.

[40] (a) ASTM is a not-for-profit organization that provides a forum for the development and publication of over 12,000 technical standards encompassing a diverse range of materials, products, processes, systems, and services. (b) The standard test for skid resistance of paved surfaces with a full-scale tire uses a measurement representing the steady-state friction force on a locked test wheel as it is dragged over a wetted pavement surface under constant load and at a constant speed while its major plane is parallel to its direction of motion and perpendicular to the pavement.

Table 3. TxDOT's rating evaluation of the friction levels (skid numbers) for the lane miles it maintained in fiscal year 2015. (The evaluation was based on skid resistance tests performed at 50 mph using a smooth tire under wet pavement conditions.)

Category	Friction Range (Skid Numbers)	Total Maintained Lane Miles in Category	% of Total Maintained Lane Miles in Category
Blue	38–99	32,293	48.5
Green	31–37	12,007	18.0
Yellow	24–30	11,140	16.7
Orange	16–23	7,987	12.0
Red	1–15	3,188	4.8
Total		66,615	100.0

In fiscal year 2015, of the 66,615 lane miles evaluated, 3,188 lane miles (4.8 percent) maintained by TxDOT had skid numbers in the 1–15 range, placing them in the lowest friction, or Red, category. TxDOT's postcrash skid resistance tests near the crash site (resistance tests performed at 50 mph using a smooth tire under wet pavement conditions) resulted in skid numbers as low as 5.4, indicating that some pavement friction levels in the vicinity of the crash site were near the bottom of this lowest category.

In addition to performing the skid resistance tests, TxDOT personnel evaluated the road surface using a transverse beam sensor. The transverse beam profile test measured the cross slope and rut depth in the northbound travel lane of US-83 near the crash.[41] The measurements began at MM 672, and data were collected northward from that point.[42] The test results revealed that the cross slope (or super-elevation rate) was about 4.3 percent at its maximum point along the horizontal curve. The rut depths in the right and left wheel paths of the northbound travel lane varied from 0.15 to 0.25 inches and from 0.10 to 0.27 inches, respectively.

Postcrash, NTSB investigators performed a series of locked-wheel skid tests using a car.[43] The tests were conducted on both wet and dry surface conditions within the northbound travel lane

[41] The transverse beam profile test consists of a five-sensor system attached to the front of a vehicle that makes measurements with ultrasonic sensor technology to collect cross slope and pavement rutting data.

[42] The crash location was at MM 670.7. For roadways oriented north–south, mile markers decrease in value in the northbound direction. In this instance, the measurements began 1.3 miles south of the crash location and continued north to the curve where the crash occurred.

[43] See NTSB docket item for this investigation, "Technical Reconstruction Group Attachment—Locked Wheel Skid Test Data." The NTSB used a Stalker ATS II RADAR system and associated software manufactured by Applied Concepts, Inc., to document the locked-wheel skid tests. Output data from the test run included time, velocity, acceleration, and distance, which were then analyzed to calculate the deceleration (drag) factor. The test vehicle was a midsize four-door sedan with its ABS disengaged.

of US-83. The skid test data were used to calculate an average deceleration factor that was later used to analyze vehicle crash dynamics.[44]

1.6.6 Pavement Core Samples

1.6.6.1 Core Sample Information. At the request of the NTSB, on May 17, 2016, TxDOT drilled and obtained ten pavement cores from the travel lanes and paved median of US-83 near the crash location. The NTSB took possession of all ten core samples and provided five to the Federal Highway Administration (FHWA) Turner-Fairbank Highway Research Center (TFHRC) for testing and analysis. The TFHRC tested the following pavement core samples, the locations of which can be seen in figure 10:

- Core sample 1B: Taken from the northbound travel lanes, about 431 feet south of the motorcoach's final rest location. (TFHRC indicated that this sample came from the left wheel path.)
- Core sample 2B: Taken from the southbound travel lanes, about 431 feet south of the motorcoach's final rest location.
- Core sample 3B: Taken from the painted median, about 431 feet south of the motorcoach's final rest location.
- Core sample 4B: Taken from the northbound travel lanes, about 3,108 feet south of the motorcoach's final rest location. (TFHRC indicated that this sample came from the right wheel path.)
- Core sample 5B: Taken from the northbound travel lanes, about 718 feet south of the motorcoach's final rest location. (TFHRC indicated that this sample came from the right wheel path.)

[44] See NTSB docket item for this investigation, "Vehicle Dynamics Study."

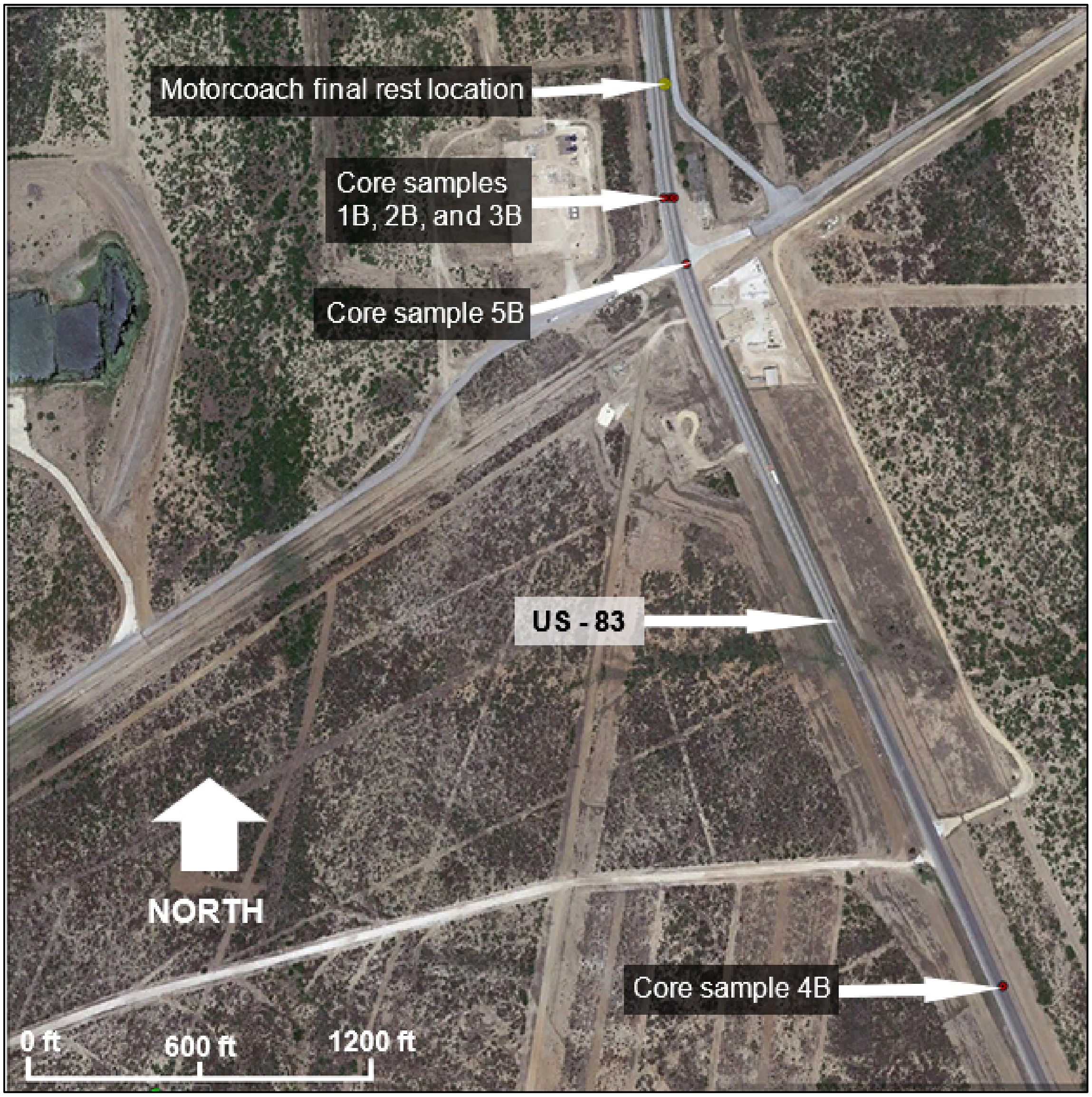

Figure 10. Locations on US-83 where the pavement core samples were obtained. (Source: Google Earth modified)

1.6.6.2 TFHRC Evaluation of Pavement Core Samples. TFHRC performed several types of tests on the core samples. (For the TFHRC testing summary report, see appendix C.)

Based on forensic analysis of the core samples from the milled area of the northbound travel lane of US-83, the TFHRC concluded that the primary factor most likely contributing to the low pavement friction was the absence of adequate aggregate particles in the wearing course of the pavement, compounded by tack coat content that created a slick asphalt surface.[45] (See figure 11 for cross section images of two of the core samples, showing how little aggregate was in the top pavement layer, and figure 12 for an image of the slick-appearing surface of the roadway.)

[45] (a) "Tack coat" is a thin bituminous liquid asphalt, emulsion, or cutback layer. (b) The "wearing course" is the uppermost layer of the roadway, which is in direct contact with traffic loads.

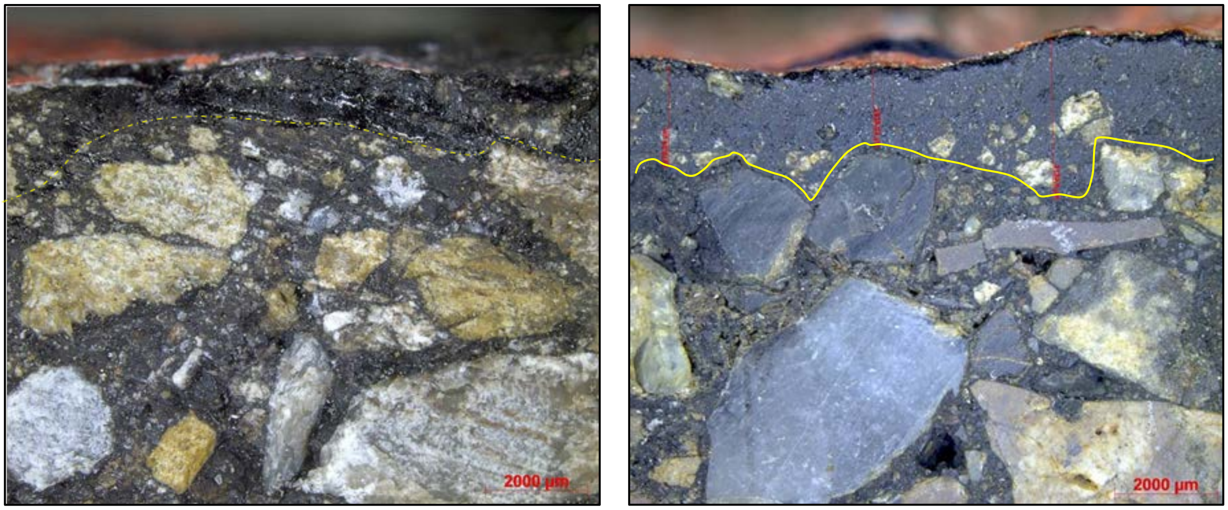

Figure 11. Cross section views of pavement core samples 1B (left) and 5B (right), showing the 2–3-millimeter-thick top layer of asphalt emulsion. The area above the yellow line in each photograph is the surface of the roadway; when compared to the material below the line, little aggregate can be seen in this top layer.

Figure 12. Postcrash view of US-83 northbound travel lane. The slick-appearing surface and increased reflectivity contrasts with the paved shoulder on the right. (Source: TxDPS)

Aggregate typically comprises 80–90 percent of the bituminous mixture used as the wearing course for highway pavement (Prowell, Zhang, and Brown 2005). Assuming that a pavement wearing course is designed and constructed properly, asphalt pavements have low friction mainly due to the type of aggregate used. In this case, however, the TFHRC's analysis of core samples 1B and 5B led it to conclude that the low pavement friction near the crash site resulted from the absence of essential elements in the wearing course. In other words, there was not enough aggregate in the wearing course to provide adequate pavement friction.

The TFHRC concluded that the presence of the 2–3-millimeter-thick asphalt layer at the top of samples 1B and 5B, and the limestone relics associated with the binder-rich thin top layer, were consistent with two possible scenarios. In one scenario, the milling operation that TxDOT performed on October 26, 2015, which reportedly removed about 0.25 inch of the pavement top overlay, did not significantly remove the asphalt emulsion that was applied during the failed chip seal job 5 days earlier. The other scenario was that an asphalt tack coat had been applied after the October 26, 2015, milling operation.

During the on-scene investigation, TxDOT stated that the pavement's slick appearance and the reduced pavement friction at the crash location were the result of asphalt bleeding.[46] However, the chemical analysis performed by the TFHRC found that the asphalt-rich surface layer of the pavement from which core samples 1B, 4B, and 5B were taken had been treated with an asphalt emulsion containing styrene butadiene rubber polymer, which would be typical of a tack coat used with chip seal operations and is consistent with the construction history reported by TxDOT. The TFHRC chemistry laboratory report concluded that there was no evidence to support the theory that the excess asphalt on the pavement surface was the result of asphalt bleeding.

1.7 Motor Carrier Operations and Regulatory Oversight

1.7.1 Company History

OGA Charters began operating in 2009, and it entered the FMCSA's new entrant program on January 12, 2009.[47] The company successfully completed a safety audit and exited the new entrant program on July 12, 2010. The carrier was registered as a "for-hire" carrier of passengers, with its principal place of business in San Juan, Texas. OGA Charters reported its commercial mileage for 2014 as 40,000 miles. The carrier engaged in both intrastate and interstate trips. At the time of the crash, the carrier operated two motorcoaches, employed two part-time drivers (one was the crash driver), and had one additional employee responsible for cleaning the motorcoaches. The company did not have an in-house maintenance facility; instead, it outsourced maintenance and repairs to businesses in the United States and Mexico.

Between July 26, 2012, and December 15, 2015, the carrier had been subject to seven roadside inspections, six of which included the motorcoach involved in the crash. Three of the

[46] Asphalt bleeding (also called flushing) is a process by which excess asphalt rises to the pavement surface.

[47] OGA Charters ceased doing business after this crash.

inspections resulted in the vehicle being placed out of service for brake system defects. Two of the seven inspections found driver logbook violations.[48]

1.7.2 Company Operation and Safety Culture

Following the crash, investigators examined the carrier's operations. OGA Charters did not provide any training to new employees, and it had no safety training, manuals, or other programs to educate drivers. Other than a drug and alcohol testing policy, which is specifically required by regulation, OGA Charters had no policies on cell phone use, fatigue management, or any other safety-related procedures. With respect to hiring, the owner stated that he did not advertise or post job openings; he only hired drivers who were recommended to him. He reported that he used the "DOT [US Department of Transportation] preemployment" process for new hires, but the carrier had no written policies or guidelines concerning this process.

The owner stated that he was responsible for recordkeeping and that he did not routinely audit drivers' hours of service. He stated he had been having issues with the crash driver not turning in his records-of-duty status as required, and he did not realize until the postcrash investigation that this driver had been scheduled to drive in excess of his allowable hours of service, as was discovered during the investigation (hours of service are detailed in section 1.7.5).

1.7.3 TxDPS Commercial Vehicle Enforcement Oversight

Title 37, part 1, chapter 4, of the *Texas Administrative Code* establishes the authority for the TxDPS to enforce the *Federal Motor Carrier Safety Regulations* (FMCSRs) as adopted by the state. By code, all intrastate carriers must comply with state and local laws, as well as with the rules governing licensing, vehicle safety, and driver safety. Texas does not have a program requiring annual compliance reviews of carriers involved in intrastate operations, and TxDPS Commercial Vehicle Enforcement officers had never conducted a review of OGA Charters. However, because the crash occurred during an intrastate trip, TxDPS officers performed a postcrash inspection of the crash vehicle and driver, which resulted in the vehicle being placed out of service for brake defects (two brakes were out of adjustment) and the driver being placed out of service for falsifying his logbooks.

1.7.4 FMCSA Oversight

The FMCSA mission is to reduce crashes, injuries, and fatalities involving large trucks and buses. The FMCSA uses a combination of programs, reviews, and inspections to provide oversight of commercial motor vehicle operations.

1.7.4.1 FMCSA Compliance Reviews. A compliance review is an onsite examination of a motor carrier's operations to determine its compliance with the FMCSRs and to evaluate its safety culture. Upon completion of a compliance review, the FMCSA rates the carrier as being "satisfactory," "conditional," or "unsatisfactory" in five safety areas, which, when combined, result in an overall rating of the company's compliance with the FMCSRs. The compliance review

[48] The driver violations found in the two inspections did not involve the crash motorcoach driver.

program is intended to improve the safety of commercial vehicle operations through heightened awareness of safety regulations and enforcement.

Before the crash, the FMCSA had performed two compliance reviews of OGA Charters—one on September 2, 2010, and the other on May 1, 2014. Both reviews resulted in satisfactory safety fitness ratings.[49]

Despite resulting in a satisfactory rating, the September 2, 2010, compliance review found several violations regarding the use and oversight of OGA Charters drivers. These violations included the following:

- Section 382.301–Using a driver before the return of a negative preemployment drug and alcohol test.
- Section 395.8–Failing to require records-of-duty status in the prescribed form and manner.
- Section 395.8–Carrier failed to obtain from driver, used for the first time or intermittently, a signed statement giving the total time on duty during the preceding 7 days and time at which last relieved from duty.

The compliance review performed on May 1, 2014, also resulted in a satisfactory rating. During the review, however, the FMCSA found five violations regarding the use and oversight of the company's drivers, one of which was a repeat violation of Section 395.8. Additionally, OGA Charters had vehicle oversight violations for the following:

- Section 396.3(b)(2)–Failure to have a means of indicating the nature and due date of various inspection and maintenance operations to be performed.
- Section 396.9(d)(3)–Failure to maintain complete roadside inspection forms for 12 months from the date of inspection at the carrier's primary place of business.

As a result of the 2014 compliance review, the FMCSA made specific recommendations to OGA Charters to improve its driver oversight. These recommendations were as follows:

- Develop a policy requiring a driver to report available hours during a "check-in call."
- Develop a policy to require drivers to comply with the hours-of-service regulations and turn in records-of-duty status and supporting documentation within 13 days of completing trips.
- Establish a policy stating that drivers are required to check with their supervisor to report "fit-for-duty" status before starting a job and require that drivers who are ill or whose abilities or alertness is impaired be prohibited from taking safety-sensitive assignments.

[49] A satisfactory rating indicates that a motor carrier has in place functioning and adequate safety management controls to meet the safety fitness standard prescribed in section 385.5 of the FMCSRs.

The OGA Charters owner did not implement the FMCSA recommendations and, at the time of the crash, none of the policies had been developed or established. The FMCSA took no further action with respect to its recommendations to OGA Charters.

Following the crash, the FMCSA performed a compliance review of the carrier and found multiple violations, including deficiencies in recordkeeping, driver oversight, and vehicle maintenance. Additionally, the postcrash review listed violations for the driver's falsification of his logbook. The FMCSA examined the carrier's accident information, and those results, combined with the logbook violations, resulted in the carrier's previous satisfactory rating being downgraded to conditional.[50]

1.7.4.2 Compliance, Safety, Accountability Program. The FMCSA uses the Compliance, Safety, Accountability program to monitor carrier safety. A key component of the program is the Carrier Safety Measurement System (CSMS), which analyzes all safety-based violations from inspections and crash data to determine a motor carrier's on-road performance and potential crash risk. Thresholds for safety measurement system scores are determined through a mathematical formula that includes vehicle miles driven, number of vehicles and drivers in the fleet, and time since a violation.

The CSMS uses the following seven behavioral analysis safety improvement categories (BASICs): unsafe driving, hours-of-service compliance, driver fitness, controlled substances and alcohol, vehicle maintenance, improper loading/cargo securement, and crash indicator.[51] Each BASIC has a threshold that triggers an intervention by the FMCSA, including warning letters or more extensive scrutiny, such as targeted roadside inspections and focused investigations.[52] OGA Charters had one BASIC alert for hours of service.

1.7.5 Driver's Logbook and Hours of Service

While investigating the crash, TxDPS officers recovered two loose-leaf logbook pages belonging to the driver. The entries on the first page showed the driver as off duty from May 6 to May 13; information on the second page, dated May 14, showed that he was tracking his hours during the trip to Eagle Pass, Texas. Later, the driver told TxDPS officers that, on May 13, he had driven the motorcoach on an OGA Charters trip to San Antonio, Texas, and that he was employed full-time as a school bus driver for the McAllen ISD.

[50] A conditional rating indicates that a motor carrier does not have adequate safety management controls in place to ensure compliance with the safety fitness standard that could result in occurrences listed in the FMCSRs Rules and Notices Section 385.5 (a) through (k).

[51] Hours-of-service compliance applies to the operation of commercial motor vehicles by drivers who are ill, fatigued, or noncompliant with regulations. Example violations for this BASIC include exceeding hours of service, maintaining an incomplete or inaccurate logbook, and operating a commercial motor vehicle while ill or fatigued (49 CFR Parts 392 and 395). For more information, see the FMCSA Compliance, Safety, Accountability website, accessed September 24, 2018.

[52] To determine alert status, carriers are compared to a peer group of other carriers with similar numbers of inspections using a percentile rating of 0–100, with the 100th percentile indicating the worst performance. For carriers with safety issues across multiple BASICs, the FMCSA will continue to conduct onsite comprehensive compliance reviews. The FMCSA intervention threshold for passenger carriers for unsafe driving, hours-of-service compliance, and crash indicator is 50 percent. For driver fitness, controlled substances and alcohol, and vehicle maintenance, the threshold is 65 percent. See the FMCSA Compliance, Safety, Accountability website, accessed September 24, 2018.

Because the driver was employed by more than one motor carrier, he was required to submit a copy of his record-of-duty status to OGA Charters, as specified in 49 CFR 395.8. This record should have reflected the hours he had accrued while working as a school bus driver.[53] The responsibility to ensure that a driver complies with hours-of-service requirements extends to the motor carrier. Title 49 CFR 395.8 requires that, when using a driver intermittently, the motor carrier shall obtain a signed statement from the driver providing the total time on duty during the immediately preceding 7 days. In this case, neither the driver nor the motor carrier followed the regulation. Additionally, the chartered trip required the driver to complete a logbook entry for his time on May 13. The driver acknowledged that he had falsified a logbook page for OGA Charters, omitting the information about his hours as a school bus driver and his chartered trip the day before the crash. The driver provided the NTSB with the logbook page that he had completed for the trip on May 13. An evaluation of the page, as well as of his reported schedule at McAllen ISD, revealed that, because he had not had 8 consecutive hours of time off duty, when the crash occurred, the driver both had exceeded his maximum driving hours and was driving beyond his maximum allowable time on duty.[54] Table 4 summarizes the driver's on-duty hours, off-duty hours, and cumulative hours since his last required 8-consecutive-hour-long rest break from the morning of May 12 till the time of the crash on May 14.

Table 4. Driver's on- and off-duty hours for May 12–14, 2016.

Date	Time	On-Duty Hours	Off-Duty Hours	Hours Since Required Rest Break	Source
May 12, 2016	6:00 a.m. to 9:00 a.m.	3	0	0	McAllen ISD payroll
	9:00 a.m. to 3:00 p.m.	0	6	3	
	3:00 p.m. to 6:00 p.m.	3	0	12	
	6:00 p.m. to 7:30 p.m.	0	1.5	13.5	Driver's interview
	7:30 p.m. to 9:00 p.m.	1.5	0	15	
	9:00 p.m. to 3:45 a.m.	0	6.75	21.75	
May 13, 2016	3:45 a.m. to 10:30 a.m.	6.75	0	28.5	
	10:30 a.m. to 6:15 p.m.	0	7.75	35.25	Driver's logbook/interview
	6:15 p.m. to 11:30 p.m.	5.25	0	40.5	
	11:30 p.m. to 3:30 a.m.	0	4	44.5	
May 14, 2016	3:30 a.m. to 11:26 a.m.	8	0	52.5	

[53] The driver was not required to complete logbook entries while working for the McAllen ISD, but he was required to account for, and self-report, the hours to OGA Charters for determination of his hours-of-service status.

[54] The crash occurred during an intrastate trip, and the driver's hours of service were regulated by Title 37, Part 1, Chapter 4, Subchapter B, Rule §4.12(2) of the *Texas Transportation Code*.

1.8 Weather

On the trip to Eagle Pass, the driver encountered rain of varying intensity, and he reported light rain at the time of the crash. Based on data from multiple sources, including airports, military installations, and satellite data, thunderstorms and rain showers began shortly before 1:00 a.m. and continued until about 3:30 p.m. that afternoon. The data also showed that, near the time of the crash, several large cumulonimbus cloud systems extended over the route traveled by the motorcoach.[55] The crash site was indicated as having experienced light rainfall. At the time of the crash, the most intense portion of the storm was about 3 miles north of the crash location.

1.9 Vehicle Dynamics Simulation Study

To better understand the vehicle loss-of-control event and the subsequent roadway departure and crash, the NTSB performed a vehicle dynamics simulation study.[56] The study employed an iterative approach in which steering and braking were varied to evaluate the vehicle response. Three-dimensional survey data of the crash environment were entered into the simulations, and the collected physical evidence was compared with the simulation results.[57] These survey data included tire marks and other physical evidence indicating the path of the motorcoach from just before it departed the right side of roadway to its final rest point. The data allowed for reconstruction of the rotation and sideslip of the motorcoach from the time it left the roadway approximately to the point of rollover. The study assessed the performance of the motorcoach through the curve and evaluated how simulated events involving braking, steering, and lane position matched the available physical evidence.

The simulation results identified two possible scenarios that were consistent with the physical evidence. The first was steering overcorrection. This scenario most likely would have occurred in response to the motorcoach drifting out of its lane toward the center median, or possibly in response to the vehicle sliding toward the middle of the roadway as a result of braking. The second scenario involved premature wheel lockup, resulting from the inoperability of the ABS. The simulations indicated that premature rear-wheel lockup in combination with slight increases of steering to the right in the curve could result in the motorcoach rapidly rotating and steering off the inside of the curve, if the driver did not intervene to prevent it from leaving the road by counter-steering. The simulations of this scenario also indicated that the driver could have controlled the vehicle by rapidly counter-steering. Possible factors contributing to the loss of control identified in the study included the low friction conditions in the curve, speed, tread differences between the front and rear tires, and the nonfunctioning ABS.

The simulations found that the motorcoach could have safely negotiated the curve at a speed of 75 mph (the posted speed limit). The simulations further indicated that if the friction had not been sufficient for the motorcoach to have safely negotiated the curve, the vehicle would have gone off the outside of the curve to the left side or continued along the tangent of the curve, rather

[55] A cumulonimbus cloud is a dense towering vertical cloud associated with thunderstorms and atmospheric instability. These clouds can produce lightning and severe weather.

[56] See NTSB docket item for this investigation, “Vehicle Dynamics Study.”

[57] The software used in the simulation study was the PC-Crash vehicle dynamics software. PC-Crash is a commercially available software that models three-dimensional motions of trucks and motorcoaches.

than going off the inside of the curve, to the right, as it did in this crash. Although the simulations showed that there was sufficient friction to negotiate the curve, they also revealed that the wet road surface, in combination with tread differences between the front and rear tires, would have made the motorcoach less stable and more prone to spinning out in the event of inappropriate steering and/or braking in the curve by the driver. These results meant that, for the driver to have safely negotiated the curve, he would have had to have minimized his steering and braking as he negotiated the curve and to have avoided situations that required significant steering or braking.

2 Analysis

2.1 Introduction

The crash occurred when an OGA Charters motorcoach, traveling northbound on US-83 near Laredo, departed the roadway to the right and rolled onto its left side. Nine passengers died, and 36 passengers received minor-to-serious injuries. The severity of injury for five passengers was undetermined, and both the bus driver and trip coordinator received minor injuries.

The analysis portion of this investigative report first discusses those factors that could be excluded as not causing the crash or contributing to the severity of its outcome. Then, it addresses the motorcoach driver's loss of control and the crash sequence, as well as how the driver's poorly treated diabetes and sleep-deficit-related fatigue affected his performance (sections 2.2 and 2.3), before providing a detailed discussion of the safety issue areas. The following safety issues are discussed:

- Inadequate federal oversight and guidance for commercial drivers with diabetes treated without insulin (section 2.3.1).
- Inaccurate and incomplete highway maintenance recordkeeping by TxDOT, leading to deficiencies in conducting safety-critical highway maintenance (section 2.4.1).
- Need for improved training for TxDOT maintenance workers to ensure that roadway maintenance operations result in acceptable levels of surface friction (section 2.4.2).
- Need for increased motorcoach crashworthiness through improvements to window glazing and retention (section 2.5).
- Driver fatigue resulting from poor safety management by OGA Charters and inadequate federal safety ratings for passenger motor carriers with repetitive driver violations in the area of driver performance (sections 2.3.2 and 2.6).

As a result of this investigation, the NTSB established that the following factors did not cause or contribute to the crash:

- ***Motorcoach driver licensing and qualifications:*** The driver held a current CDL, which included an endorsement for the transportation of passengers. In addition to driving motorcoaches part-time for various employers, he was employed full-time as a school bus driver.

- ***Substance impairment and cell phone distraction:*** Following the crash, the motorcoach driver was tested for alcohol and other drugs, and all test results were negative. Additionally, the driver's cell phone records were evaluated, and the records showed that he was not using a cell phone immediately before the crash.

- ***Roadway geometry and posted speed limit for US-83:*** The horizontal curve along US-83 where the crash occurred has a super-elevation of about 4 percent, a design that facilitates traversing the curve at the posted 75-mph speed limit. Additionally, postcrash simulations showed that the motorcoach could have successfully navigated this curve at highway speeds.

- ***Emergency response:*** Because the crash location was relatively remote, the TxDPS, the agency that had primary jurisdiction, arrived at the scene about 30 minutes after the first 911 calls were received. However, because CBP officers were patrolling near the crash scene, emergency responders were on the scene almost immediately. Two of the four law enforcement officers who were first to arrive at the scene had EMT training, allowing them to perform initial triage and evacuation assistance. By the time the first fire/rescue units arrived, the CBP had established incident command and initiated a mass casualty incident. One of the first law enforcement officers to arrive also worked part-time at Angel Care, a local ambulance service, which allowed him to communicate pertinent injury information to ambulance supervisors while the fire/rescue units were still en route. Seven EMS agencies responded to the crash and transported 44 victims to local hospitals for treatment. In summary, despite the remote location of the crash, law enforcement and incident command were timely and effective, due in part to the proximity of nearby CBP agents.

Therefore, the NTSB concludes that none of the following were factors in the crash: (1) driver licensing or qualifications, (2) alcohol or other drug use by the motorcoach driver, (3) driver cell phone distraction, and (4) roadway geometry or the posted speed limit for US-83 at the curved segment where the crash occurred.

The NTSB further concludes that the emergency response was timely and effective.

With respect to vehicle condition, the postcrash inspection of the motorcoach found no tire or wheel deficiencies, the vehicle was equipped with the appropriate size and load range of tires, and tire inflation pressures and tread depths were within reasonable operating ranges. Although the electronic control of the ABS was inoperable, the foundation components of the air brake system were functional and undamaged, and the brake disc rotors and pads were within specified wear limits. The steering wheel, steering column, steering gear box, steering linkage, and suspension system were undamaged and functional.

2.2 Driver's Loss of Control and Crash Sequence

Both the simulation study and conventional critical speed computations showed that the motorcoach could have safely negotiated the curve while traveling at the 75-mph speed limit, even with the low friction of the pavement (Dickerson and others 1995).[58] Additionally, the physical evidence indicated that the vehicle's departure from the roadway was not due to excessive speed. Had the driver entered the righthand curve of US-83 at a speed exceeding the limits of the available friction, the motorcoach would have been unable to continue along the curved path of the roadway and would have tended to move toward the outside of the curve on the roadway's west side; it would not have departed the roadway's east side, as occurred in the crash. Had the driver initiated a continuous hard brake application, resulting in a skid, the motorcoach would have continued

[58] Critical speed is the point at which a vehicle enters the limit of tire-to-road surface adhesion in a turn. Lateral force applied to the tires in a turn exceeds the tire's ability to generate an equally opposing force.

along its original path and moved toward the outside of the curve rather than departing the inside (east side) of the curve, as it did in this crash.

The results of the simulations indicated that the loss of control was consistent with a crash scenario in which the motorcoach entered the curve and began to drift or move to the left out of the northbound lane, with the driver responding by steering and braking, causing the vehicle to leave the roadway. This type of crash scenario is consistent with the driver's diminished perception of the roadway environment and the changes in the pavement markings within the curve, which would have increased the driver's risk of departing his travel lane in the curve. In this case, the pavement's reduced friction, due to its wet surface and condition (see section 2.4.2), increased the risk of the motorcoach spinning out if the driver made significant braking or steering inputs while traversing the curve.

The motorcoach's inoperable ABS compounded the problem of vehicle control. The absence of an ABS could have significantly increased the risk that the driver would lose control while braking in the curve. In a crash of this type, the low pavement friction, combined with the lack of ABS, could cause the brakes to lock up and the motorcoach to slide, potentially leading to driver overcorrection or premature rear wheel lockup. The driver's recollection that he thought the motorcoach began to slide after he braked is consistent with the wheels locking up as result of the nonfunctioning ABS.

Based on the evaluation of the driver's condition, the crash scene environment, the roadway geometry, and the results from computer simulations, the NTSB concludes that the motorcoach initially moved to the left as it entered the curve, and the driver steered to the right and braked, causing the motorcoach to depart the east side of the highway and roll over. The NTSB further concludes that the pavement's reduced friction, combined with the motorcoach's inoperable ABS, contributed to the driver's inability to regain control of the vehicle.

All new commercial vehicles manufactured since March 1, 1998, are required to be equipped with an ABS. Until July 2016, the annual vehicle inspection did not include a vehicle's ABS and its operability. As of July 2016, the annual inspections have included the ABS for those vehicles that are required to be equipped with ABS. However, some vehicles, like the motorcoach in this crash, were equipped with an ABS before March 1, 1998, when it became required equipment. For such vehicles, the annual inspection did not, and does not, include the ABS because it is not required equipment.

2.3 Driver Factors

2.3.1 Diabetes

2.3.1.1 Driver's Diabetes Management. The driver's blood glucose, measured hours after the crash, demonstrated severe hyperglycemia; his blood glucose was 373 mg/dl, while a normal random glucose result is about 60–140 mg/dl.[59] In addition, his hemoglobin A1C was 12.7 percent, which indicated that his blood glucose over the preceding weeks had averaged about 318 mg/dl (Nathan and others 2008). These levels are indicative of uncontrolled diabetes; having

[59] Hyperglycemia is the medical term for a high blood sugar (glucose) level.

a hemoglobin A1C below 7 percent is considered diabetes in "good" control. Events that create stress, such as being involved in a motor vehicle crash, may lead to release of cortisol and other fight-or-flight hormones that could result in an increase in blood sugar. However, the demonstrated extent of elevation in both the measured blood glucose and the hemoglobin A1C for the motorcoach driver postcrash was such that the NTSB concludes that the motorcoach driver's blood sugar was significantly elevated at the time of the crash due to poorly controlled diabetes.

Hyperglycemia causes a variety of symptoms, including increased urine production, increased hunger and thirst, and blurred vision (Laffel and Svoren 2016). The glucose is distributed throughout the body's fluids, including into the eyes. As a result, the shape of the eyeball changes, and vision is affected. There are case reports of farsighted individuals whose vision improves with hyperglycemia (Golay, Ferrini, and Tagan 2013). However, blood glucose elevations to about 290 mg/dl have been demonstrated to make a person more nearsighted (myopic) by about two diopters (Furushima, Imaizumi, and Nakatsuka 1999). The muscles of the eye cannot compensate for such significant effects, so blurred vision ensues. The NTSB concludes that the motorcoach driver's poorly controlled diabetes and resulting hyperglycemia most likely led to blurred vision at the time of the crash.

As discussed earlier in the report, the highway environment changed as the driver entered the curve where the crash occurred. Once the motorcoach was within the curve, the two through lanes were configured to include both a separate turn lane and the painted center median. The lane markings delineating these different configurations had degraded significantly and were, at some locations, entirely absent. Additionally, maintenance work performed before the crash made the wet surface of the northbound travel lane highly reflective, making it increasingly difficult for a driver to discern the markings. As a result, the NTSB concludes that the roadway cues available to enable the motorcoach driver to properly position his vehicle within the northbound driving lane of the highway were degraded, and the visual difficulties were compounded by the driver's likely blurred vision resulting from his poorly controlled diabetes.

2.3.1.2 Federal Oversight of Drivers with Diabetes. Guidelines exist for health care providers treating patients with type 2 diabetes. According the 2016 *Standards of Medical Care in Diabetes* from the American Diabetes Association, recommended treatment goals for type 2 diabetes include a hemoglobin A1C of 7.0 percent or less, with measurements taken at least twice a year for patients reaching their targets and at least four times a year for patients not reaching their targets. The occurrence of episodes of symptomatic and asymptomatic hypoglycemia should be discussed at every visit.

In the long term, poorly controlled diabetes causes permanent damage to the backs of the eyes (retinopathy), kidneys (nephropathy), and nerves (neuropathy). The abovementioned guidelines also state that patients with type 2 diabetes should have an initial comprehensive eye examination conducted by an ophthalmologist or optometrist shortly after the diagnosis of diabetes. If there is no evidence of retinopathy for one or more eye exams, then conducting such exams at 2-year intervals may be considered. In addition, all patients should be screened for diabetic peripheral neuropathy when a diagnosis of type 2 diabetes is made, and at least annually thereafter, using simple clinical tests (American Diabetes Association 2016).[60]

Although these diabetes treatment guidelines exist, the level of adherence to the recommended practices is low. According to the Centers for Disease Control and Prevention (CDC), in 2010 (the most recent data available), although almost 90 percent of adults with diabetes in the United States had visited a doctor at least once for their diabetes in the preceding year, less than 70 percent had had two hemoglobin A1C tests (or a foot exam) and less than 65 percent had had a dilated eye exam (CDC 2014[a] through [d]). Thus, the fact that a patient is receiving care for diabetes does not mean that the recommended treatments are being applied. Because safe vehicle operation relies on a driver's sensory processing—especially of the senses of sight, sound, and touch—degradation of these inputs increases a driver's crash risk. The NTSB concludes that the fact that a driver with diabetes receives professional medical care does not guarantee that the disease is sufficiently controlled to enable the driver to operate a vehicle safely.

In other modes of transportation, specific standards address the medical certification of workers with type 2 diabetes. Merchant mariners who have diabetes controlled with oral medication are subject to medical review beyond their periodic physical examinations. Navigation and Vessel Inspection Circular (NVIC) 04-2008 details the recommended additional evaluation, which includes—

> Internal Medicine consultation documenting interval history, blood pressure and weight, evaluation of fasting plasma glucose; and, two current hemoglobin A1C's (<8.0%) separated by at least 90 days, the most recent no more than 90 days old, ophthalmology consultation… (US Department of Homeland Security 2016).

In aviation, based on 14 CFR 67.113(a), pilots with diabetes that requires insulin, or any other hypoglycemic drug, for control are disqualified from flight. However, the FAA may issue such a pilot a special medical certificate, provided that the pilot is being treated and meets specified standards. For pilots being treated with oral medications, an aviation medical examiner (AME) can reissue a medical certificate if the pilot provides specific information from his treating physician regarding current glycemic control, episodes of hypoglycemia (low blood sugar), and the presence or absence of long-term cardiovascular, neurologic, ophthalmologic, or renal complications. If the pilot's most recent hemoglobin A1C is higher than 9.0 percent or if there have been episodes of hypoglycemia or evidence of complications, the AME cannot issue a certificate, and higher-level review must occur (FAA 2015).

These more rigorous controls on the medical certification of marine and aviation operators with diabetes are safeguards that could be applied to commercial highway operators. The NTSB concludes that, had current medical standards for merchant mariners and aviation pilots been applied to the Laredo motorcoach driver, they might have prevented him from receiving a medical certificate until his diabetes was adequately controlled.

[60] Diabetic peripheral neuropathy is a type of nerve damage that can occur in persons with diabetes. High blood sugar can injure nerves throughout the body. Diabetic neuropathy most often damages nerves in the legs and feet, causing discomfort and of the loss of ability to feel pain. Comprehensive foot exams conducted by medical professionals are recommended for patients with diabetes.

In contrast to authorities in other modes of transport, the FMCSA places on the CME all decision-making responsibility for drivers with non-insulin-treated diabetes; moreover, the FMCSA does not provide CMEs with sufficient thresholds for diabetic control. Instead, the FMCSA relies on the CME's clinical judgment and provides no guidance regarding the need to obtain laboratory information, acceptable standards for glucose control, or specialty evaluation, such as by an ophthalmologist. The only recommendation from the FMCSA to CMEs concerning drivers with non-insulin-treated diabetes is that they limit the medical certification of such drivers to 1 year rather than 2 years (FMCSA 2014).

In 2006 and again in 2011, the FMCSA formed expert panels to evaluate the issue of diabetes and commercial driver safety. The reports from both panels indicated a small, but measurable, increase in the risk of motor vehicle collisions for drivers with diabetes. Both panels, however, focused on the risks posed by hypoglycemia (low blood sugar) rather than on those posed by hyperglycemia or on the safety consequences of renal, neurologic, or ophthalmologic complications resulting from long-term, poorly controlled diabetes (FMCSA 2007 and 2011). Further, the panels' reports contain no specific guidelines for CMEs to use when certifying drivers with diabetes to limit the risks posed by hyperglycemia.

The FMCSA has chosen to include among its CMEs any health care provider licensed to perform physical exams. In most states, this includes chiropractors; in some states, it also includes physical therapists. These two types of providers, in particular, have no training or experience in providing medical care to patients who require prescription medication for diabetes. Some other CMEs that are acceptable to the FMCSA do not routinely provide primary care for patients with diabetes and may have imperfect knowledge of treatment guidelines, little experience in evaluating the quality of glucose control, and limited ability to evaluate patients for diabetic complications. The NTSB concludes that not all CMEs recognized by the FMCSA have the knowledge, skills, and experience to adequately assess the potential safety implications of poorly controlled diabetes for the drivers they examine, based solely on their clinical judgment.

Therefore, the NTSB recommends that the FMCSA develop and publish explicit guidance for CMEs to use when making medical certification decisions regarding drivers with diabetes who are not treated with insulin. At a minimum, this guidance should recommend that every certification examination of a non-insulin-treated driver with diabetes document the results of a recent hemoglobin A1C test, any symptomatic hypoglycemia episodes, and detailed findings from periodic evaluations for diabetic complications, including retinopathy, neuropathy, and nephropathy; and provide CMEs with explicit certification criteria, including certification time limits and disqualifying results.

2.3.2 Fatigue

For most of the week preceding the crash, the driver's activities were routine, as he took his regular morning and afternoon shifts driving a school bus. However, 2 days before the crash, on Thursday, May 12, after completing his afternoon shift, the driver picked up a motorcoach from OGA Charters and brought it back to his residence. The driver reportedly went to bed at 10:30 p.m., but cell phone records show that he used his phone at 11:21 p.m. that night.

In the early morning of Friday, May 13, the driver left his home to drive a chartered trip for OGA Charters. The driver went on duty that morning at 3:45 a.m. After picking up passengers in Weslaco, he drove about 248 miles to his destination in San Antonio; after dropping off his passengers, he went off duty at 10:30 a.m. The driver said he remained on the motorcoach to rest, but instead of sleeping continuously, he used his cell phone on five occasions between 11:24 a.m. and 4:53 p.m. Cell phone records showed that the time between each of these calls was less than 1 hour; indicating that during the approximately 5.5 hours that the driver was reportedly resting, he had little or no opportunity for uninterrupted sleep. About 5:00 p.m., the driver left the bus to get something to eat, and then he went back on duty at 6:15 p.m. The driver loaded his passengers, departed San Antonio, and dropped the passengers off in Weslaco at 10:30 p.m. From there, he drove the motorcoach back to his residence and went off duty at 11:30 p.m. The driver's total time in either on-duty status or driving that day totaled 13 hours 15 minutes.

On Saturday, May 14, the day of the crash, the driver made two brief calls, at 12:07 a.m. and 12:27 a.m. He reported that then, after having slept for no more than about 2 hours, he woke up at 2:30 a.m. and prepared for driving another charter trip for OGA Charters. An hour later, the driver left his residence and traveled to Brownsville to pick up passengers. Once all the passengers had been loaded, he began driving to the casino in Eagle Pass. Before the crash, the driver made two stops, one in Zapata for fuel and one at a CBP checkpoint about 10 miles south of the crash location. Some moments before 11:24 a.m., with the driver having been awake for about 9 hours, the motorcoach drifted left from the northbound travel lane of US-83, and the driver reacted with abrupt steering input and braking, resulting in the loss of control and the crash.

The NTSB concludes that, in the 2 days before the crash, the driver's total opportunity for sleep, apart from short naps while waiting on the motorcoach, was about 6 hours. Moreover, the NTSB concludes that on the night before the crash, the motorcoach driver had a sleep opportunity of only about 2 hours.

Research has shown that sleep deprivation, from either acute sleep loss over a short period or chronic partial sleep loss over multiple days, is associated with delayed reaction time and lapses in attention (Goel and others 2009). Additionally, a recent study showed that driver crash risk nearly doubles from one night of sleep of a duration less than 6 hours; moreover, as the sleep duration declines, the risk progressively worsens (Tefft 2016).[61]

The NTSB concludes that the driver's failure to maintain the motorcoach within the northbound travel lane was due, in part, to fatigue from an acute sleep deficit in the days preceding the crash.

2.4 Highway Maintenance

The crash event began in a curved section of US-83 near MM 670.7. Since August 2011, this portion of the highway had been subject to various maintenance activities, including a pavement overlay operation, a project to widen and restripe the curve to accommodate the installation of turn lanes and driveways, a chip sealing project that was unsuccessful, and a

[61] Specifically, the study stated, "Drivers who had slept for less than 4 hours, 4–5 hours, 5–6 hours, and 6–7 hours in the past 24 hours had an estimated 11.5, 4.3, 1.9, and 1.3 times the crash rate, respectively, of drivers who had slept for 7 hours or more in the past 24 hours."

pavement milling effort that was intended to improve the inadequate surface friction that resulted from the failed chip sealing project.[62]

2.4.1 TxDOT Daily Activity Reports

With respect to the chip sealing project conducted in the northbound travel lane on October 21, 2015, TxDOT's DAR dated for that day indicates that a full-width chip seal was applied on US-83; however, the report does not specifically state whether the application was made to the full width of the northbound travel lane, of the southbound travel lane, or of both lanes. The DAR also lists the work as having been performed within a 34-mile-long segment of the highway between MMs 664 and 698. The crash occurred in the vicinity of MM 670.7, and TxDOT told the NTSB that the chip seal had been applied to this location on US-83; however, nothing in the DAR for October 21, 2015, specifically verified this statement.

The NTSB examined another DAR seeking confirmation of maintenance work performed after the October 21 chip seal operation. According to TxDOT, the chip seal project was not successful, and the aggregate applied to the roadway during the operation was displaced shortly after the application, which reduced the pavement's surface friction. To address this problem, on October 26, TxDOT had the highway surface milled in an attempt to improve its friction characteristics. The DAR for October 26 stated that the milling and planing work occurred as scheduled, but the location recorded on the report did not identify the area of MM 670.7.[63] Moreover, the DAR did not provide information to show whether the work was performed in the northbound travel lane, the southbound travel lane, or both lanes.

Throughout this investigation, the NTSB routinely encountered inaccuracies in the recordkeeping and information provided by TxDOT concerning maintenance work.[64] When asked by NTSB investigators about specific maintenance activities, TxDOT personnel did not refer to DARs or other records but instead gave answers based on their own recollections of events, including on such specific facts as when, where, and how maintenance was performed. The NTSB concludes that, because the information in the TxDOT's DARs was vague and inaccurate, agency personnel had to rely on institutional knowledge rather than reports to recall details of the maintenance operations conducted on US-83, which resulted in uncertainty about when, where, and how safety-critical work was performed.

In addition to making it difficult to determine whether work has been done in a specific location, uncertainty about maintenance activities can have more far-ranging consequences to a state's highway maintenance program. Concerning pavement management systems (PMS), 23 CFR 500.106 states—

[62] A successful chip sealing project was completed in August 2016, about 3 months after the crash.

[63] Despite the lack of verification in the DARs, the analysis of the core samples of the roadway near MM 670.7 obtained by the NTSB confirmed that both the chip seal and milling operations had occurred at the location.

[64] See appendix A of the docket item for this project titled "Highway Factors Group Chairman's Memorandum of Analysis." The appendix details the communications between NTSB investigators and TxDOT personnel concerning this investigation and the many instances of confusion and correction by TxDOT concerning its highway maintenance activities.

> An effective PMS for Federal-aid highways is a systematic process that provides information for use in implementing cost-effective pavement reconstruction, rehabilitation, and preventative maintenance programs and that results in pavements designed to accommodate current and forecasted traffic in a safe, durable, and cost-effective manner.

Although maintenance recordkeeping is not a PMS element, there is a crucial connection between asset management and pavement management. Without accurate records of previous roadway maintenance, a state department of transportation cannot fully account for its assets and may not be able to accurately forecast performance targeting within its PMS. The FHWA has offered National Highway Institute training courses and peer exchanges in the interest of disseminating best practices for PMSs. Because of the connection between asset management and pavement management, the FHWA anticipates providing updates to the states for developing improved asset management practices (National Highway Institute 2018).

During the NTSB's investigation of a September 15, 2015, crash in Houston, Texas, in which a school bus collided with and overrode a bridge rail, and then fell onto the road below, investigators uncovered instances of inadequate recordkeeping related to highway maintenance by TxDOT (NTSB 2016a) similar to those found during the Laredo investigation. During the Houston investigation, TxDOT determined through a forensic examination that a previous severe impact had occurred at the bridge rail in the same location as the school bus crash. However, TxDOT could not determine when the previous impact had occurred, could not account for the repair process used to rebuild the bridge railing, and had no information regarding what entity had performed the repair because the agency did not keep maintenance records documenting bridge railing improvements and repairs. As a result of the Houston crash, the TxDOT Bridge Division evaluated its recordkeeping processes and implemented improvements. These improvements included deploying new inspection software for collecting bridge inspection data and establishing procedures to make use of the new software's capabilities for collecting and documenting bridge railing improvement projects. Despite the department's efforts to improve the documentation of bridge rail work, based on the Laredo crash investigation, the NTSB concludes that TxDOT's maintenance recordkeeping continues to be inadequate and does not accurately capture and record maintenance operations vital to roadway safety.

Therefore, the NTSB recommends that TxDOT evaluate its processes for collecting and recording maintenance information through its DARs to ensure that the reports accurately and completely reflect the location and details of the work performed. Further, the NTSB recommends that TxDOT revise its processes for collecting and recording maintenance information through its DARs based on the results of the evaluation conducted in response to Safety Recommendation H-18-52 to ensure that the information contained in the DARs is accurate, complete, and sufficiently detailed to represent the full extent of maintenance activities.

2.4.2 Surface Friction and Pavement Milling

After the crash, TxDOT performed a series of surface friction tests along US-83. The tests within the curved section of the highway where the crash event began were performed with both smooth and ribbed test tires, in compliance with ASTM Standard E-274. Using a skid number range of 1–99 for tests with a smooth tire at 50 mph in wet conditions, in the vicinity of the crash, skid numbers were as low as 5.4. According to the summary report produced by the TFHRC for the NTSB, the skid number results in the vicinity of the crash would be considered extremely low by agencies that evaluate the friction characteristics of their highways.[65] The test results showed that some friction levels along US-83 were in the lowest of TxDOT's five friction categories.

According to the TFHRC report, factors that influence pavement friction fall into the following four categories:

- Pavement surface characteristics,
- Vehicle operational parameters,
- Tire properties, and
- Environmental factors.

Pavement surface characteristics that influence pavement friction include microtexture, which corresponds to wavelengths of texture less than 0.5 millimeter, and macrotexture, which corresponds to wavelengths of texture between 0.5 and 50 millimeters, with the most significant wavelengths below 10 millimeters (AASHTO 2008). The ribbed tire friction test is generally considered insensitive to macrotexture, while the smooth tire test is considered sensitive to both microtexture and macrotexture. Results of smooth tire tests that are significantly below the corresponding ribbed tire test results, as was the case in the Laredo crash location, indicate both low microtexture and low macrotexture (Wambold, Henry, and Blackburn 1984).

On October 21, 2015, about 7 months before the crash, TxDOT had attempted to apply a chip seal on US-83. The project was not successful, and the aggregate that was applied to the top layer of pavement during the operation became displaced from the highway. Then, to address the low surface friction resulting from the loss of aggregate, TxDOT milled the northbound travel lane on October 26, 2015. However, the milling operation was also unsuccessful, and it left gouges and continuous longitudinal grooves in the pavement. (See figure 13.)

[65] For example, although it uses different criteria than TxDOT for friction levels, the Washington State Department of Transportation specifies a minimum skid number value of 30.0.

Figure 13. View of US-83 northbound travel lane shortly after the crash, showing gouges and continuous longitudinal grooves in the pavement surface.

The problems with the pavement texture in the crash area are particularly apparent when comparing the pavement immediately postcrash to the pavement as it was after successful maintenance operations—including chip sealing—were conducted in August 2016, about 3 months after the crash, as indicated in figure 14. After the successful work, the texture of the roadway surface was uniform, it no longer appeared slick, and the grooves and gouges were gone.

Figure 14. Views of the northbound US-83 lane looking south. The photo on the left shows the northbound travel lane as it appeared in May 2016. The photo on the right shows the northbound travel lane as it appeared in August 2016, after the completion of the successful chip seal operation.

The TFHRC report to the NTSB concluded that the results of the milling operation on October 26, 2015, produced results that did not conform to TxDOT standard specifications for planing and texturing as detailed in the TxDOT *Planing and Texturing Pavement Specifications*. It is unclear how the longitudinal grooves in the pavement surface were made, but the report theorized that they could have been produced by a milling head with misaligned teeth. The NTSB concludes that the pavement milling operation performed on US-83 by the TxDOT maintenance crew on October 26, 2015, was inadequate and did not conform to the agency's own specifications.

Additional TFHRC analysis of the pavement in the vicinity of the crash determined that the milling performed on October 26, 2015, did not provide adequate macrotexture and friction. Further, the TFHRC stated that pavement core samples 1B and 5B, which were taken from the milled area, had a 2–3-millimeter-thick asphalt-rich layer at their tops.[66] Finding such an asphalt-rich layer on the top of a pavement is consistent with the failed chip seal operation on October 21, 2015, in which sufficient aggregate was not retained. Further, the presence of this asphalt-rich layer demonstrates that the milling operation conducted 5 days later did not adequately remove the slick top layer of asphalt emulsion placed during the failed chip seal operation. The NTSB concludes that the asphalt-rich layer observed on the surfaces of pavement core samples 1B and 5B from the crash area contributed to the low surface friction values of the pavement. Therefore, the NTSB recommends that TxDOT assess, and modify as necessary, the training provided to its maintenance personnel to ensure that the results of milling operations conform to its *Planing and Texturing Pavement Specifications*. Because the milling did not adequately remove the asphalt emulsion placed as part of the failed chip seal operation, the NTSB also recommends that TxDOT train its maintenance personnel to evaluate milling operations so that the resulting pavement surface provides acceptable levels of friction.

2.5 Motorcoach Occupant Protection

2.5.1 Seat Belts

At the time of the crash, the 1998 Van Hool motorcoach was nearly 20 years old. Evaluation of the passenger-carrying and occupant safety aspects of the motorcoach revealed a vehicle that was outdated and worn; some of the interior furnishings, such as the armrests, exhibited precrash damage. However, features vital to passenger safety, such as seat securement to the floor and proper functioning of emergency exits, were operational. In addition, the motorcoach had been designed based on European standards in place at the time of manufacture, which required seat belts for the exposed seating positions (those without a seatback in front of them).[67] Although five passenger seats and the jump seat were equipped with lap belts, there was no clear evidence that they were used.

Since this vehicle was manufactured, motorcoach seat belt technology and regulations have evolved substantially. The NTSB's 1999 special investigation report on *Bus Crashworthiness Issues* concluded that retaining occupants within their seating compartments would reduce injury

[66] A surface layer of asphalt of 1 millimeter or more in depth will effectively negate the influence of pavement macrotexture.

[67] The European standard that Van Hool followed was directive 90/629/EEC, which became effective July 1, 1992.

risk (NTSB 1999b). The National Highway Traffic Safety Administration (NHTSA) 2007 Motorcoach Safety Plan and the DOT 2009 Departmental Motorcoach Safety Action Plan also reported safety benefits associated with passenger restraints in motorcoaches. Then, in November 2013, after completing a notice of proposed rulemaking (NPRM) process, NHTSA announced a final rule regarding seat belts on motorcoaches. The final rule amended 49 CFR 571.208 and fulfilled a statutory provision of the Motorcoach Enhanced Safety Act, which was part of the Moving Ahead for Progress in the 21st Century Act (MAP-21).[68] The amendment, which became effective in November 2016, revised Federal Motor Vehicle Safety Standard 208 to require lap/shoulder belts on all driver and passenger seats for new over-the-road buses with GVWRs greater than 26,000 pounds and for all new motorcoaches, regardless of weight. However, the amendment did not require existing motorcoaches, such as the crash motorcoach, to be retrofitted and equipped with seat belts.[69]

2.5.2 Window Glazing

During the crash sequence, the motorcoach yawed clockwise, rolled onto its left side, and came to rest with its front end partially on the easternmost edge of the road and its middle and rear on the eastern shoulder and ground (to the right of the northbound lanes). At some point during this sequence, the motorcoach's left side window glazing failed, and some passengers were ejected. Evaluation of the medical records, autopsy reports, and other crash evidence indicates that a significant number of the seriously injured passengers were partially ejected, and it is likely that all of those passengers who died were either partially or fully ejected. Further, all the passengers who died suffered crushing injuries to the chest or head or both. These injury patterns, as well as the locations of the deceased at the crash scene—they were found under the left side of the vehicle—suggest that those who were fatally injured were ejected through the left side window glazing. The exact mechanisms for ejection could not be determined, but the following are possible scenarios:

- The window glazing might have been compromised by the initial impact with the ground or by subsequent impacts, as the left side of the vehicle slid across the ground.
- As the motorcoach rolled to the left, passengers might have fallen toward the windows and struck the glazing with sufficient force to break it.
- Passengers seated next to windows might have had other passengers fall onto them, pushing them into the windows, causing the windows to break.

Because lap/shoulder belts are now required on newly manufactured motorcoaches, and because many bus manufacturers had elected to install passenger lap/shoulder belts before the requirement went into effect in November 2016, some motorcoaches are already equipped with passenger restraints. Had the Laredo motorcoach been equipped with such restraints, and had the passengers used them, the movement of passengers into the windows during the crash sequence

[68] For additional information on this legislation, see MAP-21 webpage, accessed June 7, 2018.

[69] NHTSA examined the feasibility of retrofitting existing motorcoaches with lap/shoulder belts and determined that the cost and engineering expertise needed to conduct a retrofitting operation that would be sufficiently robust to make such belts adequate safety features would be beyond the means of many bus owners (for-hire operators), many of which are small businesses. Determining that satisfactory retrofitting operations would not be technically practicable at a reasonable cost, NHTSA decided not to pursue a retrofit requirement (NHTSA 2016).

would have been curtailed. The NTSB concludes that, had the Laredo motorcoach passengers been restrained by seat belts, the potential for window breakage would have been reduced, but the flailing of the occupants nearest the windows and the contact with the ground would still have provided significant potential for window breakage.

Advanced window glazing is less likely to break in a crash. NHTSA has conducted research on advanced window glazing with the objective of retaining the windows and preventing occupant ejections. The NTSB has supported this work and, in its 1999 special investigation report on *Bus Crashworthiness Issues*, made the following safety recommendation to NHTSA (NTSB 1999b):

> Expand your research on current advanced glazing to include its applicability to motorcoach occupant ejection prevention, and revise window glazing requirements for newly manufactured motorcoaches based on the results of this research. (H-99-49)

The recommendation is currently “Open—Unacceptable Response.”

On May 6, 2016, NHTSA issued an NPRM titled “Federal Motor Vehicle Safety Standards; Bus Emergency Exits and Window Retention and Release, Anti-Ejection Glazing for Bus Portals.” The NPRM established NHTSA’s intent to require advanced window glazing in high-occupancy buses (motorcoaches) and non-over-the-road buses with GVWRs greater than 26,000 pounds. The proposed standard would specify impactor testing of glazing materials and apply performance requirements for windows or glass panels on the sides, rear, and roof of the bus, to mitigate ejection and ensure that emergency exits remain operable.

The NTSB concludes that the severity of the injuries experienced by those passengers who were ejected through the windows might have been mitigated by the effects of the use of seats belts to reduce the uncontrolled movement of passengers during the crash sequence, coupled with advanced window glazing to lessen the potential for ejections. The NTSB further concludes that the effectiveness of motorcoach occupant protection would be improved by passenger lap/shoulder belts and advanced window glazing because these safety features reduce the potential for belted passengers to fall across the vehicle during a rollover and to break out windows.

Given the likely reduction in ejections during rollover crashes that could result when motorcoaches equipped with passenger seat belts are also furnished with advanced window glazing, the NTSB reiterates Safety Recommendation H-99-49 to NHTSA.

2.6 Motor Carrier Operations

2.6.1 OGA Charters Oversight of its Drivers

At the time of the crash, the motor carrier OGA Charters had been in operation for 7 years. Throughout this period, the carrier had no safeguards in place to promote safety or mitigate risks. The carrier did not have any written policies or procedures for drivers to follow, and it did not have a company handbook. The carrier’s oversight of its drivers was minimal. Following the crash, the carrier reported that no one at OGA Charters verified the drivers’ records-of-duty status for accuracy, nor were the records audited to ensure driver compliance with hours-of-service requirements. The carrier owner made all decisions regarding company drivers on a case-by-case basis. OGA Charters lacked any systematic approach to maintaining safety, and the carrier provided only the minimum safety management required by the FMCSA to retain its operating authority. The NTSB concludes that, throughout its operational history, the motor carrier OGA Charters failed to provide adequate oversight of its drivers.

2.6.2 FMCSA Oversight of OGA Charters

2.6.2.1 Compliance Reviews. Before the crash, the carrier had been subject to two FMCSA compliance reviews (in 2010 and 2014) and seven roadside inspections. Both compliance reviews resulted in satisfactory ratings, but they also uncovered numerous driver and vehicle violations. Three of the roadside inspections resulted in the vehicle being placed out of service for brake system defects, and two of the inspections found that a company driver had logbook violations. Additionally, at the time of the crash, the carrier had an alert in the hours-of-service BASIC.

Following both compliance reviews, the FMCSA provided OGA Charters with specific recommendations and guidance on how the carrier could comply with regulations. The owner of OGA Charters failed to implement any of the recommended improvement actions. For example, although the owner was responsible for the carrier's recordkeeping, he did not routinely perform audits of drivers' hours of service. He told NTSB investigators that he had been having problems with getting the crash driver to turn in his record-of-duty status, as required. Although the owner was aware of the crash driver's failures to provide his record-of-duty status as required, he allowed the driver unrestricted access to the motorcoach and afforded him the opportunity to drive with little or no supervision.

After the crash, investigators asked the owner to provide a detailed account of the crash driver's duty status for the days preceding the crash. The owner told investigators that it was not until he was responding to this request that he realized the driver had been scheduled to drive in excess of the allowable hours of service. The FMCSA postcrash compliance review found that the crash driver had falsified his logbook entries by indicating in the log that he was off duty the day before the crash.[70]

The NTSB concludes that, despite precrash compliance reviews that provided OGA Charters with specific recommendations from the FMCSA on how to comply with regulations and thereby improve safety, the carrier failed to take any action to improve the oversight of its drivers and ensure safe motorcoach operations through compliance with federal safety regulations.

2.6.2.2 FMCSA Safety Fitness Rating. The FMCSA postcrash compliance review of OGA Charters resulted in a conditional rating for the carrier. Given the carrier owner's previous lack of compliance with federal safety regulations, the numerous and repeated violations involving driver oversight found in the postcrash review were entirely predictable. The NTSB has been and remains concerned that the FMCSA is routinely issuing satisfactory and conditional safety ratings to motor carriers, such as OGA Charters, with significant violations of regulations that are intended to ensure driver and vehicle safety.

[70] The driver later reported he had not been off duty; he had actually driven the motorcoach on a charter trip to San Antonio for OGA Charters.

Two key factors in safe motor carrier operations are the operational status of the vehicles (in this instance, the motorcoach) and the performance of the drivers. Increasing the weight of performance data for vehicle and driver factors in compliance reviews is important because such deficiencies are directly related to crashes. In its special investigation report on *Selective Motorcoach Issues*, the NTSB recommended that the DOT (NTSB 1999a)—

> Change the safety fitness rating methodology so that adverse vehicle or driver performance-based data alone are sufficient to result in an overall unsatisfactory rating for the carrier. (H-99-6)

Safety Recommendation H-99-6 is classified "Open—Unacceptable Response."

When a compliance review identifies critical violations directly linked to a crash—such as driver hours of service—the FMCSA should either require the carrier to demonstrate a commitment to mitigating safety risks or put the carrier out of service. As a result of the investigation of a New York City motorcoach crash in March 2011, the NTSB made the following recommendation to the FMCSA (NTSB 2012):

> Include safety measurement system rating scores in the methodology used to determine a carrier's fitness to operate in the safety fitness rating rulemaking for the new Compliance, Safety, Accountability initiative. (H-12-17)

Safety Recommendation H-12-17 is classified "Open—Unacceptable Response."

The NTSB urged the FMCSA to move forward expeditiously on finalizing the safety fitness determination (SFD) process to help remove unsafe motor carriers and their drivers from the nation's highways. Making CSMS scores an integral part of the SFD would provide a procedure by which the FMCSA could more directly and quickly shut down unsafe carriers. Because driver violations have been shown to be a clear indicator of crash risk, the SFD could address deficiencies in the current compliance review process by basing a motor carrier's safety rating on violations of important safety-based regulations (as found in roadside inspections), which would help to keep unsafe carriers from continuing to operate.

On January 21, 2016, the FMCSA published an NPRM to update the safety fitness rating methodology by integrating on-road safety inspection data with the results of carrier investigations and crash reports. The proposed SFD rule would facilitate updating a motor carrier's overall safety fitness on a monthly basis. It would replace the current three-tiered system that provides rankings of "satisfactory," "conditional," or "unsatisfactory" with a single determination of "fit" or "unfit;" an "unfit" rating would require the carrier to improve its performance or cease operations. However, the NTSB is concerned that the language in the proposed rule, as written, does not fully address the intent of Safety Recommendation H-99-6, because the rating process may not appropriately value vehicle and driver factors in compliance review ratings.

On March 23, 2017, the FMCSA withdrew its NPRM, citing a need to receive a Correlation Study from the National Academies of Science to enable it to determine what corrective actions are advisable, as well as the need to complete additional analysis before determining whether further rulemaking action is necessary to revise the SFD process. The NTSB is disappointed that the January 2016 NPRM has been withdrawn, further delaying improvement of the SFD process.

In its report of a 2014 multivehicle collision on Interstate 88 near Naperville, Illinois, the NTSB determined that the delay in enacting SFD rulemaking has prevented the FMCSA from obtaining the additional tools it needs to more effectively address the safety risks posed by high-risk carriers (NTSB 2016b). As a result of the Naperville investigation, the NTSB reiterated Safety Recommendation H-12-17.

In its report of a 2016 motorcoach crash in Livingston, California, in which a fatigued motorcoach driver allowed his vehicle to depart from its travel lane and collide with a signpost, causing the death of four passengers, the NTSB found that contributing to the cause of the crash were the failure of the motor carrier to follow adequate safety practices and the FMCSA's lack of oversight, which allowed the company to continue operations despite known safety issues (NTSB 2017). The safety issues addressed in the Livingston crash included the inadequate federal safety ratings for passenger motor carriers with repetitive driver and vehicle violations. The NTSB reiterated Safety Recommendations H-99-6 and H-12-17 to address this unresolved safety issue.

Had the FMCSA changed its safety fitness rating methodology to give appropriate weight to vehicle- and driver performance-based data, as the NTSB has repeatedly recommended, it would have had additional evidence before the Laredo crash that OGA Charters was a habitually unsafe carrier. The NTSB concludes that an improved safety fitness rating methodology would enable the FMCSA to better identify habitually unsafe carriers. Moreover, because of the inaccuracy of the compliance review safety ratings the FMCSA assigned to OGA Charters, the NTSB concludes that the Laredo crash further demonstrates the need for the FMCSA to implement an SFD methodology to expedite the process of shutting down unsafe carriers. The NTSB remains concerned about the delay in rulemaking and again reiterates Safety Recommendations H-99-6 and H-12-17 to the FMCSA.

3 Conclusions

3.1 Findings

1. None of the following were factors in the crash: (1) driver licensing or qualifications, (2) alcohol or other drug use by the motorcoach driver, (3) driver cell phone distraction, and (4) roadway geometry or the posted speed limit for US Highway 83 at the curved segment where the crash occurred.

2. The emergency response was timely and effective.

3. The motorcoach initially moved to the left as it entered the curve, and the driver steered to the right and braked, causing the motorcoach to depart the east side of the highway and roll over.

4. The pavement's reduced friction, combined with the motorcoach's inoperable antilock braking system, contributed to the driver's inability to regain control of the vehicle.

5. The motorcoach driver's blood sugar was significantly elevated at the time of the crash due to poorly controlled diabetes.

6. The motorcoach driver's poorly controlled diabetes and resulting hyperglycemia most likely led to blurred vision at the time of the crash.

7. The roadway cues available to enable the motorcoach driver to properly position his vehicle within the northbound driving lane of the highway were degraded, and the visual difficulties were compounded by the driver's likely blurred vision resulting from his poorly controlled diabetes.

8. The fact that a driver with diabetes receives professional medical care does not guarantee that the disease is sufficiently controlled to enable the driver to operate a vehicle safely.

9. Had current medical standards for merchant mariners and aviation pilots been applied to the Laredo motorcoach driver, they might have prevented him from receiving a medical certificate until his diabetes was adequately controlled.

10. Not all certified medical examiners recognized by the Federal Motor Carrier Safety Administration have the knowledge, skills, and experience to adequately assess the potential safety implications of poorly controlled diabetes for the drivers they examine, based solely on their clinical judgment.

11. In the 2 days before the crash, the driver's total opportunity for sleep, apart from short naps while waiting on the motorcoach, was about 6 hours.

12. On the night before the crash, the motorcoach driver had a sleep opportunity of only about 2 hours.

13. The driver's failure to maintain the motorcoach within the northbound travel lane was due, in part, to fatigue from an acute sleep deficit in the days preceding the crash.

14. Because the information in the Texas Department of Transportation's daily activity reports was vague and inaccurate, agency personnel had to rely on institutional knowledge rather than reports to recall details of the maintenance operations conducted on US Highway 83, which resulted in uncertainty about when, where, and how safety-critical work was performed.

15. The Texas Department of Transportation's maintenance recordkeeping continues to be inadequate and does not accurately capture and record maintenance operations vital to roadway safety.

16. The pavement milling operation performed on US Highway 83 by the Texas Department of Transportation maintenance crew on October 26, 2015, was inadequate and did not conform to the agency's own specifications.

17. The asphalt-rich layer observed on the surfaces of pavement core samples 1B and 5B from the crash area contributed to the low surface friction values of the pavement.

18. Had the Laredo motorcoach passengers been restrained by seat belts, the potential for window breakage would have been reduced, but the flailing of the occupants nearest the windows and the contact with the ground would still have provided significant potential for window breakage.

19. The severity of the injuries experienced by those passengers who were ejected through the windows might have been mitigated by the effects of the use of seats belts to reduce the uncontrolled movement of passengers during the crash sequence, coupled with advanced window glazing to lessen the potential for ejections.

20. The effectiveness of motorcoach occupant protection would be improved by passenger lap/shoulder belts and advanced window glazing because these safety features reduce the potential for belted passengers to fall across the vehicle during a rollover and to break out windows.

21. Throughout its operational history, the motor carrier OGA Charters LLC failed to provide adequate oversight of its drivers.

22. Despite precrash compliance reviews that provided OGA Charters LLC with specific recommendations from the Federal Motor Carrier Safety Administration on how to comply with regulations and thereby improve safety, the carrier failed to take any action to improve the oversight of its drivers and ensure safe motorcoach operations through compliance with federal safety regulations.

23. An improved safety fitness rating methodology would enable the Federal Motor Carrier Safety Administration to better identify habitually unsafe carriers.

24. The Laredo crash further demonstrates the need for the Federal Motor Carrier Safety Administration to implement a safety fitness determination methodology to expedite the process of shutting down unsafe carriers.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the Laredo, Texas, crash was the driver's failure to maintain the motorcoach fully within the northbound travel lane, due to a combination of fatigue from an acute sleep deficit and blurred distance vision due to hyperglycemia resulting from poorly controlled diabetes; then, as the motorcoach drifted left from the travel lane, the driver abruptly steered to the right and braked, causing the vehicle to leave the highway and roll over. Contributing to the driver's inability to regain control of the motorcoach was the low friction value of the wet pavement and the inoperable antilock braking system. Contributing to the severity of the passenger injuries was the failure of the left side passenger windows to keep passengers within the motorcoach.

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:

> Develop and publish explicit guidance for certified medical examiners (CMEs) to use when making medical certification decisions regarding drivers with diabetes who are not treated with insulin. At a minimum, this guidance should recommend that every certification examination of a non-insulin-treated driver with diabetes document the results of a recent hemoglobin A1C test, any symptomatic hypoglycemia episodes, and detailed findings from periodic evaluations for diabetic complications, including retinopathy, neuropathy, and nephropathy; and provide CMEs with explicit certification criteria, including certification time limits and disqualifying results. (H-18-51)

To the Texas Department of Transportation:

> Evaluate your processes for collecting and recording maintenance information through your daily activity reports to ensure that the reports accurately and completely reflect the location and details of the work performed. (H-18-52)

> Revise your processes for collecting and recording maintenance information through your daily activity reports (DARs) based on the results of the evaluation conducted in response to Safety Recommendation H-18-52 to ensure that the information contained in the DARs is accurate, complete, and sufficiently detailed to represent the full extent of maintenance activities. (H-18-53)

> Assess, and modify as necessary, the training provided to your maintenance personnel to ensure that the results of milling operations conform to your *Planing and Texturing Pavement Specifications*. (H-18-54)

> Train your maintenance personnel to evaluate milling operations so that the resulting pavement surface provides acceptable levels of friction. (H-18-55)

4.2 Recommendations Reiterated in This Report

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

To the Federal Motor Carrier Safety Administration:

> Change the safety fitness rating methodology so that adverse vehicle or driver performance-based data alone are sufficient to result in an overall unsatisfactory rating for the carrier. (H-99-6)
>
> Include safety measurement system rating scores in the methodology used to determine a carrier's fitness to operate in the safety fitness rating rulemaking for the new Compliance, Safety, Accountability initiative. (H-12-17)

To the National Highway Traffic Safety Administration:

> Expand your research on current advanced glazing to include its applicability to motorcoach occupant ejection prevention, and revise window glazing requirements for newly manufactured motorcoaches based on the results of this research. (H-99-49)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Adopted: November 7, 2018

Appendix A: Investigation

The National Transportation Safety Board (NTSB) was notified of the Laredo, Texas, crash on May 14, 2016, and dispatched an investigative team to the site. The NTSB established groups to investigate human performance; motor carrier operations; and highway, survival, and vehicle factors.

Parties to the investigation were the Federal Highway Administration, the Federal Motor Carrier Safety Administration, the Texas Department of Public Safety, the Texas Department of Transportation, and ABC Companies.

Appendix B: Skid Numbers for Northbound US-83

Table B-1. Skid numbers for northbound travel lane of US-83 in right wheel path. (The gray-shaded area provides the skid numbers in the vicinity of the crash [near MM 670.7])

Stationing* (miles)	Skid Number 50 mph using Smooth Tire (Wet Testing)	Skid Number 40 mph using Smooth Tire (Wet Testing)	Skid Number 40 mph using Ribbed Tire (Wet Testing)	Skid Number 40 mph using Smooth Tire (Dry Testing)
0.000 (RM 672)**	47.5	51.5	50.4	-
0.050	44.4	53.4	47.9	-
0.100	48.3	48.9	48.5	-
0.150	47.0	53.9	50.9	-
0.200	45.7	48.4	47.8	-
0.250	43.6	54.9	49.7	-
0.300	44.8	54.0	48.8	-
0.350	38.6	45.7	46.8	-
0.400	45.9	53.7	54.0	-
0.450	46.0	51.8	53.3	-
0.500	49.8	55.1	50.8	-
0.550	41.1	47.2	45.2	-
0.600	42.8	47.9	46.9	-
0.650	41.1	51.4	45.2	-
0.700	39.6	48.1	45.3	-
0.750	36.3	36.6	41.3	-
0.800	36.1	43.4	42.0	53.2
0.850	8.4	9.3	15.7	-
0.900	6.3	10.3	18.2	77.8
0.950	7.4	6.9	19.8	-
1.000 (RM 671)	5.9	8.9	19.3	88.6
1.050	5.7	8.6	20.4	-
1.100	7.6	9.0	21.2	88.8
1.150	6.6	9.1	20.4	-
1.200	6.0	9.6	16.4	66.6
1.250	8.9	10.4	17.7	-
1.300 (RM 670.7)	9.9	12.4	20.0	55.3
1.350	7.8	7.4	14.2	-
1.400	28.1	32.9	39.7	87.1
1.450	23.7	10.0	32.3	-

1.500	42.0	29.2	48.4	-
1.550	37.2	44.6	45.6	-
1.600	5.2	7.9	16.2	-
1.650	34.2	43.7	46.5	-
1.700	20.9	8.4	40.5	-
1.750	35.4	46.0	55.9	-
1.800	30.2	36.8	52.3	-
1.850	17.5	22.4	36.5	-
1.900	28.2	42.5	49.9	-
1.950	27.9	42.8	-	-
2.000 (RM 670)	-	25.8	-	-
2.050	-	27.2	-	-

* Stationing 0.000 started at MM 672.

** “RM” refers to mile marker.

Table B-2. Skid numbers for northbound travel lane of US-83 in left wheel path. (The gray-shaded area provides the skid numbers in the vicinity of the crash [near MM 670.7])

Stationing (miles)	Skid Number 50 mph using Smooth Tire (Wet Testing)	Skid Number 40 mph using Smooth Tire (Wet Testing)	Skid Number 40 mph using Ribbed Tire (Wet Testing)	Skid Number 40 mph using Smooth Tire (Dry Testing)
0.000 (RM 672)	53.0	69.2	50.9	-
0.050	54.9	77.3	50.8	-
0.100	53.5	56.6	49.8	-
0.150	54.7	57.9	52.6	-
0.200	52.5	54.3	49.8	-
0.250	49.8	52.2	48.8	-
0.300	48.9	55.3	50.5	-
0.350	50.2	54.0	48.7	-
0.400	55.2	58.4	52.9	-
0.450	56.9	56.7	54.3	-
0.500	53.3	58.1	54.7	-
0.550	49.4	55.5	51.7	-
0.600	48.1	53.2	48.7	-
0.650	53.9	55.9	50.6	-
0.700	54.0	58.8	49.2	-
0.750	60.2	56.3	52.9	-
0.800	50.5	60.8	53.4	77.8
0.850	43.9	40.9	48.2	-
0.900	25.2	21.2	39.1	53.0
0.950	13.5	13.7	23.3	-
1.000 (RM 671)	9.9	11.7	21.5	87.7
1.050	9.8	12.1	21.4	-
1.100	13.9	10.6	23.0	81.0
1.150	7.6	11.3	19.5	-
1.200	19.8	14.1	22.2	44.9
1.250	9.8	14.7	18.5	-
1.300 (RM 670.7)	8.7	12.3	17.1	73.1
1.350	5.4	10.7	14.1	-
1.400	11.6	28.2	32.3	85.9
1.450	35.5	10.4	29.4	-
1.500	12.1	17.8	36.7	-
1.550	45.4	44.6	44.7	-
1.600	8.4	9.3	18.3	-
1.650	35.3	25.9	44.8	-

1.700	23.3	9.4	24.8	-
1.750	36.5	40.6	52.9	-
1.800	32.9	37.6	54.5	-
1.850	16.1	18.5	42.1	-
1.900	29.8	34.8	55.4	-
1.950	27.3	37.1	59.3	-
2.000 (RM 670)	20.3	30.9	-	-
2.050	53.2	-	-	-

Table B-3. Skid numbers for northbound travel lane of US-83 between wheel paths. (The gray-shaded area provides the skid numbers in the vicinity of the crash [near MM 670.7])

Stationing (miles)	Skid Number 50 mph using Smooth Tire (Wet Testing)	Skid Number 40 mph using Smooth Tire (Wet Testing)	Skid Number 40 mph using Ribbed Tire (Wet Testing)	Skid Number 40 mph using Smooth Tire (Dry Testing)
0.000 (RM 672)	-	62.6	56.5	-
0.050	-	62.9	57.6	-
0.100	-	64.4	55.0	-
0.150	-	62.8	58.1	-
0.200	-	61.2	53.8	-
0.250	-	62.4	54.9	-
0.300	-	61.1	56.5	-
0.350	-	63.1	56.9	-
0.400	-	61.1	55.7	-
0.450	-	57.5	49.8	-
0.500	-	62.0	57.4	-
0.550	59.5	63.4	57.1	-
0.600	53.1	59.0	59.1	-
0.650	51.8	57.7	54.1	-
0.700	50.1	54.4	49.3	-
0.750	51.2	49.0	52.8	-
0.800	10.8	44.7	46.9	53.9
0.850	9.3	10.6	19.1	-
0.900	4.7	7.5	15.1	81.5
0.950	17.7	8.1	22.3	-
1.000 (RM 671)	45.2	39.2	54.8	80.3
1.050	47.6	50.1	58.8	-
1.100	34.6	38.6	56.1	85.4
1.150	26.1	46.3	49.4	-
1.200	21.9	18.3	19.0	38.7
1.250	10.1	11.9	21.0	-
1.300 (RM 670.7)	10.9	12.9	19.6	48.5
1.350	27.8	17.8	21.3	-
1.400	20.8	47.5	48.5	76.0
1.450	16.0	19.7	49.3	-
1.500	31.8	40.7	53.3	-
1.550	35.1	54.7	51.6	-
1.600	25.0	18.6	32.5	-
1.650	21.4	45.4	53.9	-

1.700	53.9	35.3	63.1	-
1.750	60.5	56.4	65.9	-
1.800	33.2	67.7	64.8	-
1.850	64.3	65.9	60.8	-
1.900	57.9	68.0	65.2	-
1.950	59.8	60.3	-	-
2.000 (RM 670)	33.0	44.3	-	-
2.050	-	-	-	-

Appendix C: Turner-Fairbank Pavement Friction Testing Summary Report

Testing Summary

(Revised May 21, 2017)

Evaluation of Low Pavement Friction Values, May 14, 2016 Bus Crash, US83, Laredo, Texas

Federal Highway Administration, Office of Infrastructure Research and Development

Turner-Fairbank Highway Research Center, McLean, VA

Background

On May 14, 2016, at approximately 11:21 am, a bus carrying a 51 passengers and a driver was travelling north on US Highway 83 (US83), in the vicinity of the Webb/Dimmit county line north of Laredo, Texas. The bus driver lost control of the bus at approximately the crest of a compound curve (horizontal and vertical curve) in the roadway. The bus crash resulted in 9 fatalities and 43 injuries.

The National Transportation Safety Board (NTSB) began an investigation of this crash. Initially, the NTSB identified low pavement friction values as a potential contributor to the crash. To assist in investigating the low pavement friction test results in the vicinity of the crash initiation, the NTSB contacted the Federal Highway Administration (FHWA), Office of Infrastructure Research and Development, for technical assistance with testing pavement cores extracted from the pavement and reviewing the available information. The specific question from NTSB to FHWA was "What were the potential causes of the low pavement friction values in the northbound lanes of US83?"

Pavement History

The revised timeline of TxDOT's account of the maintenance operations conducted in the northbound travel lane of US-83:

- **August 5, 2011:** A 1.5-inch overlay was placed on the northbound and southbound travel lanes of US-83. TxDOT's contractor began work on August 5, 2011 and TxDOT accepted the work as completed on January 10, 2012.
- **November, 2012:** Driveways were added on US83 at approximately the crest of the vertical curve to serve oil field operations for Shell Oil Company. The work only consisted of widening US-83 (on the southbound side) to provide turn lanes. The driveways matched existing conditions. No overlay was done to the northbound travel lanes.
- **2015:** The 2011 overlay experienced some distress in the form of cracking and minor rutting.
- **October 21, 2015:** TxDOT maintenance forces place asphalt emulsion and chips for chip seal. Chips are reported completely lost resulting in supplemental treatment on October 26, 2015.
- **October 26, 2015:** TxDOT maintenance forces perform milling "roughen" pavement surface in location of chip seal placement on October 21, 2015 where chips were lost and emulsion remains. Milling was performed for approximately 1000 feet starting before the driveways and continuing past the

driveways. No additional treatments were performed to the northbound travel lane after the milling operations were performed on October 26, 2015.

Pavement Testing

After the crash, TxDOT performed friction testing on the northbound lanes. Friction test results obtained using ASTM locked wheel skid trailer indicated abnormally low friction test values in approximately half mile of the northbound lane, in both wheel paths but most prevalent in the right wheel path.

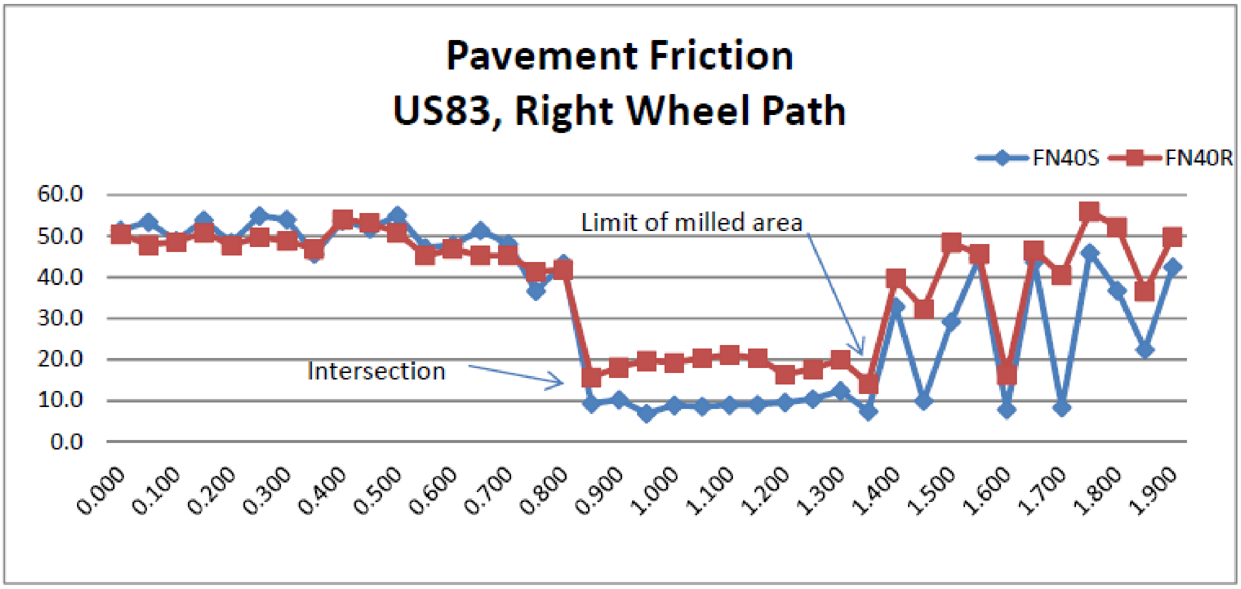

Figure 1: Friction test values (FN40S and FN40R)reported by TxDOT. Locations of "intersection" and "end of milled area" are approximate. The crest of the vertical curve is approximately at DMI reference 1.200.

As part of the crash investigation NTSB obtained cores of the pavement at 5 different locations. One set of five cores was provided to FHWA for testing. Core locations are described as follows:

Core Number	Location	Comments
#1B	North bound lane, 450 feet south of the point of final rest of motor coach	Within milled area, Left wheel path
#2B	Center painted median, 450 feet south of the point of final rest of motor coach	
#3B	South bound lane, 450 feet south of the point of final rest of motor coach	New pavement area from widening project in November, 2012
#4B	North bound lane, approximately 600 feet south of intersection	In area of higher friction values
#5B	North bound lane, 700 feet south of point of final rest of motor coach	Within milled area, right wheel path.

Table 1: Pavement core locations and description.

Core #1B and #5B are of particular interest are they were obtained from the area of low pavement friction and the area where the crash likely originated.

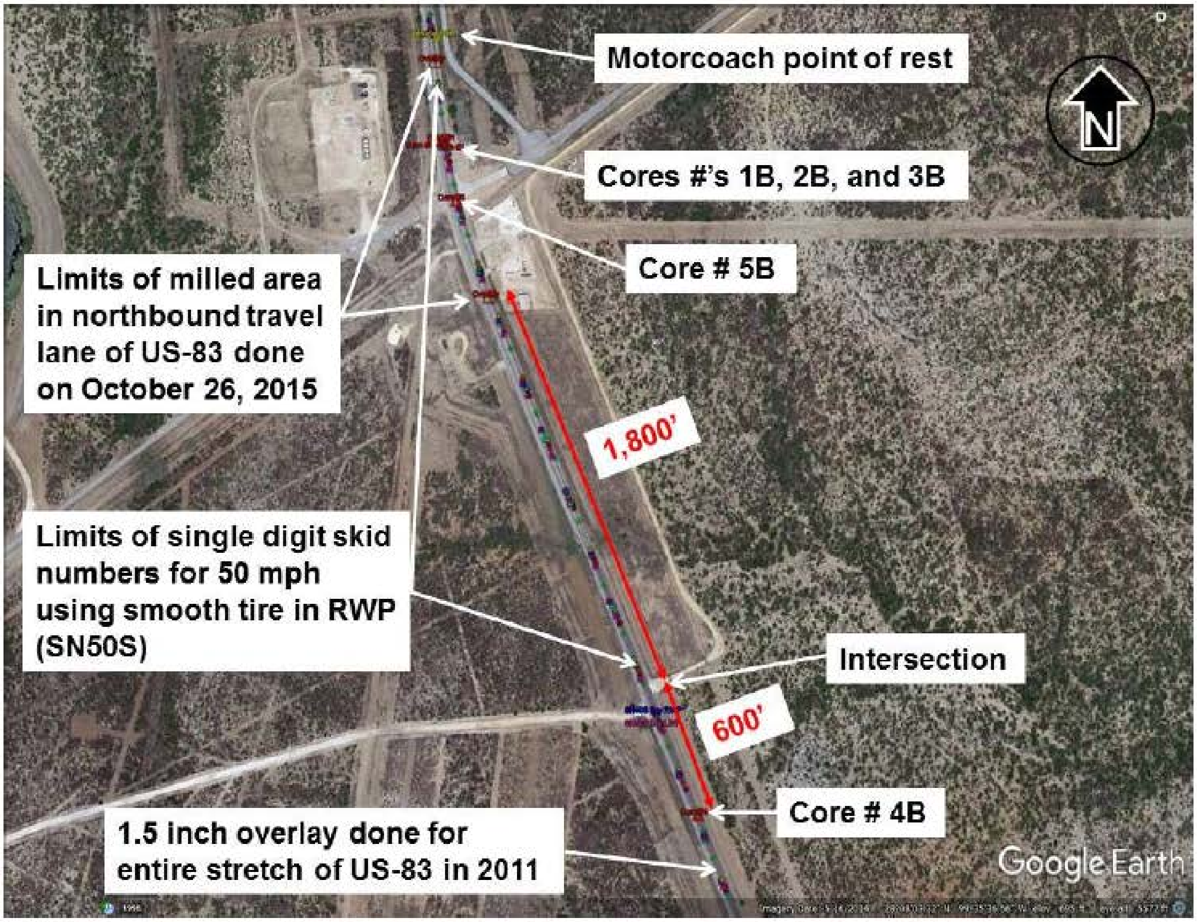

Figure 2: Site map with locations of low friction test values and NTSB-retrieved pavement cores. The point of rest of the motor coach is indicated. The locations of the driveways added in February 2014 are approximately the crest of the compound curve. The 1800 foot section of low friction from the "intersection" to the limit of the milled section is generally a slight positive grade. (Figure 3)

Site Description

Figure 3: View of US83 looking north from intersection to crest of compound curve

NTSB provided site pictures taken within hours of the crash on 05/14/2016 and pictures of the crash site taken on 05/15/2016 and 05/18/2016.

Figure 4: View of US83, northbound lane, looking north. Note the standing water in the rumble strips indicate the super-elevation of the roadway. Image obtained by Texas DPS on 05/14/2016, several hours after crash.

Figure 5: US83 northbound lane, looking south, from crest of vertical curve at vicinity of driveways. Image obtained by NTSB on 05/15/2016.

Figure 6: US83 northbound lane, looking north, from crest of vertical curve at vicinity of driveways. Image obtained by NTSB on 05/15/2016.

Figure 7: US83 northbound lane, close up of milled section in vicinity of driveways. The longitudinal grooves were reported to be from milling operation. Image obtained by NTSB on 05/15/2016.

Figure 8: US83 northbound lane, looking north, in vicinity of driveways. the car on shoulder is approximately in location of final rest of motor coach. Image obtained by NTSB on 05/15/2016.

Figure 9: US83 northbound lane, looking south, at end of milled pavement. Note the pavement cracking in foreground is consistent with pavement conditions at time of milling. Image obtained by NTSB on 05/15/2016.

Figure 10: US83 northbound lane, looking north, close up of south end of milled section. Image obtained by NTSB on 05/18/2016.

Figure 11: US83 northbound lane, close up of south end of milled section. Note the rumble strip (constructed February 10, 2016) intersects the surface asphalt material. Image obtained by NTSB on 05/18/2016

Figure 12: US83 Northbound, looking north from approximately the crest of the vertical curve. TxDOT maintenance forces performing milling on May 18, 2016 using Bobcat-mounted milling drum to restore pavement macrotexture. First pass of the milling drum adjacent to yellow stripe.

Figure 13: May 18, 2016 milling operations

Figure 14: May 18, 2016 milling operations. Note the contrast of the May 18, 2016 milling results (texture)on the left compared to the results of the milling performed on October 26, 2015 on right.

The NTSB requested that FHWA specifically perform testing and analysis to determine the probable cause(s) of the low friction values on in the north bound lanes of US83 in the vicinity of the crash

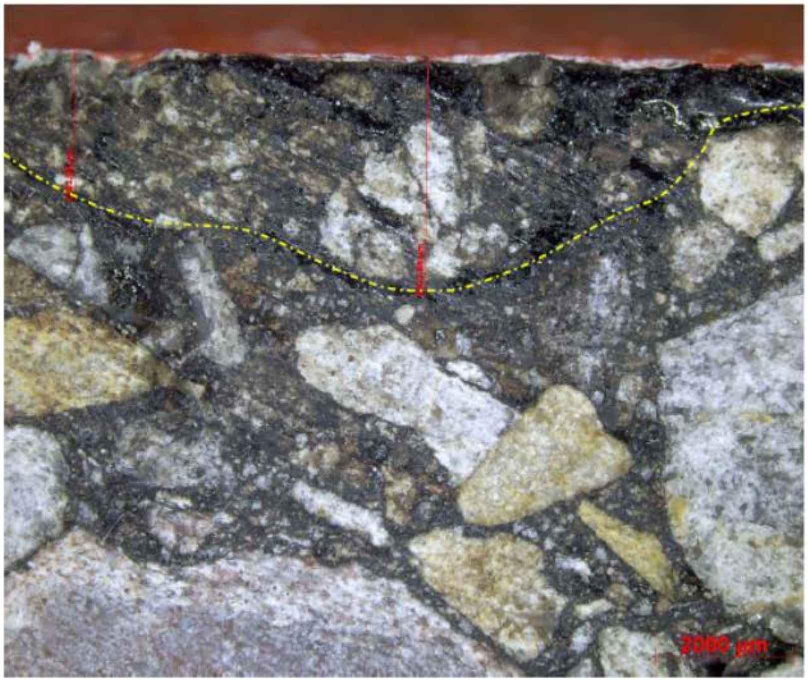

Figure 15. Cores 1B (NB #1B LWP). Saw cut section showing a thin top layer consisting of a somewhat mushy/gooey asphalt and remnants of relatively small and soft limestone particles, overlying the first lift consisting of a normal relatively hard binder and a dominantly siliceous aggregates. Broken line marks boundary between the top, asphalt-rich thin layer and the immediate bottom lift/layer.

Figure 16. Core 5B (NTL RWP #5B). Saw cut section showing a thin layer along the top consisting of somewhat mushy/gooey asphalt and remnants of relatively soft and small limestone particles, overlying the first lift consisting of a normal relatively hard binder and a dominantly siliceous aggregates. Solid line marks boundary between the top, asphalt-rich thin layer and the immediate bottom lift/layer.

Observations

Friction test results of FN40S of under 10.0 and FN40R less than 20.0 are generally considered extremely low by agencies that perform friction tests on their highway network. Washington State DOT specifies a minimum value of 30.0. The specific value an agency uses as a minimum typically depends on the type of roadway and the relative availability/cost of aggregates with high friction performance. As evidenced by FN40S and FN40R values noted in Figure 1 from DMI reference 0.0 to 0.800 FN40S and FN40R values above 40.0 are achievable with aggregates available in the local area.

Factors that influence pavement friction fall into 4 categories – pavement surface characteristics, vehicle operational parameters, tire properties, and environmental factors. The pavement surface characteristics that influence pavement friction include micro-texture and macrotexture. Micro-texture corresponds to wavelengths of texture less than 0.5mm while macrotexture corresponds to wavelengths of texture between 0.5mm and 50mm, with the most significant wavelengths below 10mm (AASHTO, 2008). The ribbed tire friction test (FN40R) is generally considered insensitive to macrotexture while the FN40S is considered sensitive to micro-texture and macrotexture. Results of FN40S tests that are significantly below the corresponding FN40R test results would indicate low micro-texture and low macrotexture (Wambold, et al. 1984).

Macrotexture can be predicted from FN40R and FN40S values in the following equation (Wambold, et al., 1984)

MTD = 0.039 -0.0029 x FN40R + 0.0035 x FN40S (MTD = Mean Texture Depth, in)

Using average values for FN40R of 20 and FN40S of 9 obtained from Figure 1 (DMI reference 0.85 to DMI reference 1.35), the average MTD could be predicted to be approximately 0.009 in. (0.22mm). Typical values for MTD of dense fine-graded HMA are 0.4 to 0.6mm and typical values MTD of dense coarse-graded HMA is 0.6 to 1.2mm (AASHTO, 2008). FHWA guidance recommends that a higher speed limit would justify a higher texture threshold value (FHWA, 2005).

Post-Crash Pavement Treatment

On May 18, 2016, after the crash, TxDOT maintenance forces performed milling on the north bound lanes of US83 to remove the low-friction surface. The equipment used was a Bobcat-mounted milling drum with a 40" width. This equipment is similar to the equipment reported by TxDOT to have been used in the October 26, 2015 milling operation. The surface texture obtained by the milling operation performed on May 18, 2016 (Figure 14) appears to be significant and would be anticipated to provide significant levels of macrotexture and pavement friction. The contrast between the results of the milling on May 18, 2016 and the results obtained from the milling of October 26, 2015 is evident in Figure 14.

Analysis/Conclusions

Based upon the images provided by NTSB (Figures 4 - 14) and the friction test results obtained by TxDOT (Figure 1) it appears the milling performed on October 26, 2015 did not provide adequate macrotexture and friction. Further, the FHWA Petrographic Analysis describes an asphalt-rich layer of 2-3mm was evident on the top of Core 1B and Core 5B from the milled area (Figure 15 and Figure 16) demonstrating that the milling performed on

October 26, 2015 did not make a material impact on removal of the asphalt emulsion placed as part of the chip seal on October 21, 2015. It should be noted the MTD is an "average" depth of the pavement surface texture and thus a surface layer of asphalt of 1mm or more in depth will effectively negate the influence of pavement macrotexture. It appears the asphalt-rich layer observed on the surface of Core 1B and Core 5B contributed to the low macrotexture of the pavement surface

TXDOT standard Specifications, Item 354, Planing and Texturing Pavement require a finished surface that is "..free from gouges, longitudinal grooves, and other imperfections of workmanship." It is recognized that the October 26, 2015 milling was performed by TxDOT maintenance forces and not by contract, however it is clear the results on the milling operation on October 26, 2015 produced results that did not conform to standard specifications for planing and texturing. If the intent of the October 26, 2015 milling was to produce results that generally conformed to the requirements of Item 354, the results were inadequate. It is unclear how the longitudinal grooves observed in Figure 8 were produced. It is theorized they could have been produced by a milling head with mis-aligned teeth.

The Asphalt Chemistry Report confirms the asphalt-rich surface layer is an asphalt emulsion that contained styrene butadiene rubber (SBS) polymer which would be typical of a tack coat used with chip seal. This is consistent with the construction history reported by TxDOT.

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