April 19, 2022

NTSB/HIR-22/02

Bus Roadway Departure and Rollover

Pala Mesa, California

February 22, 2020

Abstract: On February 22, 2020, about 10:23 a.m. Pacific standard time, during a moderate rainfall, a 30-passenger bus left the southbound lanes of Interstate 15 just past a bridge over the San Luis Rey River and overturned in Pala Mesa, California. The bus was operated by Executive Lines Inc. and occupied by a 52-year-old driver and 20 passengers. While completing the crossing of the bridge, the driver lost control of the bus, which eventually departed the roadway to the right, traveled about 81 feet farther before it rolled over 1.5 times (540°), moved across a 95-foot-wide clear zone, and slid about 16 feet down the embankment of the clear zone. The bus came to rest on its roof, 118 feet west of the white edge line of the roadway and 306 feet south of the end of the bridge deck. As a result of the crash, 3 passengers died, 12 passengers sustained serious injuries, and 5 passengers and the driver received minor injuries. The safety issues addressed in this report include driving at safer speeds on wet roadways, ensuring adequacy of tire tread depth standard for commercial vehicles, maintaining safe tire tread depths on commercial vehicles, addressing lack of roof strength standards for certain buses, and increasing seat belt usage on buses.

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ABA	American Bus Association
ABS	antilock braking system
BASIC	Behavior Analysis and Safety Improvement Categories (FMCSA)
Caltrans	California Department of Transportation
CDL	commercial driver's license
CFR	*Code of Federal Regulations*
CHP	California Highway Patrol
CPUC	California Public Utilities Commission
CR	compliance review
CVC	*California Vehicle Code*
CVSA	Commercial Vehicle Safety Alliance
ECM	engine control module
ELD	electronic logging device
ESC	electronic stability control
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMVSS	Federal Motor Vehicle Safety Standard
GVWR	gross vehicle weight rating
HOS	hours-of-service
I-15	Interstate 15
IC	incident commander
MAIT	Multidisciplinary Accident Investigation Team (California)
NCFPD	North County Fire Protection District
NHTSA	National Highway Traffic Safety Administration
NPRM	notice of proposed rulemaking
NTSB	National Transportation Safety Board
psi	pounds per square inch
SB-20	Senate Bill No. 20 (California law)

TASAS	Traffic Accident Surveillance and Analysis System (California)
UDOT	Utah Department of Transportation
UMA	United Motorcoach Association
USDOT	US Department of Transportation
USTMA	U.S. Tire Manufacturers Association

Executive Summary

What Happened

On February 22, 2020, about 10:23 a.m. Pacific standard time, during a moderate rainfall, a 30-passenger bus left the southbound lanes of Interstate 15 just past a bridge over the San Luis Rey River and overturned in Pala Mesa, San Diego County, California. The bus was operated by Executive Lines Inc. and occupied by a 52-year-old driver and 20 passengers.

While completing the crossing of the bridge, the driver lost control of the bus, which eventually departed the roadway to the right, traveled about 81 feet farther before it rolled over 1.5 times (540°), moved across a 95-foot-wide clear zone, and slid about 16 feet down the embankment of the clear zone. The bus came to rest on its roof, 118 feet west of the white edge line of the roadway and 306 feet south of the end of the bridge deck. As a result of the crash, 3 passengers died, 12 passengers sustained serious injuries, and 5 passengers and the driver received minor injuries.

What We Found

The bus was transporting passengers despite having two tires with unacceptably low tread depths, which can reduce a vehicle's traction with the road. There was a moderate rain at the time, so the roadway was wet, which would further reduce the available traction. Moreover, the bus was traveling at an excessive speed for the wet roadway conditions, given the suboptimal condition of the bus's tires, which would have made it more difficult to recover from a loss of control event.

As the bus neared the end of the bridge, the driver experienced a loss of traction, to which he responded by braking and steering. These inappropriate driver responses exacerbated the situation to a complete loss of control, so that the bus left the roadway to the right and rolled over. During the rollover, the integrity of the bus's roof was compromised, so that the roof partially collapsed, and many windows were broken out, putting occupants' safety at risk. Additionally, most of the 20 passengers were not wearing the available lap/shoulder belts, which further increased passengers' risk of ejection and displacement.

We determined that the probable cause of the Pala Mesa, California, bus crash was the loss of vehicle control due to the combination of the low and substandard tread depth of the rear axle tires, the excessive speed for the wet roadway and vehicle conditions, and the driver's inappropriate inputs before and during the loss of control event. Contributing to the crash was Executive Lines Inc.'s inadequate vehicle inspection process, which permitted the bus to operate in passenger service despite having two tires with treads below the minimum required depth. Contributing to the severity of the injuries were the National Highway Traffic Safety Administration's failure to require roof strength standards for buses, Executive Lines Inc.'s failure to follow California's requirement to inform passengers about the state's mandatory seat belt use law, and the passengers' limited use of the available lap/shoulder belts.

What We Recommended

As a result of this investigation, we recommended that the National Highway Traffic Safety Administration (NHTSA) sponsor research to determine the appropriate minimum tire tread depths necessary for safe operation of commercial vehicles, particularly buses, taking into consideration the effect on vehicle handling when different tread depths are used for tires on the steer (front) versus the rear axles. We issued additional recommendations to NHTSA and the Federal Motor Carrier Safety Administration to revise the relevant sections of the *Code of Federal Regulations* based on the outcome of the research.

We also recommended that the state of California revise state law to require that passenger-carrying motor carriers document the tread depths of tires on their vehicles during any required, periodic vehicle inspection and that the California Highway Patrol (CHP) revise its motor carrier self-inspection form to include the measured tire tread depths of all tires on inspected buses. We recommended that the CHP develop and implement an education program to increase passenger-carrying motor carriers' awareness of the state's requirements about informing passengers of the seat belt use law. Further, we recommended that the CHP use its regular terminal inspections of passenger-carrying motor carriers to verify that carriers are meeting the state's requirements about pretrip briefings and/or signage in buses concerning the state's mandatory seat belt use law.

To ensure industry awareness of this crash investigation and its findings, we recommended that the American Bus Association and the United Motorcoach Association inform their members about the circumstances of this crash and encourage them to create a policy on speed and safe driving on wet roadways and under inclement weather conditions based on authoritative guidance. We also recommended that these two associations encourage their members to adopt the recommended tire rotation practices established by the U.S. Tire Manufacturers Association, and inform their members who operate in California of the requirements about pretrip briefings and/or signage in buses concerning California' mandatory seat belt use law.

Finally, we reiterated NTSB Safety Recommendation H-21-2 to NHTSA, asking the agency to require all newly manufactured buses, other than school buses, with gross vehicle weight ratings above 10,000 pounds to meet a roof strength standard that provides maximum survival space for all seating positions and accounts for typical window dimensions.

1 Factual Information

1.1 Crash Description

On Saturday, February 22, 2020, about 10:23 a.m. Pacific standard time, a bus departed the southbound lanes of Interstate 15 (I-15) just past a bridge over the San Luis Rey River and overturned in Pala Mesa, San Diego County, California.[1] The bus, consisting of a 2014 Freightliner chassis with a General Coach America 30-passenger coach body, was operated by Executive Lines Inc. and occupied by a 52-year-old driver and 20 passengers. The southbound bus had departed El Monte, California, about 7:30 a.m., en route to San Ysidro, California, and had made several stops on its way (see figures 1 and 2).

Figure 1. Map showing location of crash.

[1] Visit ntsb.gov to find additional information in the public docket for this National Transportation Safety Board (NTSB) investigation (case number HWY20FH003). Use the CAROL Query to search safety recommendations and investigations.

Figure 2. Aerial view of crash area showing bus's southbound direction of travel (yellow arrow) and rest position (enclosed by red rectangle). The bridge crosses over both the San Luis Rey River and Dulin Road. [Note: This figure is not standard-compass-oriented. The bottom of the figure is roughly "north," and the top is roughly "south."] (Source: California Highway Patrol [CHP] with NTSB modifications)

The bus had left its last stop in Temecula, California, about 15 minutes before approaching the bridge over the San Luis Rey River. In this area, I-15 is an eight-lane, divided highway with the northbound and southbound lanes separated by a depressed earthen median and a median barrier. The posted speed limit is 70 mph, and the southbound lanes of I-15 have an ascending grade with a leftward horizontal curvature.

While completing the bridge crossing, the driver lost control of the bus, which eventually departed the roadway to the right, traveled about 81 feet farther before it rolled over 1.5 times (540°), moved across a 95-foot-wide clear zone, and slid about 16 feet down the embankment of the clear zone. The bus came to rest on its roof, 118 feet west of the white edge line of the roadway and 306 feet south of the end of the bridge deck (see figure 3).

As a result of this crash, 3 passengers died, 12 passengers sustained serious injuries, and 5 passengers and the driver received minor injuries.

Figure 3. Overturned bus on embankment. (Source: CHP)

Based on recorded vehicle data, the bus had been traveling 73–75 mph for about 1 minute before the crash sequence began. Vehicle data also showed that the driver had applied sustained braking for 7 seconds before the rollover sequence began (see section 1.5.5 for additional details).

The crash occurred in daylight, moderate rain was falling, the temperature was 52°F, and winds were from the southwest at 6 mph about the time of the crash. (Weather conditions related to the rainfall are further described in section 1.4.3.)

1.2 Roadway Evidence

The NTSB examined the physical and roadway evidence still available at the scene at the time of arrival, as well as photographic and other evidence provided by the California Highway Patrol (CHP) Multidisciplinary Accident Investigation Team (MAIT).[2] The NTSB incorporated all the pertinent roadway photographic evidence into a 3D point cloud to aid in assessing the evidence.[3]

Three separate tire friction marks were identified on the roadway.[4] The first mark—consistent with the wheel path of the bus's left rear dual tires—started 1.7 feet into the right side of the center-left lane, about 14 feet before the south end of the bridge deck, and it arced south toward the right shoulder (see figure 4). Based on the start point of the first friction mark, the bus had yawed clockwise about 2° relative to the travel lanes when this mark was initiated.

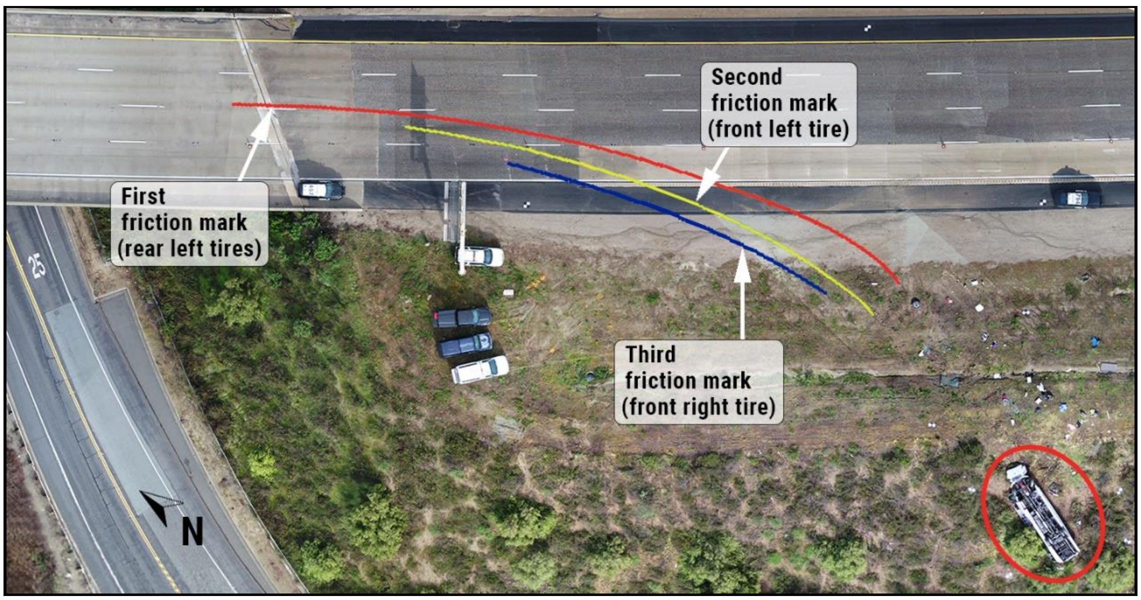

Figure 4. Orthomosaic image rendered from aerial photographs depicting arcing path of bus from point of first roadway evidence to bus's at-rest position. Image also shows three friction lines created by bus's rear left tires (red), front left tire (yellow), and front right tire (blue). (Source: CHP, modified by the NTSB)

About 61 feet south of the beginning of the first tire friction mark, a second tire friction mark began, consistent with the wheel path of the bus's left front tire. At this location, the bus had yawed clockwise 14° relative to the travel lanes. This mark

[2] NTSB investigators arrived on the scene the day after the crash.

[3] The 3D point cloud was created with Pix4DMapper, which is a photogrammetry software package designed to use overlapping photographic images to generate 3D point clouds. Additional outputs from the generated point cloud include 3D models (textured mesh), digital surface and terrain models, and 2D orthomosaic maps.

[4] No friction marks were noted for the right rear tires, likely because they carried the least load due to weight shift.

began in the center-right lane and arced south past the paved right shoulder, leaving the pavement 160 feet south of the end of the bridge deck.

The third tire friction mark, consistent with the wheel path of the bus's right front tire, began in the right lane about 38 feet south of the onset of the second tire friction mark. This mark arced south past the paved right shoulder, leaving the pavement about 144 feet south of the end of the bridge deck. At the point of pavement departure, the bus had yawed clockwise about 42° relative to the travel lanes.

The three tire friction marks on the pavement transitioned to soil furrows when the bus left the pavement. As the bus continued along an arced path of travel, the tires created deeper furrows in the soil, the deepest of which appeared to be made by the bus's front left tire. About 81 feet after they began, the furrows abruptly ended, consistent with the initiation of the rollover. At this location, the bus had yawed clockwise about 90° relative to the highway lanes. In total, the bus traveled about 225 feet from where the first pavement friction mark began to the point of rollover, as measured along the bus's approximate center of mass. The bus came to final rest about 108 feet west of the rollover initiation point.

1.3 Injuries, Occupant Protection, and Emergency Response

1.3.1 Injuries

As a result of this crash, 3 passengers died, 12 passengers sustained serious injuries, and 5 passengers and the driver received minor injuries. Five passengers were ejected during the crash sequence. The passengers ranged in age from 5 to 75 and comprised 11 males and 9 females. The NTSB was able to determine the seating positions for 13 of the 20 passengers.[5]

Based on the autopsy reports, the three passengers who died sustained blunt-force trauma to the head, neck, and torso; two were ejected during the crash sequence, and one was found lodged between two seats. One of the two ejected passengers who died had been seated adjacent to a window on the left (driver's) side in the middle part of the bus; the seating locations of the other two passengers who died could not be determined.

[5] The seating positions of the passengers were determined based on NTSB interviews with the surviving passengers.

The 12 seriously injured passengers sustained injuries consisting of fractures to multiple body regions as well as head and spine injuries; two of these passengers were ejected during the crash sequence. The driver and the five passengers with minor injuries sustained lacerations, abrasions, and contusions to multiple body regions; one of these passengers was ejected during the crash sequence.

1.3.2 Occupant Protection

The bus was equipped with seven rows of two-person seats on the right side of the bus and eight rows of two-person seats on the left side of the bus. The driver's seat was equipped with a lap/shoulder belt. The driver stated that he had been using the lap/shoulder belt at the time of the crash. The passenger seats on the bus were also equipped with lap/shoulder belts.[6] When inspected postcrash, all but two of the seat belts were functional; the functionality of the remaining two seat belts could not be verified due to crash-related damage to the buckle assemblies. Based on witness interviews, passenger injuries, and stretching and damage to the seat belt webbing, the following seat belt use information was determined:

- 1 passenger was properly belted; she sustained minor injuries.
- 2 passengers were improperly belted, with the upper portions of the seat belts behind their shoulders; both sustained serious injuries.
- 14 passengers were unbelted; 2 died, 9 sustained serious injuries, and 3 sustained minor injuries. (All 5 of the ejected passengers were unbelted.)
- Seat belt use for the remaining 3 passengers is unknown; 1 died, 1 sustained serious injury, and 1 sustained minor injuries.

To summarize, 13 of the 16 passengers who investigators determined were not wearing or were improperly wearing their seat belts sustained fatal or serious injuries. The one passenger who was properly wearing a seat belt sustained only minor injuries.

Postcrash examination of the interior of the bus showed that several unbelted passengers were thrown into seats, the ceiling, video screens, and luggage bins during the overturn sequence. When interviewed by NTSB investigators, six passengers reported being unaware that the bus was equipped with lap/shoulder belts for all passenger seats.

[6] This bus had been voluntarily equipped with lap/shoulder belts; it was not required to be so equipped at the time of its manufacture.

In October 2017, California adopted legislation mandating proper seat belt use for all occupants of vehicles equipped with seat belts; this requirement included buses.[7] Section 27318 of the *California Vehicle Code* (*CVC*) mandates seat belt use in equipped buses. It also requires that passenger-carrying motor carriers take at least one of the following actions: (1) require their drivers to provide briefings informing the passengers of the availability of seat belts and of the California law that mandates their use and applicable fines; and (2) include on their buses signs or placards informing the passengers of the state's requirement to wear a seat belt.[8]

The bus driver stated that he did not provide a pretrip safety briefing or otherwise inform the passengers of the availability of seat belts or of the California law requiring the use of seat belts in all vehicles. The bus did not include any signs or placards informing the passengers of the California requirement to wear a seat belt. The motor carrier did not have a policy on pretrip safety briefings, and the carrier's owner stated that he was unaware of the California seat belt use mandate, as well as of the motor carrier requirements in *CVC* 27318.

1.3.3 Emergency Response

A 911 call at 10:23 a.m. notified a CHP dispatcher and NorthComm communications center about the crash. The NorthComm communications center informed the North County Fire Protection District (NCFPD) of the crash. The NCFPD dispatched two fire engine units and one ambulance unit, the first of which arrived on scene at 10:31 a.m. The CHP dispatcher assigned the first CHP unit at 10:26 a.m.; this unit arrived on the scene at 10:40 a.m. The CHP notified the California Department of Transportation (Caltrans) of the crash at 10:32 a.m.

The captain of the second NCFPD engine arrived on scene at 10:34 a.m. and assumed the role of incident commander (IC). The IC requested two additional engines, a truck company, and four more ambulances. The NCFPD battalion chief arrived on the scene 9 minutes later, and he assumed the IC role and declared a mass casualty incident. The NCFPD ultimately dispatched a total of five ambulances, five fire engines, and a ladder truck to the crash. As part of a mutual aid response, six

[7] See California Senate Bill No. 20 Chapter 593 (accessed April 18, 2022) for the full list of the *CVC* items added and amended.

[8] See *CVC 27318* (accessed April 18, 2022) for additional requirements.

other agencies responded with eight ambulances, two fire engines, and six support vehicles.[9]

Five ambulances transported the 17 surviving passengers to area hospitals; the driver, who had minor injuries, refused transport. The last surviving passenger was transported from the scene at 11:07 a.m.

1.4 Highway Factors

1.4.1 Design Characteristics

The crash occurred on southbound I-15 near mile marker 46, just past the south end of the twin bridge structures over the San Luis Rey River. At this location, the southbound and northbound directions of travel each consist of four 12-foot-wide lanes. At the location of the bus's departure from the roadway—about 97 feet south of the south end of the twin bridge structures—the two directions of travel are separated by a 70-foot-wide earthen median and a thrie-beam barrier.[10] The southbound roadway had an 11-foot-wide paved right shoulder with rumble strips and an 8.5-foot-wide left paved shoulder; the right and left shoulders were delineated from the travel lanes by 6-inch-wide solid white and yellow lines, respectively. The travel lanes were delineated by 6-inch-wide broken white lines. The area where the bus departed the roadway—the west side of the southbound lanes—had an approximately 95-foot-wide "clear zone," which is an unobstructed, relatively flat area beyond the edge of the road that is designed to allow drivers who depart the roadway to stop or return to the road safely.[11]

Near the crash location, the roadway's horizontal alignment consists of a 7,570-foot-radius curve to the left in the southbound direction of travel, which was the bus's direction of travel. The bus departed the roadway about 2,836 feet into the 3,817-foot-long curve. The vertical alignment near the crash location includes a Type I sag vertical curve that provides a transition between a descending grade of 0.4 percent and an ascending grade of 4.39 percent.[12] The bus departed the roadway

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[9] The six other agencies responding were San Diego California Fire, Vista Fire Department, Camp Pendleton Fire Department, Pala Good Samaritan, Pala Fire Department, and Oceanside Fire Department.

[10] A *thrie-beam barrier* is a steel beam rail element shaped like a "W" with an additional undulation in it. The height of the rail from the ground to the top of the rail was about 31 inches.

[11] According to the American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide* (AASHTO 2011), the minimum desired clear zone for the geometry of the crash location is 30 feet.

[12] A Type I sag vertical curve connects a descending grade to an ascending grade.

about 2,138 feet into the approximately 2,400-foot-long sag vertical curve, where the ascending grade is 3.87 percent.

The posted speed limit at this location is 70 mph. The southbound roadway had several “Slippery When Wet” warning signs placed in advance of the crash location; the closest of these signs was 5.8 miles north of the crash location.[13]

1.4.2 Traffic and Crash History

As measured in 2018, the average daily traffic for southbound I-15 in the vicinity of the crash was about 135,000 vehicles; 90 percent were passenger vehicles. At the time of the crash, traffic was moderate to heavy, based on witness statements.

Examination of the 6-year crash history—from 2013 to 2018—within 0.5 mile of the crash location revealed 27 crashes, 1 of which was fatal.[14] Ten of these crashes occurred in wet roadway conditions, five of which involved commercial vehicles.[15] The fatal crash occurred on December 13, 2013, during wet roadway conditions. It involved a motorcoach that lost control and overturned. The CHP MAIT investigative report on this fatal crash stated that three of the tires on the motorcoach had less than the required tire tread depth, and another tire had been overinflated.

Caltrans uses a data-driven approach—structured in California’s Traffic Accident Surveillance and Analysis System (TASAS)—to identify segments of California highways that require safety improvements. TASAS gathers traffic reports of crashes occurring on California highways provided by the CHP and other law enforcement agencies. These crash reports, with information regarding route, location, and traffic volume, are used to create the TASAS database. TASAS provides quarterly reports on all of California’s highway systems, broken down into 0.2-mile segments. One of those quarterly reports, called “Table C,” identifies segments that have a statistically significant concentration of crashes. Another report, “Wet Table C,” identifies segments that have a statistically significant concentration of crashes during wet roadway conditions. Caltrans considers the segments identified in these two tables as locations that may require safety improvements. Once such segments are identified, Caltrans conducts additional work at these potentially unsafe locations, such as

[13] The “Slippery When Wet” warning signs were pictorial signs that contained no lettering. The sign style is identified as W8-5 in the Federal Highway Administration (FHWA) *Manual on Uniform Traffic Control Devices for Streets and Highways* (FHWA 2009). The placement of these signs was consistent with the criteria specified in the manual.

[14] In the remaining 26 crashes, 9 involved injuries to at least some of the vehicle occupants, and 17 did not result in injuries to any vehicle occupants.

[15] Six of the 10 crashes that occurred in wet roadway conditions did not result in injuries to any vehicle occupants.

surface friction testing, to determine the need for and type of possible safety improvement. The highway segment in the crash area did not appear in either Table C or Wet Table C of Caltrans' most recent TASAS quarterly reports.[16]

1.4.3 Rainfall and Roadway Drainage

On the day of the crash, two separate rainfall events occurred in the area where the crash took place. (The first rainfall was preceded by at least 10 days of no precipitation.) The first rainfall event occurred in the morning, during a period encompassing the time of the crash, and the second occurred in the afternoon. The NTSB obtained data from the weather station at Fallbrook Community Airpark, located about 5 miles west-northwest from the crash site. With respect to rainfall, the Fallbrook data showed that the rainfall started early in the morning, with total accumulated precipitation of 0.05 inch by 9:30 a.m.; between 9:55 a.m. and 10:15 a.m., an additional 0.08 inch of precipitation fell. The weather station reported moderate rain on either side of this 20-minute window. Within the next 20-minute period, during which the crash occurred, an additional 0.01 inch of precipitation fell. Data from an unofficial weather station located closer to the crash location, about 3 miles west-northwest of the site, indicated that 0.01 inch of precipitation fell between 10:00 a.m. and 10:15 a.m., and another 0.02 inch of precipitation fell in the next 15-minute window.[17] In total, this weather station recorded that 0.30 inch of precipitation fell within a 1-hour period surrounding the morning rainfall.

The second rainfall event at the location of the crash occurred between 2:00 p.m. and 2:30 p.m., while MAIT investigators were still on scene. Data from the unofficial weather station noted above indicated that 0.32 inch of precipitation fell within a 1-hour period surrounding the afternoon rainfall. The two rainfall events had similar 1-hour precipitation accumulations. The MAIT investigators observed the roadway for any signs of water ponding or pooling in the travel lanes during and after the afternoon rain but did not notice any such accumulations (see figure 5).

[16] Both tables addressed the 36-month period between July 1, 2016, and June 30, 2019.

[17] Unofficial weather observation sites are not regulated by the National Weather Service or the Federal Aviation Administration. The unofficial observation site referred to in this report has not been indicated to have any quality control issues.

Figure 5. Looking south at I-15 southbound lanes from south end of bridge. Photograph taken at 2:53 p.m., about 30 minutes after second rainfall event on crash day ended. (Source: CHP)

Passengers on the crash bus and drivers of vehicles traveling behind the bus at the time of the crash provided statements to the CHP and the NTSB regarding the crash circumstances. Their statements regarding the rainfall at the time varied considerably and included the following:

- Four witnesses reported that it was raining,
- Four reported light rain or drizzle,
- One reported on-and-off rain,
- One stated that it was raining heavily, and
- Two stated only that the roadway was wet.[18]

The area where the crash occurred is equipped with numerous drainage appliances. Along the east rail of the southbound bridge, there are scupper drains designed to channel stormwater off the bridge.[19] South of the end of the bridge deck,

[18] Witness statements regarding driver actions are described in section 1.6.3.

[19] *Scupper drains* are vertical holes through a bridge deck or horizontal openings through the base of a bridge rail designed to drain rainwater and prevent pooling.

mountable drainage dikes border the edges of paved shoulders and channel stormwater to drainage inlets and catch basins along the roadway (see figure 6).[20] The median has concrete-lined drainage ditches that channel the stormwater to nine drains at the ditch bottoms. CHP and NTSB investigators visually inspected the drainage inlets, slots, and scupper and area drains, and found them to be clear of major debris.

Figure 6. Drainage devices along southbound lanes in area of crash. Depicted are (left image) scupper drains along the left shoulder on the bridge and (right image) a drainage dike along the right shoulder past the bridge.

The design of the highway and bridge drainage systems on and along southbound I-15 near the crash conformed to the general national guidance provided by the American Association of State Highway and Transportation Officials (AASHTO), as well as to guidance specific to the state of California (AASHTO 2018 [sections 4.7 and 4.8], Caltrans 2020 [chapters 800–890]).

1.4.4 Surface Friction Test

Caltrans typically performs surface friction tests on roadways only for new projects or as part of a safety investigation. Caltrans has established a minimal surface friction threshold value of 0.30 for new pavements. The 0.30 threshold represents the minimum acceptable friction value, which is used when evaluating the friction qualities of a new section of pavement or as a factor for determining whether a surface treatment is needed to provide adequate friction. During a Caltrans safety

[20] *Drainage dikes* function like standard curbs by channeling stormwater to drainage inlets or storm drains along the edges of a roadway. The asphalt drainage dikes installed along I-15 are wider than a standard curb and have a sloped top surface, allowing a vehicle to traverse the drainage dike more easily.

investigation, a roadway's surface friction threshold is examined, in combination with the TASAS Table C and Wet Table C reports, when evaluating whether a safety improvement should be made at that location.

Postcrash, at the request of the NTSB, Caltrans performed surface friction tests on the four southbound lanes of I-15 near the crash site. The testing was performed over five segments spanning a 0.5-mile-long area, 0.25 mile in each direction from the crash location. As part of the testing process, Caltrans engineers visually identified areas that appeared to have the lowest coefficients of friction; those areas were then tested. From left to right, for each lane, the surface friction values ranged as follows:

- From 0.36 to 0.41 for the left lane,
- From 0.37 to 0.38 for the center-left lane,
- From 0.27 to 0.36 for the center-right lane, and
- From 0.26 to 0.39 for the right lane.

Three of the 20 tested segments had a surface friction value below 0.30. The tire friction marks started just before the south end of the bridge. The surface friction values on the south half of the bridge—spanning 400 feet—in the two center lanes in which the bus was traveling had surface friction values ranging from 0.36 to 0.37.[21]

Based on the results of the surface friction measurements and TASAS crash reports for this location, Caltrans determined that the section of I-15 near the crash site did not warrant surface friction treatment interventions at this time. Caltrans also stated that it does not rely on surface friction testing alone to determine whether an improvement project should be undertaken for any specific roadway segment or section; it also considers TASAS crash reports to evaluate the need for a safety improvement. Caltrans further stated that mainline pavement surfaces that have a coefficient of friction value of 0.30 or above exhibit sufficient skid resistance even under adverse weather conditions.

[21] For the full set of surface friction values from the testing and additional information, see the highway factual report in the docket for this investigation.

1.5 Vehicle Factors

1.5.1 General Description

The crash bus was built in two stages; it consisted of a 2014 Freightliner S2 106 chassis coupled with a General Coach America 30-passenger coach body.[22] The bus was equipped with a 6.7-liter Cummins ISB engine and an Allison B210 automatic transmission. At the time of manufacture, the bus had a gross vehicle weight rating (GVWR) of 29,000 pounds. It was electronically limited to a maximum speed of 75 mph. The bus was equipped with a dual air antilock braking system (ABS) with pneumatic drum brakes on all axles. The bus was not equipped with an electronic stability control (ESC) system, nor was it required to be so equipped when manufactured in 2013.[23] Video display screens for entertainment purposes were located throughout the bus.

1.5.2 Damage

The bus sustained significant damage during the crash and rollover event, when it came to rest on its roof. The bus roof structure sustained extensive damage, and its structural support members were severely deformed (see figures 7 and 8). Several of the support members failed during the rollover, which created openings through which several passengers were ejected.[24] The roof hatch cover was torn away from the bus, creating an opening through which two passengers were able to self-extricate postcrash.[25] Substantial lateral roof displacement, in places measuring 24 inches to 30 inches, occurred at some sections of the bus. The most extensive damage occurred at the front of the bus. The lateral roof displacement substantially reduced the interior height, exposing the tops of passenger seatbacks and integrated headrests on the left side of the bus. At the point of maximum roof deformation,

[22] The final-stage build was completed in September 2013. The 2014 chassis model was built in 2013.

[23] Since August 1, 2019, newly manufactured buses with GVWRs between 26,000 pounds and 33,000 pounds, such as the crash bus, have been required to be equipped with ESC. (See 49 *CFR* 571.136, *Federal Motor Vehicle Safety Standards*: Electronic stability control systems for heavy vehicles.)

[24] Five passengers were ejected, but the investigation was unable to determine how many were ejected through the openings in the roof as opposed to the openings created by window frame displacement.

[25] At final rest, the overturned bus was not lying entirely flat on its roof. There was a small gap between part of the collapsed roof and the sloped terrain, which allowed two women to climb out through the opening.

located between seat rows 2 and 3, the bus's interior height decreased from 84 inches, as constructed, to 54 inches postcrash.

Figure 7. View of damage to front and left side of bus.

Figure 8. View of damage to front and right side of bus.

Damage to the front end of the bus included a displaced windshield, damage to the hood and the front bumper, and displacement of the right headlight from its mount. Damage to the left side included displaced covers for the battery and the spare wheel; additionally, the glazing from all seven windows on the left side of the bus was missing. Damage to the right side of the bus included a shifting of the support brackets forward and deformation to the front-loading door, which remained wedged against the frame and inoperative; the glazing from four of the six windows on the right side of the bus was missing.

Although there was some intrusion into the driver's area, the driver's seat pan remained intact. The steering wheel, steering column, and other vehicle controls were undamaged. All passenger seats remained attached to the floor and the metal sidewall rails.

1.5.3 Mechanical Inspection

NTSB investigators evaluated the functionality of the bus's steering, suspension, and electrical systems and examined the wheels and tires. The vehicle's steering, suspension, and electrical systems were functional and showed no evidence of preexisting damage or defects. Examination of the engine revealed no defects. Due to the overall damage, a functional check of the braking system could not be performed, but individual braking components were examined and found to be within required specifications. Examination of the vehicle's ABS showed that it was functional.

Examination of the wheels showed no preexisting damage or defects. According to federal regulations, the minimum tread depth for tires on axles other than the steer (front) axle is 2/32 inch (49 *Code of Federal Regulations* [*CFR*] 393.75[c] and 49 *CFR* 570.62). The minimum tread depth for tires on the steer axle is 4/32 inch (49 *CFR* 393.75[b]). California has adopted the same minimum tread depth requirements for tires on the steer and rear axles; that is, 4/32 inch for steer axle tires and 2/32 inch for tires on rear axles.[26]

The two inside rear tires had tread depths of 1/32 inch, while the two outside rear tires had tread depths of 2/32 inch. Although the two inside tires did not meet the minimum tread depth requirements, they were not worn enough for the condition

[26] See *CVC*, Vehicle Division 12: Equipment of Vehicles Chapter 5, Article 4: Tires 27465.

to constitute an out-of-service violation.[27] The steer axle tires had tread depths of 11/32 inch for the left and 10/32 inch for the right front tire. The left front and both outside rear tires deflated during the crash sequence. The remaining three tires had slightly below the recommended inflation pressures but were well within normal operating parameters.[28]

1.5.4 Roadside Inspection, Maintenance, and Safety Recalls

The bus had its most recent roadside inspection on November 5, 2019, during which two vehicle equipment violations were documented; neither were out-of-service conditions.[29] The motor carrier's maintenance records indicated that the vehicle had undergone regular service, periodic maintenance, and regular safety inspections. As required by California law (*CVC* 34505), Executive Lines performed safety inspections every 45 days.[30] The carrier also completed the Bus Maintenance and Safety Inspection Form—CHP Form 108A—documenting maintenance and safety inspection elements for each bus in the fleet.

During a 24-month period ending January 31, 2020, Executive Lines underwent 20 driver inspections and 19 vehicle maintenance inspections. The motor carrier was cited for 6 hours-of-service (HOS) compliance violations and 13 vehicle maintenance violations, 1 of which placed a motorcoach out of service for exposure of tire-ply or belt material (49 *CFR* 393.75(a)(1)). Another violation involved a bus with a tire tread depth of less than 2/32 inch, measured in two adjacent major tread grooves (49 *CFR* 393.75(c)). The Federal Motor Carrier Safety Administration (FMCSA) assigns a severity weight for each violation: 1 represents lower crash risk

[27] (a) Roadside inspections are examinations of commercial motor vehicles or drivers conducted by specially trained inspectors on behalf of the Federal Motor Carrier Safety Administration (FMCSA) to check that they are in compliance with the *Federal Motor Carrier Safety Regulations* and/or *Hazardous Materials Regulations*. If a roadside inspection results in detection of a serious violation, the driver may be issued an out-of-service order. These violations must be corrected before the driver or vehicle can return to service. (b) The out-of-service criteria are established by the Commercial Vehicle Safety Alliance (CVSA) and are adopted by states for roadside inspection of commercial vehicles. A commercial vehicle is placed out of service when any of the steer axle tires have a tread depth less than 2/32 inch, or when any tires on the nonsteer axle(s) have a tread depth less than 1/32 inch; for a vehicle with dual rear tires, the violation occurs when both tires have tread depths of less than 1/32 inch.

[28] The recommended inflation pressure for these tires is 120 pounds per square inch (psi). The right front and the two inside rear tires had tire pressures between 111 and 116 psi at the time of the postcrash inspection. Because tires can lose some pressure during a crash, these may not necessarily have been the tire pressure values at the time of the crash.

[29] (a) The FMCSA uses data from roadside inspections, among other information, to quantify the safety performance of a carrier in the FMCSA's Behavior Analysis and Safety Improvement Categories. See section 1.7 for more information on the carrier's safety performance. (b) The violations were for the lack of (1) spare fuses and (2) washer fluid for the windshield wipers.

[30] For more information, see [CVC 34505](), accessed April 18, 2022.

and 10 represents the highest crash risk relative to other violations in the Behavior Analysis and Safety Improvement Categories (BASICs). Out-of-service violations receive an additional severity weight of 2. The motorcoach violation cited above received a total severity weight of 10, and the bus violation received an 8.

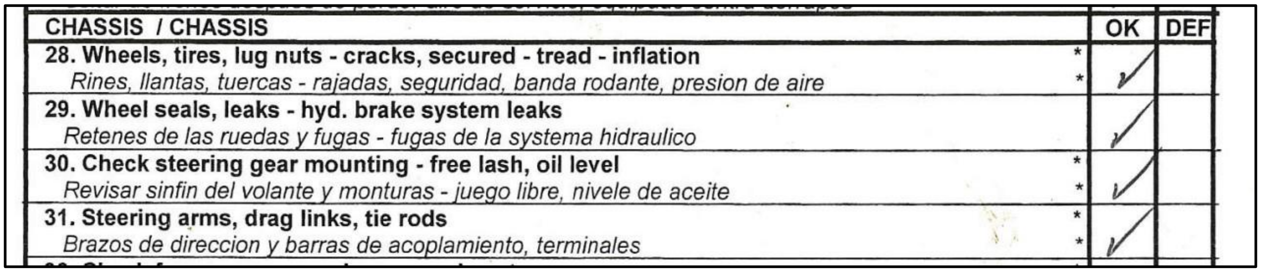
The carrier's maintenance records indicated that tires on the rear axle of the crash bus were repeatedly replaced in the months before the crash. On November 3, 2019, all four tires on the rear axle were replaced with used tires. On December 27, 2019, both left-side tires on the rear axle were replaced with used tires. On January 3, 2020, both right-side tires on the rear axle were replaced with used tires.

The steer axle tires had also been recently replaced. The two steer axle tires were replaced with new tires on September 19, 2019. These new tires had a tread depth of 18/32 inch and were of the same type as the inside rear tires; the steer axle tires were replaced at vehicle mileage of 141,687 miles. The vehicle mileage at the time of the crash was 193,290 miles.

The maintenance records also indicated that non-tire-related repairs were made on the crash bus on February 4 and 10, 2020.[31] These repairs were completed in response to issues found during the pre- and post-trip inspections of the bus performed by drivers.

The crash-involved driver had performed a pretrip inspection of the bus on the day of the crash. He did not indicate any concerns on the inspection form; however, in the postcrash interview with the NTSB, he stated that he had "a concern about the right tread of the tire, rear tire" and estimated the tire's tread depth to be "probably like less than 1/4 inch." Executive Lines had completed its most recent mandatory safety inspection on February 10, 2020; the carrier also completed CHP Form 108A documenting the inspection (see figure 9). The items on this checklist, including the one pertaining to the crash bus's wheels and tires that read "Wheels, tires, lug nuts – cracks, secured – tread – inflation," were checked as "OK." The bus had traveled 3,363 miles in the 12 days since Executive Lines had completed its last safety inspection (and CHP Form 108A) before the February 22, 2020, crash.

[31] The records show repairs to a headlight and to an air hose leading to the driver's seat.



CHASSIS / CHASSIS	OK	DEF
28. Wheels, tires, lug nuts - cracks, secured - tread - inflation * *Rines, llantas, tuercas - rajadas, seguridad, banda rodante, presion de aire* *	✓	
29. Wheel seals, leaks - hyd. brake system leaks *Retenes de las ruedas y fugas - fugas de la systema hidraulico*	✓	
30. Check steering gear mounting - free lash, oil level * *Revisar sinfin del volante y monturas - juego libre, nivele de aceite* *	✓	
31. Steering arms, drag links, tie rods * *Brazos de direccion y barras de acoplamiento, terminales* *	✓	

Figure 9. Excerpt from Bus Maintenance and Safety Inspection Form—CHP Form 108A—for the crash bus, showing condition of wheels and tires checked as "OK."

The NTSB asked the carrier owner about the company's policy on tire maintenance. The owner stated that the standard practice included removing the steer axle tires when their tread depths reached 5/32 inch and placing them on the rear axle wheels until their tread depths reached 2/32 inch, at which point they would be removed from service. In postcrash interviews, the carrier's maintenance staff verified that this practice was followed.

There were no safety recalls affecting the bus.[32]

1.5.5 Data Recording Systems

The bus was equipped with an engine control module (ECM) that records engine hours and controls various engine operations and other factors based on onboard sensors. The system can also record and store vehicle parameters, such as vehicle and engine speed, when triggered by sudden acceleration or deceleration events.[33] Data extracted from the ECM included three sudden deceleration events, the last of which was associated with the crash. The ECM captured 75 seconds of data associated with this last event—60 seconds before the triggering of the sudden deceleration event and 15 seconds after it (see table 1).

[32] The safety recall information was obtained from the NHTSA safety recall database website, accessed April 18, 2022.

[33] For the ECM on the crash bus, the threshold for a sudden deceleration or acceleration event was a 9-mph change in speed in 1 second.

Table 1. Selected parameters recorded by bus ECM.

Seconds from Sudden Deceleration Event	Vehicle Speed (mph)	Throttle (percent)	Brake Status
-59	74	86.0	Off
-58 to -6	73–75	various[a]	Off
-5	75	100.0	Off
-4	71	0.0	Off
-3	64	0.0	On
-2	63	0.0	On
-1	57	0.0	On
0	50	0.0	On
1	40	0.0	On
2	30	0.0	On
3	20	0.0	On
4	16	0.4	Off
5	2	0.0	Off
6[b]	0	0.0	Off

[a] The throttle ranged from 0 to 100 pecent during this 52-second period. The average throttle during this period was 78.4 percent. In the period between 11 seconds and 6 seconds, the minimum throttle value was 95.2 percent.

[b] The ECM recorded an additional 9 seconds of data. The reported values remained the same as the last reported value at 6 seconds.

The recorded data show that the bus was traveling at a fairly constant speed of 73–75 mph for nearly a minute before the sudden deceleration event and roadway departure. Four seconds before the sudden deceleration event, the recorded speed began to decrease without a brake application being recorded. One second later, as the vehicle speed was reduced by 7 mph, the ECM recorded a brake application; the driver kept the brakes engaged for 7 seconds.[34] By the time the driver stopped braking, the bus had entered the rollover sequence.

[34] The brake status is an indicator of pressure being applied to the brake pedal; it does not indicate the degree of braking force.

1.6 Bus Driver

1.6.1 Licensing, Employment History, and Driving Record

The 52-year-old driver started working for Executive Lines in April 2019. At the time of the crash, he held a California class B commercial driver's license (CDL), with a passenger endorsement and a restriction prohibiting him from operating a commercial vehicle with a manual transmission.[35] He obtained his CDL—which was his first CDL—in May 2018, and it had an expiration date of February 2022. When he obtained his CDL, the driver was employed by Greyhound Lines Inc. where he completed that carrier's driver training program.[36]

The NTSB examined multiple sources to obtain the bus driver's history of traffic violations, including the National Highway Traffic Safety Administration (NHTSA) National Driver Register, CDL information systems, and California Department of Motor Vehicles records. The sources showed that the driver was involved in one crash in 2018 but had no violations or suspensions on his CDL.[37]

1.6.2 Medical Certification, Health, and Toxicology

The bus driver obtained his most recent CDL medical certificate in February 2020; it was valid for 2 years. On the medical certification form, the driver reported not having any illness or injury, and that he had not taken any medications in the past 5 years. The driver's corrected visual acuity was reported as 20/20. When interviewed by the NTSB, the driver reported being healthy, occasionally consuming alcohol, and never taking any illicit drugs.

During the application process with Executive Lines, the bus driver underwent a preemployment urine drug test in March 2019; the test results were negative. Postcrash, the driver was evaluated by a drug recognition expert; following this examination, and at the request of the CHP, the driver submitted to a blood drug test

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[35] According to 49 *CFR* 323.5, a class B CDL allows drivers to operate a single vehicle with a GVWR greater than 26,000 pounds, and it allows towing another vehicle weighing up to 10,000 pounds.

[36] Greyhound is a for-hire passenger carrier that provides intercity transportation throughout the United States and Canada. The bus driver left Greyhound in September 2018.

[37] This crash occurred on August 7, 2018, while the driver was employed by Greyhound. The driver struck a sign—a pedestrian crossing signal—while making a right turn.

that screened for alcohol and other drugs; the test results were negative.[38] Additionally, on February 24, 2020, Executive Lines had the driver take a US Department of Transportation (USDOT) postcrash drug test, as required by 49 *CFR* 382.303. Because the testing was conducted beyond the 32-hour time limit specified by federal regulations, the test was considered as failed, even though the results were negative.[39]

1.6.3 Route History and Activities Before the Crash

At the time of the crash, the driver was driving a regularly scheduled route from El Monte, California, to San Ysidro, California, which included four stops.[40] The crash occurred after the stop in Temecula, California, as the bus continued to its final destination of San Ysidro. The driver stated that he had operated the route many times.

The NTSB used information obtained from interviews with the driver, his cell phone records, Executive Lines records, and witness statements to reconstruct the driver's activities before the crash.

On February 19, after waking up at 4:00 a.m. and arriving at the bus yard in El Monte an hour later, the driver began operating an El Monte—San Ysidro—El Monte roundtrip. He returned to El Monte and completed his shift at 3:48 p.m. He did not work on February 20–21, and the available information showed that he had a 10-hour opportunity for sleep on each of those nights.

On the day of the crash, February 22, after having a 9-hour opportunity for sleep, the driver reported waking up at 5:00 a.m. and arriving at the bus yard in El Monte about 6:30 a.m., at which time he performed a pretrip safety inspection of the bus. He left the bus yard at 7:36 a.m. and collected the first passengers in Baldwin Park, California, at 8:10 a.m. The driver continued driving to the next three stops, arriving in Temecula at 9:53 a.m. At this stop, the driver used his cell phone to send a text message at 10:03 a.m. while he was logged as on-duty, not driving. The crash

[38] The blood sample was taken at 3:18 p.m. The test screened for a minimum of 150 drugs. For the most part, the drug recognition expert's examination did not observe any potentially impairing signs. However, due to a few inconclusive observations, the CHP requested that the driver submit to a blood drug test.

[39] (a) In the USDOT-required test, the driver was tested for amphetamines, marijuana, phencyclidine, cocaine, opioids, MDA analogues, oxycodones, and 6-Acetylmorphine. (b) If a postcrash drug test is not conducted within the required period, the carrier would be cited for violation of the federal regulation at 49 *CFR* 382.303(d)(2). The driver would not be cited for this violation unless they refused the test.

[40] The four stops, with El Monte as the starting location and San Ysidro as the destination, were as follows: Baldwin Park, Pomona, Riverside, and Temecula, all in California.

occurred 20 minutes later, about 15 minutes after resuming the trip from Temecula to San Ysidro. Although he was using his cell phone at various times that day, his phone records (calls and texts through short message service [SMS]) indicate that he was not using it at the time of the crash.[41] Figure 10 shows the driver's activities in the 3 days before and on the day of the crash.

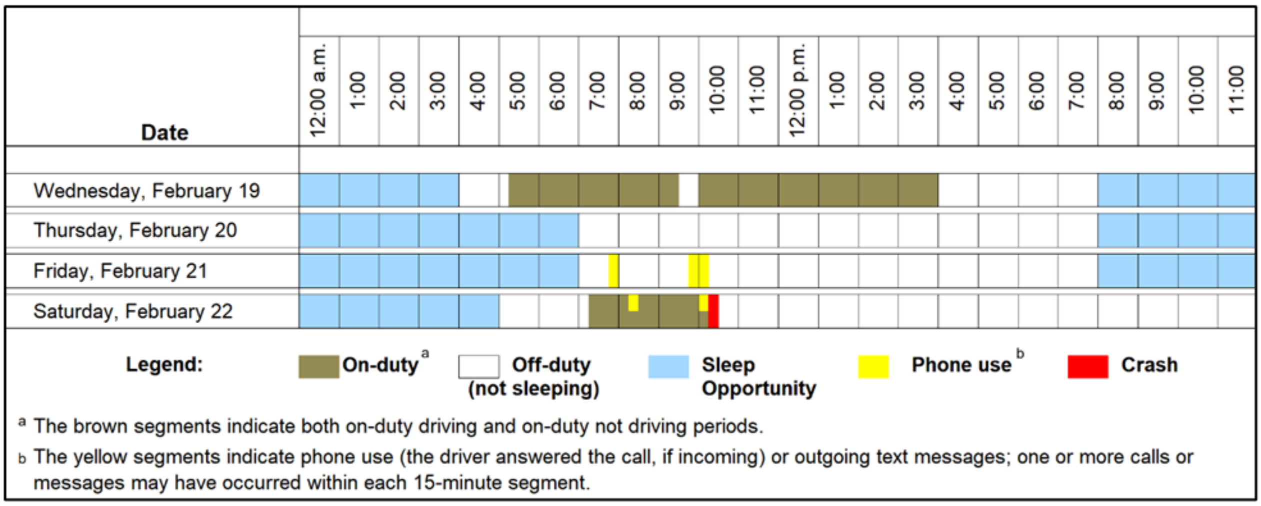

Figure 10. Precrash activities of bus driver, February 19–22, 2020.

In his postcrash interview with the CHP, the driver stated that, before the crash sequence began, he was in the leftmost lane. He stated that, as he was approaching the hill south of State Route 76—a spot that is about 0.6 mile north of the crash location—he moved into the rightmost lane. He stated that, as he was proceeding up the hill, he felt that the steering wheel "locked up," at which time he applied brakes with medium pressure. He stated that the bus was out of control at that time, first moving into the adjacent left lane and then back into the right lane before moving onto the shoulder and departing the roadway.

In a subsequent interview with the CHP and the NTSB, the driver estimated that he moved from the far-left to the far-right lane about 1 minute before the crash. He also reported that, when the wheel locked up, the bus started "wandering" into the lanes to the left, and that "my vehicle started to drift to the left …but I was still straight." The driver stated that he then applied brakes with medium pressure and

[41] (a) The driver stated that he was not using the cell phone at the time of the crash. (b) Although records show that the driver had used his cell phone earlier in the day, due to the lack of other evidence (such as continuous data from the vehicle's ECM), it could not be determined whether the driver's use of his cell phone earlier in the day had occurred while driving.

steered about 15° to the right to return to the right lane, at which point the bus departed the roadway.

When interviewed by the NTSB and the CHP, 7 of the 10 interviewed bus passengers stated that the bus was traveling at high speed or too fast for weather conditions, and 3 passengers stated that the bus was traveling at “normal” speed or “not too fast.” CHP investigators interviewed three drivers who were driving about 50–100 yards behind the bus at the time of the crash; their statements indicated that the bus was traveling at the speed of the surrounding traffic. These witnesses estimated that they were traveling about 60–65 mph at that time. One of the witnesses estimated that the bus was traveling 60 mph, while the other two witnesses did not provide an estimate; none of the witnesses indicated that the bus was traveling faster than their vehicles were. There was no other evidence to corroborate the witnesses’ speed estimates.

1.7 Motor Carrier Operations

1.7.1 Overview

Executive Lines Inc., domiciled in El Monte, California, was a for-hire interstate passenger motor carrier that obtained USDOT authorization to operate in February 2004.[42] At the time of the crash, the carrier operated in California and made trips to the border with Mexico, remaining on the US side of the border crossing.[43] At that time, it operated 8 vehicles and employed 12 drivers.

1.7.2 Carrier Policies, Records, and Hours of Service

Executive Lines’ hiring policy included only hiring drivers who were familiar with tour bus operations, had received driver training in the past, and met federal requirements.[44] As required by 49 *CFR* 391.51, Executives Lines had a complete

[42] The carrier is no longer in business. On January 31, 2021, Executive Lines’ liability insurance expired, as the carrier could not afford the greatly increased premium. Without this required insurance, the carrier could not operate its passenger transportation business. Executive Lines is now a ticket booking agent for another carrier that operates the routes previously serviced by Executive Lines.

[43] In the past, the carrier had operated inside Mexico, but it stopped that practice about 1 year before the crash due to delays in crossing the border.

[44] For a driver to be considered for hiring, federal regulations—49 *CFR* 391.11—mandate that drivers, among other requirements, (1) be at least 21 years old, (2) hold a valid driver’s license, (3) have no drug offenses on their driving record, (4) pass the carrier’s road test, and (5) be approved by the carrier’s insurance company.

driver qualifications file for the crash involved driver.[45] The carrier also maintained a drug testing program, as required by 49 *CFR* 382 Subpart C; the crash-involved driver was in the carrier's random test pool but had not been selected for testing before the crash.

Executive Lines did not follow some of the industry best practices that define a safe carrier, such as having a safety plan or a training program for drivers, and it did not offer performance-based incentives to drivers. The carrier did hold an annual safety meeting for drivers.

Executive Lines used electronic logging devices (ELD) from Samsara Inc. for recording and monitoring drivers' compliance with HOS regulations.[46] The NTSB reviewed the crash-involved driver's electronic log data and compared that data to supporting documentation, such as the driver's timecards, to verify HOS compliance; the records indicated that the driver was in compliance with HOS regulations. The ELD data were also examined for possible false log entries; none were found.

1.7.3 Federal and State Oversight

1.7.3.1 Federal. Executive Lines entered the FMCSA new entrant safety assurance program on February 28, 2004, and successfully passed an audit on February 25, 2005. The carrier had six FMCSA compliance reviews (CRs) between 2006 and 2019. All but one of the CRs received *satisfactory* ratings; a 2009 CR was initially rated as *conditional* and later upgraded to *satisfactory*.[47] At the time of the crash, Executive Lines had a *satisfactory* safety rating.[48]

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[45] Among other documentation, driver qualification files are required to include (1) the driver's employment application; (2) a copy of their driver's license or CDL; (3) motor vehicle records obtained within 30 days of hire and annually after hiring; (4) investigation into the driver's background and safety record, including crashes that do not result in towing of vehicles; and (5) a copy of the driver's medical certification.

[46] (a) According to 49 *CFR* 395.5, a passenger-carrying carrier cannot permit a driver to operate a passenger-carrying commercial vehicle for "more than 10 hours following 8 consecutive hours off duty" or after "having been on duty 70 hours in any 8 consecutive days if the employing motor carrier operates commercial motor vehicles every day of the week." (b) The Samsara ELDs on the carrier's vehicles consisted of hardware units inside the vehicles.

[47] A *conditional* rating means that a motor carrier does not have adequate safety management controls in place to ensure compliance with the safety fitness standard in 49 *CFR* 385.5.

[48] The safety rating at the time of the crash was based on a CR conducted on April 27, 2017. The CR conducted in 2019 was considered to be a focused review, so it was not rated.

At the time of the crash, the carrier had had one BASIC—HOS compliance—in alert status since February 22, 2019.[49] The alert status was based on 20 roadside driver inspections in the previous 8-month period, which resulted in 7 violations of HOS regulations.[50] All seven violations related to the failure of those drivers to adhere to requirements related to proper operation of their ELDs or automatic onboard recording devices—a predecessor technology to the ELD. None of these violations were considered out-of-service violations. The carrier had never had the vehicle maintenance BASIC in alert status.

1.7.3.2 California. Oversight of motor carriers operating in California is a shared responsibility between the California Public Utilities Commission (CPUC), the Department of Motor Vehicles, and the CHP. The CPUC is responsible for licensing passenger-carrying motor carriers. The California Department of Motor Vehicles registers and records vehicle ownership and other driving-related information; it also conducts and oversees other functions, including tasks associated with driver training. The CHP is the law enforcement agency responsible for ensuring compliance with portions of the *CVC* related to the safe operation of commercial motor vehicles. *CVC* 34501 requires the CHP to inspect every designated maintenance facility or terminal, or any person who operates any regulated truck or bus, at least once every 13 months.

The state's terminal inspections are similar to the CRs conducted by the FMCSA, but they have a greater focus on vehicle maintenance. During terminal inspections, the CHP is required to inspect a portion of the carrier's entire fleet. By the date of the crash, Executive Lines had undergone five CHP terminal inspections, the last one occurring on January 3, 2019. The CHP rated all five inspections as *satisfactory*.

1.7.3.3 Postcrash Oversight. After the crash, the FMCSA conducted a postcrash CR that resulted in a *satisfactory* safety rating for Executive Lines. This CR

[49] This information is contained in the FMCSA Motor Carrier Management Information System. The FMCSA uses data from roadside inspections—including all safety-based violations, state-reported crashes, and the Federal Motor Carrier Census—to quantify a carrier's performance in seven BASICs. These BASICs are (1) unsafe driving, (2) HOS compliance, (3) driver fitness, (4) controlled substances and alcohol, (5) vehicle maintenance, (6) hazardous materials compliance (if applicable), and (7) crash indicator.

[50] These inspections occurred between June 18, 2018, and February 2, 2019. During this period, the roadside inspections revealed 19 violations of vehicle maintenance regulations, 1 of which related to less than required tire tread depth; however, the BASIC scores for the violations were below the threshold required for alert status. A score of 65 percent or higher is required for a passenger-carrying motor carrier to receive an alert status in a BASIC; Executive Lines' vehicle maintenance score was 48 percent.

revealed seven noncritical, non-acute violations; none of these violations were related to vehicle maintenance.[51]

The BASIC alert status in HOS compliance for the carrier was removed on June 26, 2020, based on the results of roadside inspections of Executive Lines' vehicles following the crash. Additionally, on December 10, 2020, the CHP performed a terminal inspection of the carrier; the inspection was rated as *satisfactory*.

[51] Critical and acute violations are defined in 49 CFR Part 385 Appendix B. The postcrash CR did not include inspection of the crash bus.

2 Analysis

2.1 Introduction

On the morning of February 22, 2020, a bus, occupied by a driver and 20 passengers, was traveling southbound on I-15 in Pala Mesa, California, when the driver lost control and the bus departed the roadway and overturned. Three passengers died, and the driver and 17 passengers were injured.

The analysis first examines factors that can be excluded as being causal or contributory to the crash. Next, the analysis discusses elements that might have affected the bus's departure from the roadway—first, stability systems (section 2.2.1) and roadway surface conditions (section 2.2.2)—and then, the combined effect of factors that preceded the loss of control, including the driver's actions, the condition of the bus's tires, and the vehicle's speed (section 2.2.3). Finally, the analysis discusses the following safety issue areas revealed during the investigation:

- Driving at safer speeds on wet roadways (section 2.2.4.1)
- Ensuring adequacy of tire tread depth standard for commercial vehicles (section 2.2.4.2)
- Maintaining safe tire tread depths on commercial vehicles (section 2.2.4.3)
- Addressing lack of roof strength standards for certain buses (section 2.3.1)
- Increasing seat belt usage on buses (section 2.3.2)

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

- ***Bus driver's licensing and experience:*** The bus driver had a valid CDL with appropriate endorsements and 2 years of experience driving passenger-carrying motor vehicles.
- ***Cell phone use, alcohol and other drugs, and fatigue:*** Cell phone records indicate that the bus driver was not engaged in texting or a cell phone conversation at the time of the crash. Postcrash toxicology test results revealed no evidence that the driver had used alcohol or other drugs before the crash. Records related to the driver's activities in the days preceding the crash show that he had adequate opportunity for rest, and the circumstances of the crash do not include usual fatigue indicators, such as gradual roadway departure.

- ***Mechanical condition of the bus:*** With the exception of the condition of the tires, postcrash examination of the bus did not identify any preexisting mechanical conditions that might have contributed to the crash. The consequences of the substandard tires are discussed later in the analysis.
- ***Highway design:*** The section of I-15 where the crash occurred conformed to current design guidance, had appropriate regulatory and warning signage, and had a clear zone area adjacent to the west side of the southbound lanes that more than met design guidelines. The roadway surface and the bridge deck of the southbound lanes of I-15 in the area of the crash were in good condition. Although the highway design was not a factor in the crash, this topic is further discussed within the broader context of roadway departure factors in section 2.2.2.

The NTSB therefore concludes that none of the following were factors in the crash: (1) the licensing or driving experience of the bus driver; (2) cell phone use, use of alcohol or other drugs, or fatigue; (3) the non-tire-related mechanical condition of the bus; and (4) highway design.

The investigation found that the emergency responders were swiftly dispatched, surviving passengers were quickly transported from the scene, and appropriate communication protocols were followed. The NTSB therefore concludes that the emergency response to the crash was timely and adequate.

2.2 Roadway Departure Factors

Approximately half of the traffic fatalities that occur annually in the United States resulted from roadway departure crashes.[52] Although such crashes typically occur on higher-speed roads, they can be caused by a variety of factors. In this investigation, we explored a number of those factors. The NTSB examined the roadway evidence, including the evidence collected and documented by the CHP MAIT during their on-scene investigation. Also examined were the driver and passenger statements, recorded vehicle data, and postcrash pavement testing results, to identify factors that could potentially have caused or contributed to the bus's loss of control and subsequent roadway departure.

The first evidence on the roadway of the bus's loss of control was a tire friction mark in the center-left lane, starting about 14 feet before the southern end of the bridge deck and 1.7 feet from the right edge of the lane. This tire friction mark,

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[52] For additional information, see the FHWA reference webpage for roadway departure safety, accessed April 18, 2022.

caused by a tire slip, was consistent with the vehicle's left rear tires and arced toward the right shoulder. At the onset of this mark, the bus had yawed clockwise about 2° relative to the travel lanes and was straddling the line between the center-left and center-right lanes, with its rear tires still on the bridge.

This analysis of the bus's arcing trajectory off the road and the clockwise yaw of the bus is supported by the evidence of two other tire friction marks. The offset, or separation between the three friction marks, was used to determine the degree of the yaw rotation. At the onset of the second tire friction mark, which was consistent with the bus's left front tire and began 61 feet south of the first mark, the bus had yawed clockwise about 14° relative to the travel lanes. The vehicle's clockwise rotation continued; at the point of roadway departure, the bus had yawed clockwise about 42° relative to the travel lanes.

The way the bus lost control suggests that it first lost rear wheel traction. Various factors can bring about such a loss, including driver steering and braking inputs, vehicle speed, low tire tread depth, and inadequate surface friction (Kulakowski, Chi, and Lin 1992). The effect of driver input can be particularly significant. Excessive driver input, particularly in combination with low tire tread depth and inappropriate vehicle speed for conditions may reduce friction with the roadway surface, leading to the loss of tire traction and, potentially, to the loss of vehicle control. The effect of the crash bus driver's actions following the initial loss of traction is discussed in section 2.2.3.1.

Although the roadway evidence shows that the bus experienced a loss of control, some aspects remain unknown. The roadway marks, ECM data, and other evidence were insufficient for the NTSB to determine (1) when the loss of control began (although it likely occurred before the first tire friction mark appeared on the road), or (2) whether the loss of control would have occurred without the driver's input.

2.2.1 Stability Systems

The bus was equipped with ABS. The primary benefit of ABS is that it prevents wheels from locking up, allowing the vehicle to move in the steered direction. The tire friction marks on the roadway before the roadway departure were barely visible, which indicates that the ABS was functioning and preventing the bus's wheels from locking up.[53]

[53] Dark tire friction marks indicate a locked wheel.

The bus was not equipped with an ESC system. The primary benefit of ESC is that it helps the driver maintain vehicle control during steering maneuvers, when the system detects that the vehicle is not traveling in the direction of the driver's steering input. ESC assists the driver by reducing vehicle speed through engine throttle and brake application at specific wheels to counteract the loss of control. Consequently, the initial loss of traction at the rear wheels that led to the loss of vehicle control in this crash could have been prevented or mitigated by ESC. However, at the time of its final-stage manufacture in 2013, the bus was not required to be equipped with ESC. As established in 49 *CFR* 571.136, the mandate for ESC on newly manufactured buses with GVWRs between 26,000 pounds and 33,000 pounds began in August 2019.[54] Because of the complexity of sensor locations, wiring, and on-vehicle testing requirements, it is not currently feasible to retrofit ESC systems onto existing vehicles that are equipped with either pneumatic or hydraulic brakes. The NTSB concludes that, had the bus been equipped with an ESC system—which was not required equipment at the time of its manufacture—the system would have assisted the driver in maintaining control, which could have prevented the crash.

2.2.2 Roadway Drainage and Surface Friction

According to witness statements, light-to-moderate rain was in the area at the time of the crash. The NTSB examined the extent to which roadway conditions contributed to the driver's loss of vehicle control and the subsequent crash.

The numerous drainage appliances in the vicinity of the crash were found to be free of obstructions. In addition, the design of the drainage systems conformed to the national and state guidelines established by AASHTO and Caltrans (AASHTO 2018, Caltrans 2020). The combination of the roadway's grade and the cross-slope would have caused stormwater to clear from it in a diagonal, southwest-to-northeast direction, minimizing the depth of the resulting water sheet and speeding the drainage process.

At the request of the NTSB, Caltrans conducted surface friction tests on the four southbound lanes of I-15 in the vicinity of the crash. The test results showed that

[54] The NTSB has a long history of making safety recommendations pertaining to ESC in commercial vehicles. In 2008, the NTSB issued Safety Recommendation H-08-15 to NHTSA to conduct research regarding the effectiveness of installing automatic emergency braking and ESC on heavy vehicles already equipped with collision warning systems, and, if deemed effective, to require their use on those vehicles. Due to lack of progress, particularly on the collision avoidance system mandate, Safety Recommendation H-08-15 was classified "Closed—Unacceptable Action" in 2015. Following the investigation of a cargo tanker rollover crash in Indianapolis, Indiana, in 2009 (NTSB 2011), the NTSB issued recommendations to NHTSA to develop performance standards for ESC in commercial vehicles and require such systems to be installed in all new commercial vehicles (Safety Recommendations H-11-7 and -8). Because the NHTSA mandate for ESC on new motorcoaches excludes medium-size buses, Safety Recommendations H-11-7 and -8 remain classified "Open—Unacceptable Response."

only 3 of the 20 tested segments in the southbound lanes near the crash had minimum surface friction values slightly below the Caltrans threshold for new pavements, a metric that may not be suitable for evaluation of in-service pavements. However, Caltrans does not have a minimum surface friction coefficient threshold for in-service pavements. For in-service roadway pavements, the agency assesses the surface friction values in combination with crash rates obtained from TASAS reports to determine whether a segment requires improvement. Based on the surface friction testing and the information from TASAS reports, Caltrans determined that the section of I-15 containing the crash area did not warrant surface friction roadway improvements. The agency further stated that the coefficient of friction threshold value considers possible adverse weather conditions.

The NTSB examined the extent to which the Caltrans surface coefficient of friction values could be compared to those of another state that uses a different method of measuring surface friction that may be more applicable for in-service pavements.[55] By correlating these different methodologies, we evaluated the friction of the tested segments using criteria adopted by the Utah Department of Transportation (UDOT), as well as several other states.[56] According to the criteria in the UDOT pavement management manual, none of the tested segments in the area of the Pala Mesa crash would have been considered as "needing further evaluation" on the basis of surface friction (UDOT 2020).[57]

Although several surface friction values in the southbound lanes were below the Caltrans threshold for new pavements, these values were consistent with acceptable in-service values used by other states. Moreover, the surface friction values in the area where the bus was traveling immediately before where the first tire friction mark was documented—the two middle lanes in the 400-foot span of the second half of the bridge—were above the Caltrans threshold for new pavements. Therefore, the NTSB concludes that the roadway in the area where the bus initially lost control provided a sufficient level of friction; therefore, it is unlikely that the bus driver lost control due to poor roadway friction.

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[55] Caltrans uses a California portable skid tester, while most other states use a locked-wheel skid trailer to conduct surface friction testing.

[56] For additional details, see the highway factual report in the docket for this investigation.

[57] (a) According to the UDOT manual, surface friction values are categorized using the following condition ratings, based on the skid number at 40 mph: values greater than 45 are considered sufficient, values between 35 and 45 are approaching the need for further evaluation, and values below 35 need further evaluation. Half of the tested segments in the area of the crash had corresponding values of at least 45. (b) UDOT's method for evaluating surface friction of in-use pavements is a typical method that is used by other states.

2.2.3 Bus Loss of Control: Combined Effect of Multiple Factors

Although the roadway surface friction was sufficient for normal traffic, a wet roadway can be risky when combined with additional factors such as inappropriate driver actions, inadequate tire tread depth, and vehicle speed that is too high for conditions. In this section, we discuss the bus driver's actions and examine how those actions, in combination with the bus's speed on the wet roadway and low tire tread depth, contributed to the loss of control and subsequent departure from the roadway. In section 2.2.4, we explore countermeasures—guidance on reasonable speeds for conditions and more adequate tire tread depths—that could address the factors that contributed to the loss of vehicle control in this crash.

2.2.3.1 Driver Actions. In his initial interview with the CHP, the driver stated that he felt the steering wheel lock up and that he applied brakes with medium pressure, at which point the bus went out of control and moved into the adjacent left lane. In his second interview with the CHP (this interview included the NTSB), the driver described the bus as "wandering" into the adjacent lane and stated that "my vehicle started to drift to the left …but I was still straight." The driver reported that, in an attempt to steer the bus back to the right, he applied brakes with medium pressure and steered right at an estimated angle of 15°.

Based on the recorded vehicle data, the bus was traveling 73–75 mph before the crash sequence began. The driver applied brakes 3 seconds before a sudden deceleration event was triggered, and he kept at least some pressure on the brake pedal for the next 4 seconds. The ECM data show that about 2 seconds later—after the brake status changed to "Off"—all data parameters transitioned to zero; the zeroing out of the data would have occurred sometime during the rollover. It is reasonable to assume that the driver would not have been able to maintain brake pedal pressure during the rollover. Given that the distance between the onset of the first tire friction mark and the initiation of the rollover sequence was 225 feet, that the driver applied the brakes continuously for 7 seconds before the rollover, and that the speed of the bus when braking began was 64 mph, the driver had to have begun applying brakes well before the first sign of roadway evidence.[58]

The bus's ECM did not capture steering data, nor was it designed to do so. In his second postcrash interview, the driver said that he had steered right; the roadway evidence, including the arcing tire marks, indicate that the right steering input led to the roadway departure.

[58] Based on the average speed of 64 mph, the bus would have traversed 225 feet in 2.4 seconds. Because the bus was being braked at this time, it would have taken slightly longer to traverse the distance of 225 feet but considerably less than 7 seconds.

In loss of traction situations, drivers must make specific and time-critical responses to maintain or regain vehicle control. The California commercial driver handbook offers guidance on driving on wet and slippery roadways (California Department of Motor Vehicles 2019). To correct a drive-wheel braking skid, the handbook advises drivers to "Stop Braking. This will let the rear wheel roll again, and keep the rear wheels from sliding."[59] The manual goes on to suggest actions that drivers should take once the vehicle turns back onto its correct course, as follows: "Counter-steer. As a vehicle turns back on course, it has a tendency to keep on turning. Unless you turn the steering wheel quickly the other way, you may find yourself skidding in the opposite direction."

The bus driver's actions in response to the unpredicted vehicle movement that he reported experiencing were the opposite of those suggested by the handbook. When driving on wet roadways, driver best practices include avoiding sustained braking as well as sudden and sharp steering. The driver's sustained brake application, even after the initial loss of traction, would have intensified the rotation of the vehicle, despite the functioning ABS. In this way, the driver's braking and steering in response to the bus's loss of traction and its leftward movement exacerbated its clockwise yaw and led to the subsequent roadway departure and overturn. The California driver's handbook acknowledges that learning to stay off the brake and to turn the steering wheel quickly while counter-steering during the skid are actions that take practice to perform in real-world situations.

2.2.3.2 Effect of Tread Depth and Speed. Inadequate tire tread depth and excessive vehicle speed for conditions were also contributing factors to the bus's loss of traction, which was exacerbated by the driver's inappropriate braking and steering inputs.

The bus's two inside rear tires had tread depths of 1/32 inch—below the minimum tire tread depth requirement of 2/32 inch—and the tread depths on the two outside rear tires just met that requirement. The tires on the steer (front) axle had tread depths of 10–11/32 inch.

Given such tread depths, the bus would most likely respond to the driver's steering input, but its lateral stability might be compromised. The rear axle tires are primarily responsible for maintaining a vehicle's lateral stability. On wet roadways, traction decreases with lower tire tread depths (Blythe and Day 2002). In addition, tire traction, particularly for the tires on the rear axle, decreases further with uneven tread depth between tires on the steer and rear axles (Blythe and Day 2002, Ervin and

[59] Braking skids can occur on wet or dry surfaces if sufficient braking is applied to lock the wheels or to cause them to slip significantly.

Balderas 1990). The wet roadway in combination with the very low tread depths of the rear tires, and the large difference in tread depths between the rear and front tires, would have diminished the ability of the rear tires on the crash-involved bus to maintain traction.

Although the driver may not always be aware of whether the vehicle's tire tread depth is adequate for conditions, the driver has immediate and complete control over one of the main factors affecting a vehicle's traction—vehicle speed.[60] As vehicle speed increases, the friction between the tires and a wet roadway surface decreases (Kulakowski, Chi, and Lin 1992; Williams 1992). Also, a driver's sudden or sustained brake application when traveling at high speeds on a wet roadway further decreases tire traction. All these factors were present in this crash: the roadway was wet, the bus was traveling too fast for the environmental and vehicle conditions, the rear tires had very low tread depths, the steer axle tires had substantially higher tread depths than the tires on the rear axle, and the driver applied sustained braking. In combination, these factors enabled an initial loss of traction that ultimately led to the loss of control and the bus's leaving the roadway and rolling over.

Therefore, based on the foregoing information, the NTSB concludes that the loss of vehicle control was due to the combined effects of the low and substandard tread depth of the rear axle tires, the excessive speed for the wet roadway and vehicle conditions, and the driver's inappropriate inputs before and during the loss of control event.

2.2.4 Countermeasures to Loss of Control Factors

2.2.4.1 Driving at Safer Speeds on Wet Roadways. Postcrash, some passengers reported that the bus was traveling too fast for conditions at various times during the trip. At the time of the crash, based on the accounts from the three witnesses who were driving vehicles behind the bus at that time, the bus was not moving faster than the speed of traffic.

The California commercial driver handbook contains advice on safe driving speed, including the following: (1) reduce speed by one-third on wet roads; and (2) when driving in heavy traffic, the safest speed is the speed of other vehicles (California Department of Motor Vehicles 2019). At the time of the crash, the traffic was moderate to heavy, according to witness statements.

[60] A driver may be unable to inspect the tread depths of a large vehicle's inside tires because they are not easily visible or accessible. Although he did not note it on the pretrip inspection form, the crash driver stated in a postcrash interview that he had concerns about the low tire tread depth on the bus's right rear tire.

Although these two pieces of guidance may appear contradictory, a driver should use them as circumstances warrant. For instance, if reducing speed by one-third under wet and/or rainy roadway conditions when other traffic is traveling at or near the speed limit would represent a safety risk, then a speed reduction of less than a third may be appropriate. It is left to the prudent driver to make such judgments based on reasonable guidance. For example, the FMCSA maintains a webpage that provides tips for commercial drivers about maintaining safe speeds under various driving conditions; the guidance identifies potentially hazardous weather conditions and advises drivers on appropriate speeds for conditions.[61]

The circumstances of this crash included moderate rain, a wet roadway, and tires with low tread depths and large differences between the tread depths of the tires on the rear and steer axles. Given these conditions, a safety-conscious commercial vehicle driver would not travel at the speed of traffic—or 3–5 mph above the 70-mph speed limit.

Although Executive Lines is no longer in the passenger-carrying business, this crash could remind passenger-carrying motor carriers and commercial drivers of the safety risks involved in driving on wet roadways and that the risks are exacerbated when traveling at or above highway speeds on tires with low tread depths (especially on a vehicle without an ESC system). Under such conditions, the speed at which a commercial vehicle travels becomes an important safety factor in that a lower speed can reduce the safety risk while a higher speed may lead to a loss of control. Of the factors that affect safe driving on wet roadways, speed is one that is directly, easily, and immediately controlled by the driver. Therefore, based on the driver's failure to adjust his speed and driving behavior to the wet roadway and vehicle conditions in this crash, the NTSB concludes that drivers responsible for commercial vehicles that transport passengers would benefit from their motor carrier implementing a driver training program that, at a minimum, includes consistent and authoritative guidance on driving at safe speeds on wet roadways and in other inclement weather conditions. The American Bus Association (ABA) and the United Motorcoach Association (UMA) are industry associations that represent nearly all US motorcoach operators. Therefore, the NTSB recommends that the ABA and the UMA inform their members about the circumstances of the Pala Mesa, California, bus crash and encourage them to create a policy on speed and safe driving on wet roadways and under inclement weather conditions based on authoritative guidance, such as the FMCSA's safe driving tips for commercial motor vehicle drivers or information provided in state commercial driver's handbooks.

[61] For more information, see CMV Driving Tips—Too Fast for Conditions, accessed April 18, 2022.

2.2.4.2 Adequacy of Tire Tread Depth Standard for Commercial Vehicles. To remain relevant, regulations associated with safe vehicles must change over time. The federal requirements regarding minimum tire tread depths on commercial vehicles are established in 49 *CFR* 393.75 and 49 *CFR* 570.62. These standards were adopted almost 50 years ago, in 1974, and were supported by NHTSA's research and review of existing studies to determine the minimum tread depth of tires on commercial vehicles.[62]

In a recent conversation with NTSB investigators, NHTSA discussed the decision-making process used in the development of the regulations for tires on commercial vehicles, specifically the requirements pertaining to minimum tread depth—49 *CFR* 570.62.[63] Additionally, NHTSA discussed a 1996 petition that the agency received to increase the minimum tire tread depth requirement to 3/32 inch (61 *Federal Register* 2991). NHTSA referenced several studies that influenced the agency's decision to reject the petition, some of which also bolstered the agency's argument when setting the minimum tread depth in the 49 *CFR* 570.62 regulation. These studies concluded that tires behave like smooth tires when tread depth is reduced to 2/32 inch (Horne 1967) and that tires should be replaced when they reach tread depth of 2/32 inch (Fancher and Bernard 1975). NHTSA further referenced the longstanding industry practice of replacing tires when tread depth reaches 2/32 inch. In its summary of petition rejection, NHTSA concluded that the agency was unaware of data suggesting a safety need to increase the minimum tire tread depth to 3/32 inch.

However, some of the more recent research suggests a different tire tread depth threshold at which tires exhibit significant loss of traction. Braking tests conducted in 0.05 inch of water at various speeds and with tires of varied tread depths showed that tires with tread depths of 1/32 inch and 2/32 inch perform similarly, and considerably below the performance of tires with tread depths of 4/32 inch (Blythe and Day 2002).

As discussed earlier, tire tread depth should also be considered with respect to the placement of tires on the steer and rear axles. Placing tires with poor tread on the rear axle and tires with substantially better tread on the steer axle can adversely affect the vehicle's handling on wet surfaces (Blythe and Day 2002, Ervin and Balderas 1990). Although steering can be preserved, poor traction at the rear axle can lead to a loss of vehicle control.

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[62] See 1974 tire tread standards, accessed April 18, 2022.

[63] The discussion took place during a meeting between NTSB staff and staff from NHTSA's Office of Crash Avoidance Standards on November 17, 2021.

The research that led NHTSA to set the minimum tire tread depth requirements to 2/32 inch for commercial vehicles may have been appropriate, considering the available research at the time. However, nearly half a century has passed since NHTSA established the standard, and updated research is necessary to determine the appropriateness of those tread depth values, including research to examine the effect of different tread depths for tires on the steer and rear axles.

The federal tire tread depth requirements are the same for all commercial vehicles, including buses. However, federal regulations recognize that some motor carriers and their vehicles are different because they transport passengers rather than cargo. The FMCSA gives the safety of passenger-carrying motor carriers special attention. For example, the FMCSA threshold—based on BASIC scores—for initiating a carrier inspection is considerably lower for passenger-carrying motor carriers than for those carriers that transport cargo; and passenger motor carriers are required to meet more stringent safety requirements than are other carriers.

The NTSB concludes that, based on currently available research, minimum tire tread depth requirements may be insufficient to ensure adequate traction for commercial vehicles, particularly passenger-carrying vehicles, such as buses. Therefore, the NTSB recommends that NHTSA sponsor research to determine the appropriate minimum tire tread depths necessary for the safe operation of commercial vehicles, particularly passenger-carrying vehicles. The research should include the effect on vehicle handling when different tread depths are used for tires on the steer versus the rear axles (Safety Recommendation H-22-12). The NTSB further recommends that NHTSA revise 49 *CFR* 570.62 based on the outcome of the research described in Safety Recommendation H-22-12. Additionally, the NTSB recommends that the FMCSA revise 49 *CFR* 393.75 based on the outcome of the research described in Safety Recommendation H-22-12.

2.2.4.3 Maintaining Safe Tire Tread Depths on Commercial Vehicles. The NTSB's postcrash examination of Executive Lines' operations showed that the carrier complied generally with federal regulations, despite not following some best industry practices for safety, such as having a safety plan or a driver training program. Over a 13-year period, all but one of the carrier's federal CRs and California terminal inspections were rated as *satisfactory*.[64] At the time of the crash, the carrier had one BASIC alert—for HOS compliance. Based on the results of roadside inspections conducted after the crash, this alert status was removed on June 26, 2020. Additionally, the terminal inspection conducted by the CHP on December 10, 2020, was rated as *satisfactory*.

[64] One CR in 2009 was initially rated as *conditional* but later upgraded to *satisfactory*.

Even though Executive Lines' safety record per its CRs and terminal inspections was adequate, at the time of the crash, the carrier was operating a bus with two of its tires—the inside tires on the rear axle—having tread depths below the minimum requirements. Based on the CVSA criteria, the two inside tires were not worn enough to constitute an out-of-service violation, which would have required immediate removal of the bus from service. However, the condition of the tires could have incurred a citation for not meeting the minimum tread depth requirements. Consequently, had the crash-involved bus undergone an inspection 1 day before the crash and received a citation for violation of minimum tire tread depth requirements, it would have been illegal for the bus to operate the next day with those same tires.

In fact, this bus operated in passenger service with these two noncompliant tires for considerably longer than a day. Executive Lines' maintenance records show that several repairs were made to the bus in February 2020, the last of which occurred on February 10, 2020. Passenger-carrying motor carriers registered in California are required to complete safety inspections for each vehicle in the carrier's fleet at least every 45 days. The CHP has created the Bus Maintenance and Safety Inspection Form—CHP Form 108A—as a guidance document to assist carriers in documenting safety inspections, although use of this form to record documentation is not mandatory.

On February 10, 2020, Executive Lines completed CHP Form 108A for the crash-involved bus. One of the items on the form relates to tires: "Wheels, tires, lug nuts – cracks, secured – tread – inflation." Executive Lines' maintenance staff checked this item as "OK" on February 10, just 12 days before the crash, indicating that the tire tread depths all met requirements, which would mean that all tires on the rear axle had tread depths of at least 2/32 inch at that time. Further, Executive Lines' maintenance practice was to remove tires from service once their tread depths reached 2/32 inch. Based on the elapsed vehicle mileage from the time that the steer axle tires were replaced to the day of the crash—51,603 miles—the tread depth of the steer axle tires on the bus, which were the same type as the rear axle tires, decreased by 1/32 inch about every 7,000 miles. The crash-involved bus traveled 3,363 miles from February 10 to February 22 (the day of the crash). Even taking into account possibly different rates of tread depth wear between the tires on the steer and rear axles, and the nonlinear tread wear (Kravchenko, Sakno, and Lukichov 2012), the two inside tires on the rear axle would likely have already had less than the required minimum tread depth of 2/32 inch at the time of the February 10 inspection. Therefore, when the carrier filled out CHP Form 108A on February 10, the rear axle tires likely did not meet minimum tread depth requirements. The NTSB concludes that Executive Lines' deficiencies in tire replacement and rotation procedures allowed the bus to operate in service with tires that had less than the required tread depths, which contributed to the crash.

Executive Lines is no longer in the business of transporting passengers. Nevertheless, according to UMA staff, some motor carriers follow the practice of replacing tires on the rear axle(s) with used tires from the steer axle to use the remaining available tread.[65] This practice is not recommended by the UMA or the U.S. Tire Manufacturers Association (USTMA). In the USTMA publication on the care and service of commercial tires, the recommended tire rotation plan does not include moving tires from the steer to the rear axle (USTMA 2017).[66] Instead, the USTMA recommends rotating steer axle tires side to side, while it recommends rotating rear axle tires between axles or side to side. As discussed earlier, placing tires with poor tread on the rear axle and tires with substantially better tread on the steer axle can adversely affect the vehicle's handling on wet surfaces.

The NTSB concludes that the practice used by Executive Lines and some other motor carriers of replacing tires on the rear axle with used tires from the steer axle and placing new tires on the steer axle can result in non-uniform tread depths between the front and rear tires, leading to a loss of traction, as evidenced by this crash. Therefore, the NTSB recommends that the ABA and the UMA encourage their members to adopt the recommended tire rotation practices established by the USTMA.

CHP Form 108A, which assists motor carriers in documenting the regular CHP-required safety inspections, was last revised in 2005. Currently, the item on the form that pertains to the inspection of tire tread depth also refers to the inspection of proper tire inflation and the condition of wheels and lug nuts. It does not instruct the carrier to include any specific information, beyond confirming that the status of these tire elements is "OK." Considering the criticality of tires to the overall safety of a vehicle, particularly when the practice of some segments of the industry is to keep tires in service as long as possible (within regulatory limits), careful and frequent inspection of tires on buses is essential.

Having carriers fill out CHP Form 108A is a means of measuring minimum adequate maintenance of passenger-carrying vehicles in California. But, given the concerns specifically related to tire tread depths identified in this investigation, the form could serve additional safety purposes. For example, the form could be used to check and report, on a regular basis, the tread depths of a bus's tires. By adding such information to the form, carriers would have to pay more attention to tire tread depths at every inspection because they would have to measure and record them.

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[65] The NTSB obtained the industry practice information in an October 21, 2021, conversation with staff from the UMA vehicle council.

[66] For additional information, see USTMA publication *Care and Service of Commercial Truck and Bus Tires*, accessed April 18, 2022.

Having carriers report the tire tread depth values on CHP Form 108A would also serve as a visual reminder to carrier maintenance staff about the wear status of the tires on the bus and of the need to plan for tire replacement. It would also indicate to the CHP the thoroughness of the carrier's inspection processes when it conducts its terminal inspections every 13 months.

The NTSB concludes that safety can be enhanced by requiring motor carriers to record the tread depths of the tires on buses in California because it would provide a reminder to maintenance staff about the wear status of the tires. Therefore, the NTSB recommends that the CHP revise CHP Form 108A to include the measured tire tread depths of all tires on buses.

The revision of CHP Form 108A would provide that carriers using CHP Form 108A to fulfill the inspection requirement record the measurement of the tire tread depths on the inspected buses. However, the revision would be only an intermediate measure because use of CHP Form 108A is not required. Consequently, the safety benefit provided by revision of the form would not include any carrier that uses its own inspection form. Moreover, because documenting specific tread depth measurements is not explicitly required in CVC 34505, recording exact tread depth values would be voluntary, regardless of what inspection form a carrier uses. In the long run, to ensure that carriers record the measured tread depth values of the inspected tires, CVC 34505 should be revised as well. Therefore, the NTSB also recommends that the state of California revise state law to require that passenger-carrying motor carriers document the tread depths of tires on their vehicles during any required, periodic vehicle inspection.

2.3 Occupant Protection

Crashes with ejections are especially dangerous because 75 percent of ejected vehicle occupants sustain fatal injuries in those crashes (NHTSA 2009). For a full ejection to take place, two crash conditions are necessary: (1) an opening must be created in a vehicle and (2) a vehicle occupant must be unbelted. Both conditions were present in this crash.[67] This crash highlighted the consequences of lack of restraint use and of structural deficiencies in buses during rollover events, particularly the increased risk of ejection for unbelted occupants. The next two sections discuss how adequate roof strength and the use of seat belts can protect occupants during a crash.

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[67] In certain crash circumstances, a belted passenger may be partially or even fully ejected if their seat becomes detached.

2.3.1 Roof Strength Standards

2.3.1.1 Events of This Crash. The bus sustained significant damage during the rollover event, which included the bus rolling 1.5 times and coming to rest on its roof. The roof structure was severely deformed and skewed rightward, away from the driver's side. The interior height of the bus, at the point of maximum deformation at the front, between rows 2 and 3, was reduced by 30 inches. The roof deformation resulted in intrusion into the passenger seating space as well as exposure to the exterior environment. Further, the structural components that supported the roof also supported the window frames. As the integrity of the roof structures collapsed, the window frames lost the capacity to hold the window glazing in place. As a result, the glazing from all but two windows was lost. Five unbelted passengers were ejected through the empty window frames; two died and two sustained serious injuries. The NTSB concludes that the failure of the bus roof's structural integrity caused intrusion into the occupant space and the loss of nearly all window glazing, creating openings in the bus's roof and sides, which allowed five unbelted passengers to be ejected.

To be crashworthy, a vehicle must be able to maintain structural integrity and survival space to protect its occupants. Some aspects of vehicle crashworthiness, such as the capacity to maintain roof structural integrity, are mandated through the *Federal Motor Vehicle Safety Standards* (*FMVSSs*). At the time of the crash, FMVSS 216 established crashworthiness requirements for roof strength to "reduce deaths and injuries due to the crushing of the roof into the occupant compartment in rollover crashes." However, the application of the crashworthiness requirements varies across vehicle types. Specifically, FMVSS 216 applies to passenger cars and multipurpose passenger vehicles, trucks, and buses with GVWRs of 10,000 pounds or less.[68] At the time of the Pala Mesa crash, no other requirements for maintaining structural integrity during rollover crashes applied to buses such as the one involved in this crash.

2.3.1.2 History. The NTSB has been concerned about ensuring roof structural integrity in buses for more than 20 years. In a 1999 safety study investigating the crashworthiness of buses, the NTSB issued two recommendations to NHTSA to develop a performance standard for roof strength in motorcoaches, and then require manufacturers to meet those standards (NTSB 1999).[69] Ten years later, NHTSA had not acted on those recommendations when a 2009 crash occurred in Dolan Springs, Arizona, in which a bus departed the roadway onto a median, starting a rollover

[68] (a) FMVSS 216 and FMVSS 216a provide slightly different roof strength requirements, depending on a vehicle's weight. (b) FMVSS 220 establishes performance requirements for school bus rollover protection.

[69] For additional information, see the NTSB special investigation report on Bus Crashworthiness Issues. The two recommendations pertaining to the development of performance standards for roof strength in motorcoaches were H-99-50 and -51.

sequence that resulted in the ejection of 15 of 17 bus passengers (NTSB 2010).[70] As a result of the Dolan Springs investigation, the NTSB issued Safety Recommendation H-10-3, recommending that NHTSA include all buses with GVWRs above 10,000 pounds in rulemaking on roof strength, occupant protection, and window glazing standards.[71] When this recommendation was issued, NHTSA was in the early stages of promulgating rulemaking to improve the safety of motorcoaches, including roof strength, occupant protection, and window glazing.

NHTSA continued its rulemaking process and, in 2014, the agency published a notice of proposed rulemaking (NPRM) regarding enhanced rollover structural integrity for all new over-the-road buses and other buses with GVWRs greater than 26,000 pounds.[72] The NTSB supported this proposal but also argued for the inclusion of buses with GVWRs below 26,001 pounds.[73]

The NTSB has continued to investigate bus rollover crashes involving loss of structural integrity. As a result of an investigation of a bus rollover crash near Bryce Canyon City, Utah, in 2019 (NTSB 2021), the NTSB issued the following recommendation to NHTSA:[74]

> Require all newly manufactured buses, other than school buses, with gross vehicle weight ratings above 10,000 pounds to meet a roof strength standard that provides maximum survival space for all seating positions and accounts for typical window dimensions. (H-21-2)

Safety Recommendation H-21-2 superseded several earlier recommendations, including the two issued in the 1999 safety study (H-99-50 and -51) and Safety Recommendation H-10-3, issued as a result of the Dolan Springs investigation. When Safety Recommendation H-21-2 was issued on June 3, 2021, it was classified "Open—Unacceptable Response." In August 2021, NHTSA provided its initial response to Safety Recommendation H-21-2, stating that it expected to publish a final rule by December 2021.

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[70] For additional details, see the NTSB Dolan Springs, AZ, report. The Dolan Springs bus had a GVWR of 19,500 pounds.

[71] See Safety Recommendation H-10-3, which was issued in the Dolan Springs report.

[72] (a) See "Bus Rollover Structural Integrity, Motorcoach Safety Plan," proposed rule, August 6, 2014 (79 *Federal Register* 46090, docket no. NHTSA-2014-0085). (b) The term *over-the-road* bus refers to a bus characterized by an elevated passenger deck located over a baggage compartment. See section 3038(a)(3) of the Transportation Equity Act for the 21st Century, cited in section 32702(6) of Subtitle G, Motorcoach Enhanced Safety Act.

[73] For additional details, see the October 2, 2014, NTSB response to this NPRM, accessed April 18, 2022.

[74] For additional details, see the Bryce Canyon City, UT, report.

On December 29, 2021, NHTSA issued a final rule on rollover structural integrity for motorcoaches.[75] The final rule established FMVSS 227, which sets requirements for maintaining structural integrity during rollover crashes for all new over-the-road buses and buses with GVWRs over 26,000 pounds. Because the Pala Mesa crash-involved bus had a GVWR of 29,000 pounds, a new bus of this type, manufactured after the effective date of the rule (December 30, 2024), would be required to meet FMVSS 227.[76]

The Pala Mesa investigation again shows the importance of adequate roof strength in protecting bus occupants during a rollover. As discussed above, the NTSB continues to investigate rollover crashes in which the structural integrity of a bus's roof is severely compromised, leading to injuries. Although the newly established standard would apply to new over-the-road buses (or motorcoaches) and other buses with GVWRs above 26,000 pounds, many other buses are not addressed by the requirements. Until NHTSA establishes a minimum performance standard for maintaining roof structural integrity during rollover crashes for all buses with GVWRs above 10,000 pounds, buses without adequate roof strength will continue to be manufactured, and avoidable fatalities and injuries from rollover crashes will continue to occur. The NTSB concludes that the failure to include buses with GVWRs below 26,001 pounds in the new roof strength standard excludes passengers of buses below the GVWR threshold from the safety benefits provided by the standard. Therefore, the NTSB reiterates Safety Recommendation H-21-2 to NHTSA.

2.3.2 Seat Belt Use

2.3.2.1 Events of This Crash. The crash-involved bus was equipped with lap/shoulder belts in all seating positions. Still, only 1 of the 20 passengers was known to be properly belted; she received minor injuries. The five passengers who were ejected during the crash sequence did not use their restraints. A NHTSA study examining motorcoach rollover crash dynamics using lap/shoulder-belted and -unbelted crash test dummies showed that the belted dummies exhibited a greater level of injury mitigation and were considerably more likely to remain restrained and within the passenger compartment during the rollover event (NHTSA 1999). In another study, NHTSA argued that equipping large buses with lap/shoulder belts would reduce the risk of fatal injuries in rollover crashes by 77 percent, assuming the belts were used (NHTSA 2000).

[75] See final rule, Motorcoach Rollover Structural Integrity, accessed April 18, 2022.

[76] The final rule notes that (optional) early compliance is permitted.

Two of the passengers who died were ejected during the rollover event; they were not belted. The third passenger who died was not ejected, but she was not properly belted and was displaced from her seat. The NTSB concludes that, had the bus passengers properly worn the available lap/shoulder belts, they would have been more likely to stay in their seating compartments, which would have prevented ejection and reduced the risk of fatal and serious injuries.

2.3.2.2 History. The NTSB has been advocating for seat belts on buses for more than half a century, issuing its first recommendation in 1968.[77] Through rulemaking initiated in 2013, NHTSA required—effective November 28, 2016—lap/shoulder belts for all seating positions on buses meeting the definition of "motorcoach" or "over-the-road bus," regardless of the vehicle's GVWR, and for all buses with GVWRs over 26,000 pounds.[78] The NTSB expressed support for this rulemaking but recommended that NHTSA include other buses not covered by the mandate.[79] Despite not being required at the time of its manufacture, the bus involved in this crash was equipped with lap/shoulder belts at all seating positions.

Postcrash examination of the bus interior showed that several unbelted passengers had been thrown into other seats and into the ceiling area, video display units, and luggage bins. When interviewed by NTSB investigators, several passengers reported having been unaware that the bus was equipped with lap/shoulder belts at all passenger seats.

Although lap/shoulder belts are very effective in improving occupant survivability during crashes, they provide a safety benefit only when used. Consequently, the NTSB has supported and promoted efforts to increase the use of seat belts in all vehicles equipped with them, particularly buses. We have focused on two primary recommendation areas: (1) enacting legislation to require the use of seat belts in all vehicles and (2) requiring carriers to provide pretrip safety briefings that inform passengers about proper seat belt use and emergency evacuation.

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[77] In a 1968 report about a rollover crash in Baker, California (NTSB 1968), the NTSB recommended expediting a process to require seat belts on commercial motor carriers (Safety Recommendation H-68-18).

[78] (a) The NHTSA mandate (see Federal Motor Vehicle Safety Standards; Occupant Crash Protection," at 78 *Federal Register* 70416), amended FMVSS 208. The mandate came into effect in November 2016 for motorcoaches and in November 2017 for multistage buses. (b) According to the final rule, the requirement includes all large buses with GVWRs above 26,000 pounds, but it excludes school buses, transit buses, and prison buses.

[79] To address the critical deficiencies in the new mandate, the NTSB recommended that NHTSA amend FMVSS 208 to include all new buses with GVWRs between 10,000 pounds and 26,000 pounds. (See Safety Recommendation H-18-59, issued in the Concan, Texas, report [NTSB 2018]).

For more than 30 years, since 1991, the NTSB has been recommending that states enact legislation to require the use of seat belts in passenger vehicles (cars and light trucks).[80] Following the investigation of a 2014 crash in Davis, Oklahoma, involving a medium-size bus (NTSB 2015), the NTSB focused on seat belt use in all vehicles, issuing the following recommendation to all 50 states, the District of Columbia, and Puerto Rico:[81]

> Enact legislation that provides for primary enforcement of a mandatory seat belt use law for all vehicle seating positions equipped with a passenger restraint system. (H-15-42)[82]

In October 2017, California adopted legislation—Senate Bill No. 20 (SB-20)—that provides for primary enforcement of a requirement that bus drivers and passengers use seat belts in buses that are equipped with them.[83] As a result, the NTSB classified Safety Recommendation H-15-42 to California as "Closed—Acceptable Action."

SB-20 also included a requirement to inform vehicle passengers about California's seat belt use law. With an effective date of July 1, 2018—as described in *CVC* 27318—passenger-carrying motor carriers operating a bus equipped with seat belts are required to take, at a minimum, one of the following actions:

> (1) Require the bus driver, before departure of a bus carrying passengers, to inform passengers of the requirement to wear the seatbelt under California law and inform passengers that not wearing a seatbelt is punishable by a fine.
>
> (2) Post, or allow to be posted, signs or placards that inform passengers of the requirement to wear a seatbelt under California law and that not wearing a seatbelt is punishable by a fine. The signs or placards shall be

[80] In 1991, the NTSB issued a recommendation (H-91-13) to 12 states that, at that time, did not have seat belt use laws, to mandate seat belt use in all passenger vehicles regardless of seating position. This recommendation was associated with the NTSB's 1988 safety study concerning the performance of lap/shoulder belts in 167 crashes (NTSB 1988).

[81] For additional details, see the NTSB Davis, OK, report.

[82] Safety Recommendation H-15-42 superseded a recommendation issued in 1997 (Safety Recommendation H-97-2).

[83] (a) *Primary enforcement* use laws for seat belts allow enforcement officers to ticket a driver/vehicle occupant for not wearing a seat belt without the driver having committed any other traffic offense. Secondary enforcement use laws allow enforcement officers to ticket a driver or vehicle occupant for not wearing a seat belt only after stopping the vehicle for another offense. (b) Senate Bill No. 20 Chapter 593 is an act that amended sections 12810.2 and 34505.8 and added sections 27318 and 27319 to the *CVC* (accessed April 18, 2022).

in a font type and font size that is reasonably easy to read and shall be affixed to a bus in multiple, conspicuous locations.

SB-20 also mandated that charter motor carriers provide pretrip safety briefings when operating a bus carrying at least 39 passengers.[84] The crash bus had only 30 passenger seats, so this specific mandate did not apply to it. (The separate SB-20 requirement to inform passengers about California's seat belt use law did apply to the crash bus.) Safety briefings are required to describe the safety equipment on the bus and the location and operation of emergency exits.

The NTSB supports the California mandatory seat belt use law, including the requirement that carriers inform bus passengers of that mandate. The NTSB also supports the requirement for conducting pretrip safety briefings, even if limited to charter buses carrying at least 39 passengers. Such safety briefings are not required by federal regulation, although the NTSB has been recommending them since 1999.[85] Although the FMCSA has failed to implement these recommendations, it has developed free and ready-to-use multilingual versions of pretrip safety briefings, both in video and audio formats. The bus involved in this crash was equipped with a video display entertainment system, which could have been used to play the basic message informing the passengers of the California seat belt use law or even a full pretrip safety briefing.

The crash bus driver did not provide a pretrip safety briefing or otherwise inform the passengers of the availability of lap/shoulder belts on the bus or of the California seat belt use law, and the bus did not contain any signs or placards informing passengers of that mandate. Moreover, the carrier did not have a policy on pretrip safety briefings, and the owner told the NTSB that he was unaware of the California seat belt use law or of the requirements to provide seat belt briefings and/or signage informing passengers of the law. The NTSB concludes that, had the motor carrier followed state law and (1) required the bus driver to provide a briefing to the passengers informing them of the availability of the lap/shoulder belts and of California's mandatory seat belt use law, or (2) posted signs in the bus explaining the seat belt use mandate, it would have increased the likelihood of passengers being properly belted when the crash occurred.

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[84] See *CVC* 34505.8 for complete requirements.

[85] The NTSB issued its first recommendation pertaining to mandatory pretrip safety briefings in 1999 (H-99-8). More recently, in 2015, the NTSB superseded Safety Recommendation H-99-8 with an expanded version, Safety Recommendation H-15-14. The FMCSA told the NTSB that it encourages motor carriers to voluntarily provide pretrip safety briefings but would not mandate that carriers provide the safety briefing. Due to the FMCSA decision not to implement the recommended action, the NTSB classified Safety Recommendation H-15-14 "Closed—Unacceptable Action."

In summary, the bus involved in this crash was equipped with lap/shoulder belts at all seating positions. The state in which this crash occurred—California—had a mandatory seat belt use law with primary enforcement applicable to all vehicles and all seating positions. California also required passenger-carrying motor carriers to inform the passengers of the state law and to include on their buses signs reminding passengers of that mandate. Yet, despite all these requirements, only one passenger on the crash bus was properly belted. The motor carrier's owner claimed to be unaware of California seat belt-related laws.

Ignorance of the California laws does not excuse a carrier from adhering to them. A responsible carrier should know and follow all the laws affecting its business, especially those concerning safety. Lack of seat belt use was a major factor in the severity of passenger injuries in this crash, and the NTSB is concerned that some passenger-carrying motor carriers operating in California could be unaware of the mandates. Although Executive Lines is no longer in the business of transporting passengers, as of December 2021, more than 4,200 passenger-carrying motor carriers were operating in California. During the CHP's regular terminal inspections, which occur at 13-month intervals, inspectors do not verify whether a carrier fulfills California's requirements to provide briefings to passengers on seat belts nor do they check for signage on buses informing passengers of the mandatory seat belt use law. Also, the CHP does not have any outreach efforts to inform carriers of the state's laws pertaining to seat belt use and the carriers' responsibilities under the laws.

The NTSB concludes that increasing motor carriers' compliance with California's mandatory seat belt use law would likely increase proper seat belt use by vehicle occupants, which would reduce injuries and save lives in the event of a crash. The NTSB recommends that the CHP develop and implement an education program to increase passenger-carrying motor carriers' awareness of the requirements in *CVC* 27318 for providing pretrip safety briefings and/or signage in buses informing passengers of the mandatory seat belt use law. Additionally, the NTSB recommends that the CHP, as part of regular terminal inspections of passenger-carrying motor carriers, verify carriers' adherence to the requirements in *CVC* 27318 for providing pretrip briefings and/or signage in buses informing passengers of the mandatory seat belt use law. Further, the NTSB recommends that the ABA and the UMA inform their members who operate in California of the requirements in *CVC* 27318 for providing pretrip safety briefings and/or signage in buses informing passengers of the mandatory seat belt use law.

3 Conclusions

3.1 Findings

1. None of the following were factors in the crash: (1) the licensing or driving experience of the bus driver; (2) cell phone use, use of alcohol or other drugs, or fatigue; (3) the non-tire-related mechanical condition of the bus; and (4) highway design.
2. The emergency response to the crash was timely and adequate.
3. Had the bus been equipped with an electronic stability control system—which was not required equipment at the time of its manufacture—the system would have assisted the driver in maintaining control, which could have prevented the crash.
4. The roadway in the area where the bus initially lost control provided a sufficient level of friction; therefore, it is unlikely that the bus driver lost control due to poor roadway friction.
5. The loss of vehicle control was due to the combined effects of the low and substandard tread depth of the rear axle tires, the excessive speed for the wet roadway and vehicle conditions, and the driver's inappropriate inputs before and during the loss of control event.
6. Drivers responsible for commercial vehicles that transport passengers would benefit from their motor carrier implementing a driver training program that, at a minimum, includes consistent and authoritative guidance on driving at safe speeds on wet roadways and in other inclement weather conditions.
7. Based on currently available research, minimum tire tread depth requirements may be insufficient to ensure adequate traction for commercial vehicles, particularly passenger-carrying vehicles, such as buses.
8. Executive Lines Inc.'s deficiencies in tire replacement and rotation procedures allowed the bus to operate in service with tires that had less than the required tread depths, which contributed to the crash.
9. The practice used by Executive Lines Inc. and some other motor carriers of replacing tires on the rear axle with used tires from the steer axle and placing new tires on the steer axle can result in non-uniform tread depths between the front and rear tires, leading to a loss of traction, as evidenced by this crash.

10. Safety can be enhanced by requiring motor carriers to record the tread depths of the tires on buses in California because it would provide a reminder to maintenance staff about the wear status of the tires.

11. The failure of the bus roof's structural integrity caused intrusion into the occupant space and the loss of nearly all window glazing, creating openings in the bus's roof and sides, which allowed five unbelted passengers to be ejected.

12. The failure to include buses with gross vehicle weight ratings (GVWRs) below 26,001 pounds in the new roof strength standard excludes passengers of buses below the GVWR threshold from the safety benefits provided by the standard.

13. Had the bus passengers properly worn the available lap/shoulder belts, they would have been more likely to stay in their seating compartments, which would have prevented ejection and reduced the risk of fatal and serious injuries.

14. Had the motor carrier followed state law and (1) required the bus driver to provide a briefing to the passengers informing them of the availability of the lap/shoulder belts and of California's mandatory seat belt use law, or (2) posted signs in the bus explaining the seat belt use mandate, it would have increased the likelihood of passengers being properly belted when the crash occurred.

15. Increasing motor carriers' compliance with California's mandatory seat belt use law would likely increase proper seat belt use by vehicle occupants, which would reduce injuries and save lives in the event of a crash.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the Pala Mesa, California, bus crash was the loss of vehicle control due to the combination of the low and substandard tread depth of the rear axle tires, the excessive speed for the wet roadway and vehicle conditions, and the driver's inappropriate inputs before and during the loss of control event. Contributing to the crash was Executive Lines Inc.'s inadequate vehicle inspection process, which permitted the bus to operate in passenger service despite having two tires with treads below the minimum required depth. Contributing to the severity of the injuries were the National Highway Traffic Safety Administration's failure to require roof strength standards for buses, Executive Lines Inc.'s failure to follow California's requirement to inform passengers about the state's mandatory seat belt use law, and the passengers' limited use of the available lap/shoulder belts.

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 National Highway Traffic Safety Administration:

Sponsor research to determine the appropriate minimum tire tread depths necessary for the safe operation of commercial vehicles, particularly passenger-carrying vehicles. The research should include the effect on vehicle handling when different tread depths are used for tires on the steer versus the rear axles. (H-22-12)

Revise 49 *Code of Federal Regulations* 570.62 based on the outcome of the research described in Safety Recommendation H-22-12. (H-22-13)

To the Federal Motor Carrier Safety Administration:

Revise 49 *Code of Federal Regulations* 393.75 based on the outcome of the research described in Safety Recommendation H-22-12. (H-22-14)

To the state of California:

Revise state law to require that passenger-carrying motor carriers document the tread depths of tires on their vehicles during any required, periodic vehicle inspection. (H-22-15)

To the California Highway Patrol:

Revise California Highway Patrol Form 108A to include the measured tire tread depths of all tires on buses. (H-22-16)

Develop and implement an education program to increase passenger-carrying motor carriers' awareness of the requirements in *California Vehicle Code* 27318 for providing pretrip safety briefings and/or signage in buses informing passengers of the mandatory seat belt use law. (H-22-17)

As part of regular terminal inspections of passenger-carrying motor carriers, verify carriers' adherence to the requirements in *California Vehicle Code* 27318 for providing pretrip briefings and/or signage in

> buses informing passengers of the mandatory seat belt use law. (H-22-18)

To the American Bus Association and the United Motorcoach Association:

> Inform your members about the circumstances of the Pala Mesa, California, bus crash and encourage them to create a policy on speed and safe driving on wet roadways and under inclement weather conditions based on authoritative guidance, such as the Federal Motor Carrier Safety Administration's safe driving tips for commercial motor vehicle drivers or information provided in state commercial driver's handbooks. (H-22-19)

> Encourage your members to adopt the recommended tire rotation practices established by the U.S. Tire Manufacturers Association. (H-22-20)

> Inform your members who operate in California of the requirements in *California Vehicle Code* 27318 for providing pretrip safety briefings and/or signage in buses informing passengers of the mandatory seat belt use law. (H-22-21)

4.2 Previously Issued Recommendation Reiterated in this Report

The National Transportation Safety Board reiterates the following safety recommendation.

To the National Highway Traffic Safety Administration:

> Require all newly manufactured buses, other than school buses, with gross vehicle weight ratings above 10,000 pounds to meet a roof strength standard that provides maximum survival space for all seating positions and accounts for typical window dimensions. (H-21-2)

> This recommendation is reiterated in section 2.3.1 of this report.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JENNIFER HOMENDY
Chair

BRUCE LANDSBERG
Vice Chairman

MICHAEL GRAHAM
Member

THOMAS CHAPMAN
Member

Report Date: April 19, 2022

Appendix A: Investigation

The National Transportation Safety Board (NTSB) received notification of the Pala Mesa, California, crash on February 22, 2020, and dispatched a limited investigative team to the site. The NTSB established groups to investigate highway, survival, and vehicle factors; motor carrier operations; and human performance.

The Federal Motor Carrier Safety Administration, the California Department of Transportation, and the California Highway Patrol were parties to the investigation.

Appendix B: Consolidated Recommendation Information

Title 49 *United States Code* (USC) 1117(b) requires the following information on the recommendations in this report.

For each recommendation–

(1) a brief summary of the NTSB's collection and analysis of the specific accident investigation information most relevant to the recommendation;

(2) a description of the NTSB's use of external information, including studies, reports, and experts, other than the findings of a specific accident investigation, if any were used to inform or support the recommendation, including a brief summary of the specific safety benefits and other effects identified by each study, report, or expert; and

(3) a brief summary of any examples of actions taken by regulated entities before the publication of the safety recommendation, to the extent such actions are known to the Board, that were consistent with the recommendation.

To the National Highway Traffic Safety Administration:

H-22-12

Sponsor research to determine the appropriate minimum tire tread depths necessary for the safe operation of commercial vehicles, particularly passenger-carrying vehicles. The research should include the effect on vehicle handling when different tread depths are used for tires on the steer versus the rear axles.

Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.2.4.2, Adequacy of Tire Tread Depth Standard for Commercial Vehicles. Information supporting (b)(1) and (b)(2) can be found on pages 37–38; (b)(3) is not applicable.

H-22-13

Revise 49 *Code of Federal Regulations* 570.62 based on the outcome of the research described in Safety Recommendation H-22-12.

Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.2.4.2, Adequacy of Tire Tread Depth Standard for Commercial Vehicles. Information supporting (b)(1) and(b)(2) can be found on pages 37–38; (b)(3) is not applicable.

To the Federal Motor Carrier Safety Administration:

H-22-14

Revise 49 *Code of Federal Regulations* 393.75 based on the outcome of the research described in Safety Recommendation H-22-12.

Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.2.4.2, Adequacy of Tire Tread Depth Standard for Commercial Vehicles. Information supporting (b)(1) and (b)(2) can be found on pages 37–38; (b)(3) is not applicable.

To the state of California:

H-22-15

Revise state law to require that passenger-carrying motor carriers document the tread depths of tires on their vehicles during any required, periodic vehicle inspection.

Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.2.4.3, Maintaining Safe Tire Tread Depths on Commercial Vehicles. Information supporting (b)(1) and (b)(2) can be found on pages 38–41; (b)(3) is not applicable.

To the California Highway Patrol:

H-22-16

Revise California Highway Patrol Form 108A to include the measured tire tread depths of all tires on buses.

Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.2.4.3, Maintaining Safe Tire Tread Depths on Commercial Vehicles. Information supporting (b)(1) and (b)(2) can be found on pages 38–41; (b)(3) is not applicable.

H-22-17

> Develop and implement an education program to increase passenger-carrying motor carriers' awareness of the requirements in *California Vehicle Code* 27318 for providing pretrip safety briefings and/or signage in buses informing passengers of the mandatory seat belt use law.

Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.3.2, Seat Belt Use. Information supporting (b)(1) and (b)(2) can be found on pages 44–48; (b)(3) is not applicable.

H-22-18

> As part of regular terminal inspections of passenger-carrying motor carriers, verify carriers' adherence to the requirements in *California Vehicle Code* 27318 for providing pretrip briefings and/or signage in buses informing passengers of the mandatory seat belt use law.

Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.3.2, Seat Belt Use. Information supporting (b)(1) and (b)(2) can be found on pages 44–48; (b)(3) is not applicable.

To the American Bus Association and the United Motorcoach Association:

H-22-19

> Inform your members about the circumstances of the Pala Mesa, California, bus crash and encourage them to create a policy on speed and safe driving on wet roadways and under inclement weather conditions based on authoritative guidance, such as the Federal Motor Carrier Safety Administration's safe driving tips for commercial motor vehicle drivers or information provided in state commercial driver's handbooks.

Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.2.4.1, Driving at Safer Speeds on Wet Roadways. Information supporting (b)(1) and (b)(2) can be found on pages 35–36; (b)(3) is not applicable.

H-22-20

> Encourage your members to adopt the recommended tire rotation practices established by the U.S. Tire Manufacturers Association.

Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.2.4.3, Maintaining Safe Tire Tread Depths on

Commercial Vehicles. Information supporting (b)(1) and (b)(2) can be found on pages 38–41; (b)(3) is not applicable.

H-22-21

> Inform your members who operate in California of the requirements in *California Vehicle Code* 27318 for providing pretrip safety briefings and/or signage in buses informing passengers of the mandatory seat belt use law.

Information that addresses the requirements of 49 USC 11179(b), as applicable, can be found in section 2.3.2, Seat Belt Use. Information supporting (b)(1) and (b)(2) can be found on pages 44–48; (b)(3) is not applicable.

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For more detailed background information on this report, visit the NTSB investigations website and search for NTSB accident ID HWY20FH003. Recent publications are available in their entirety on the NTSB website. Other information about available publications also may be obtained from the website or by contacting–

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