AVIATION HIGHWAY MARINE RAILROAD PIPELINE

February 27, 2023 Highway Investigation Report HIR-23-01

Multivehicle Crash in Icy Conditions on Interstate 35 West

Fort Worth, Texas
February 11, 2021

Abstract: On the morning of Thursday, February 11, 2021, a multivehicle crash occurred in the southbound toll lanes of Interstate 35 West (I-35W), in Fort Worth, Tarrant County, Texas. The crash sequence began on an elevated portion of the roadway near the exit to Northside Drive and ultimately involved 130 vehicles. In the days before the crash, the area had experienced 36 consecutive hours of below-freezing temperatures. In anticipation of forecast freezing rain and sleet, North Tarrant Express Mobility Partners Segments 3 (NTEMP S3), which was responsible for operations and maintenance on the I-35W right of way at this location, pretreated the traffic lanes with a liquid brine solution. NTEMP S3 applied the solution to the two southbound toll lanes about 44 hours before the multivehicle collision occurred. The crash event began about 6:00 a.m. on February 11, when several vehicles in the southbound toll lanes slid on the elevated roadway and struck the concrete barriers beside the toll lanes. As approaching drivers encountered the vehicles involved in these initial crashes, they were unable to stop on the icy roadway, leading to secondary crashes. As a result of the crash event, six people were fatally injured. Four of the fatally injured people remained inside their vehicles; two were struck on the roadway after they had exited their vehicles. The report discusses the following safety issues: inadequate methods to monitor the condition of the roadway and elevated structures during inclement weather, insufficient training for personnel responsible for snow and ice control on how to monitor moisture and icy conditions and when to apply suitable roadway treatments, and the need for technological countermeasures to help drivers and vehicles respond appropriately to inclement weather conditions. The NTSB issued new recommendations to the state of Texas and reiterated recommendations to the US Department of Transportation, the National Highway Traffic Safety Administration, the Federal Communications Commission, and the state of Texas.

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ESS	environmental sensor station
FHWA	Federal Highway Administration
GPS	global positioning system
I-35W	Interstate 35 West
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTEMP S3	North Tarrant Express Mobility Partners Segments 3
NTSB	National Transportation Safety Board
NWS	National Weather Service
RWIS	road weather information system
TxDOT	Texas Department of Transportation
USDOT	US Department of Transportation
V2X	vehicle-to-everything

Executive Summary

What Happened

On Thursday, February 11, 2021, about 6:00 a.m. central standard time, a multivehicle crash occurred in the southbound toll lanes of Interstate 35 West (I-35W), in Fort Worth, Tarrant County, Texas. The crash sequence began on an elevated portion of the roadway near the exit to Northside Drive and ultimately involved 130 vehicles. The posted speed limit on the I-35W toll lanes was 75 mph.

In the days before the crash, the area had experienced 36 consecutive hours of below-freezing temperatures. In anticipation of forecast freezing rain and sleet, North Tarrant Express Mobility Partners Segments 3 (NTEMP S3), which was responsible for operations and maintenance on the I-35W right of way at this location, pretreated the traffic lanes with a liquid brine solution. NTEMP S3 applied the solution to the two southbound toll lanes about 44 hours before the multivehicle collision occurred. On the morning of February 11, the first measurable precipitation occurred between 1:34 and 2:10 a.m.; light mist and fog were reported from 2:53 to 4:53 a.m. Before the crash, dynamic message signs managed by NTEMP S3 along the southbound toll lanes were displaying the following message to drivers: "ICY CONDITIONS EXIST/PLEASE USE CAUTION."

The crash event began about 6:00 a.m., when several vehicles in the southbound toll lanes slid on the elevated roadway and struck the concrete barriers beside the toll lanes. As approaching drivers encountered the vehicles involved in these initial crashes, they were unable to stop on the icy roadway, leading to secondary crashes. As a result of the crash event, six people were fatally injured. Four of the fatally injured people remained inside their vehicles; two were struck on the roadway after they had exited their vehicles.

What We Found

The National Transportation Safety Board (NTSB) undertook this focused investigation to examine the inclement weather road maintenance performed before the crash on the toll lanes of I-35W. During the investigation, we also identified the need for technological measures to help drivers and vehicles respond appropriately to inclement weather conditions.

We found that the surface of the elevated roadway in the area of the crash was icy, which made drivers lose control of their vehicles, which then slid into road barriers and other vehicles. Although NTEMP S3's pretreatment of the roadway before the storm was reasonable, its roadway monitoring process was deficient because it failed to detect that the elevated portion of I-35W required additional deicing treatment on the morning of the crash when precipitation arrived in the area. If environmental sensor stations had been installed near the crash location, NTEMP S3 would have had additional data at its disposal, which might have helped it to detect that the location needed additional deicing treatments before the crash. Greater deployment and use of environmental sensor stations, used widely nationwide, would enable more efficient detection and monitoring of roadway conditions, as well as better responses to environmental events, likely reducing crashes and injuries during inclement weather.

We also found that the training that NTEMP S3 provided its employees was insufficient to prepare them to monitor roadway conditions effectively during winter weather events. Coordination between the Texas Department of Transportation (TxDOT) and contracted entities, such as NTEMP S3, on best practices for training employees responsible for snow and ice control would help ensure consistent use of effective procedures by all entities responsible for treating the roadway during inclement weather.

Finally, we found that, had drivers been traveling slower, they would have had more time to react and possibly avoid the crashed vehicles ahead. Reduced speeds would also have lessened the severity of the crashes once the vehicles began to slide on the icy road. Had technologies such as variable speed limit signs and speed safety cameras been used, drivers might have been more likely to slow to a speed appropriate for the conditions. In addition, connected vehicle technology, if installed on at least some of the vehicles involved in the crash, could have provided information about the stopped vehicles in the roadway once the crashes began to occur, so that approaching drivers might have been alerted to the imminent hazard and might have avoided or mitigated secondary crashes.

The NTSB determined that the probable cause of the multivehicle crash in Fort Worth, Texas, was ice accumulation on the surface of the elevated roadway, which made drivers lose control of their vehicles, which then slid into road barriers and other vehicles. Contributing to the unsafe roadway condition was the failure of North Tarrant Express Mobility Partners Segments 3 to effectively monitor and address roadway conditions along Interstate 35 West during and after periods of freezing rain and mist. Contributing to the severity of the crash outcome was drivers traveling at speeds too fast for the winter weather conditions.

What We Recommended

As a result of this investigation, the NTSB issued three new recommendations to the state of Texas and reiterated five recommendations. We issued a recommendation to the state of Texas to implement a statewide plan to install environmental sensor stations in priority locations to enable timely response to hazardous road conditions during inclement weather. We also issued a recommendation to the state of Texas to provide a comprehensive winter weather training program to private and state-regulated toll facilities so that they can train their employees using the program. Finally, we issued a recommendation to the state of Texas to enact legislation to allow TxDOT to install variable speed limit signs on Texas roadways.

We reiterated Safety Recommendation H-22-1 to the US Department of Transportation to implement a nationwide deployment plan for connected vehicle technology that resolves issues related to interference, ensures sufficient spectrum, and defines the communication protocols to be used. We reiterated Safety Recommendations H-13-30 and -31 to the National Highway Traffic Safety Administration to develop minimum performance standards for connected vehicle technology and require use of this technology. We reiterated Safety Recommendation H-22-6 to the Federal Communications Commission to implement appropriate safeguards to protect vehicle-to-everything communications from harmful interference. Finally, we reiterated Safety Recommendation H-17-31 to the state of Texas to amend current laws to authorize state and local agencies to use automated speed enforcement.

1. Factual Information

On Thursday, February 11, 2021, a multivehicle crash occurred near milepost 53.5 in the southbound toll lanes of Interstate 35 West (I-35W), in Fort Worth, Tarrant County, Texas.[1] This National Transportation Safety Board (NTSB) investigation initially focused on the inclement weather road maintenance used before the crash.[2] During the investigation, the need for technological countermeasures to help drivers and vehicles respond appropriately to inclement weather conditions became apparent. The factual portion of the report concentrates on the crash, as well as the highway, weather, and road maintenance factors.

1.1 The Crash

1.1.1 Precrash Information

Before the crash, the Fort Worth area had experienced 36 consecutive hours of below-freezing temperatures. The National Weather Service (NWS) issued multiple weather advisories in the days before the crash, advising of the possibility of freezing rain and sleet, along with below-freezing temperatures. In anticipation of the forecast freezing rain and sleet, the I-35W traffic lanes were pretreated with a liquid brine solution. The solution was applied to the two southbound toll lanes in the area of the crash on February 9, 2021, at 10:12 a.m.[3]

On February 11, the first measurable precipitation occurred between 1:34 and 2:10 a.m. Light mist and fog were reported from 2:53 to 4:53 a.m.

At 3:40 a.m., seven dynamic message signs on and leading onto the I-35W southbound toll lanes near the crash location began displaying the message "ICY CONDITIONS EXIST/PLEASE USE CAUTION."[4]

[1] Visit ntsb.gov to find additional information in the public docket for this National Transportation Safety Board (NTSB) investigation (case number HWY21FH005). Use the CAROL Query to search safety recommendations and investigations.

[2] Due to safety protocols related to the COVID-19 pandemic, NTSB investigators did not travel to the scene at the time of the crash.

[3] Unless otherwise noted, all times are central standard time.

[4] The messages were provided following an earlier crash at another location in the northbound general use lanes.

1.1.2 Crash Narrative

In the crash area, I-35W is configured with toll lanes separated from general use lanes by concrete barriers along both sides of the travel lanes.[5] About 6:04 a.m., a vehicle in the southbound toll lanes slid on an elevated part of the roadway near the Northside Drive exit and struck the concrete barrier on the right side of the toll lanes.[6] Other vehicles in the southbound toll lanes also began to slide, spin, and strike the barriers. About 6:13 a.m., a combination vehicle in the southbound toll lanes collided with some of the disabled vehicles from the previous crashes that were blocking the lanes and came to a stop. Thereafter, additional vehicles in the southbound toll lanes slid and were unable to stop in time to avoid the vehicles blocking the lanes, leading to a complex, multivehicle crash event. As secondary crashes occurred, a queue of previously crashed vehicles formed, blocking all through-traffic on the southbound toll lanes, leading to additional crashes. As a result of the crash event, six people were fatally injured. Four of the six fatally injured remained inside their vehicles, and two were struck on the roadway after they had exited their vehicles. In total, the crash involved 130 vehicles and a 1,100-foot-long segment of roadway (figure 1).[7]

[5] The toll lanes are used by drivers who pay a premium through a toll tag account. It does not include high occupancy vehicles, and there are no toll booths. Vehicles are detected by overhead gantries located at periodic intervals; the gantries contain cameras that capture the license plates of vehicles. The speed limit for the toll lanes is higher than the speed limit for the general use lanes (75 mph compared to 65 mph).

[6] In the general use lanes, crashes occurred earlier. About 6:00 a.m., several minor crashes occurred in the southbound general use lanes, including a tractor-trailer that slid and struck a concrete barrier on the right side of the roadway. The focus of the NTSB investigation was the circumstances leading to the crashes and fatalities in the southbound toll lanes.

[7] Because of terminology differences, the number of involved vehicles derived by the NTSB differs from the number that appears in the police report on this crash. The Fort Worth Police Department documented the crash using the state's CR-3 crash report, which treats truck-tractor semitrailer combination vehicles as two traffic units—the power unit (the truck-tractor) and the towed unit (the semitrailer). The department's report states that 148 traffic units were involved in the crash, including 32 truck-tractor semitrailer combination units, 114 passenger vehicle units, and 2 units classified as pedestrians.

Figure 1. Overhead view of crash scene. (Source: Google Earth image adapted by NTSB.)

1.2 Highway

1.2.1 Management

In the I-35W crash location, roadway operations, maintenance, and weather treatment were managed by North Tarrant Express Mobility Partners Segments 3 (NTEMP S3), a private company contracted by the Texas Department of Transportation (TxDOT). NTEMP S3 has a public-private partnership agreement with TxDOT to develop and construct the I-35W right of way (also called the “facility”).[8] Per the facility agreement, NTEMP S3 is responsible for operations and maintenance

[8] The total project consists of three "segments"—3A, 3B, and 3C. Segment 3B was finished first, in 2017. Segment 3A (on which the crash occurred) opened partially in April 2018 and fully in July 2018. Segment 3C is still being constructed and is expected to open in 2023.

within the facility, which includes the toll lanes, the general use lanes, and the frontage roads. NTEMP S3's responsibilities included monitoring environmental conditions and treating the road surface for freezing precipitation, as well as providing dynamic messaging on highway signage.[9] NTEMP S3 has the right to collect tolls from toll lane users during the term of the agreement, which is to expire in 2061. In the Fort Worth District, NTEMP S3 maintained about 188 highway lane-miles, while TxDOT maintained about 9,000 highway lane-miles.[10]

1.2.2 History

The toll lanes on which the crash occurred partially opened to traffic in April 2018 and fully opened in July 2018. From July 2018 through December 2020, about 20,200 vehicles traveled daily on the southbound toll lanes. From July 2018 through December 2020, 1 fatal crash, 7 crashes resulting in injuries, and 35 non-injury crashes occurred in the southbound toll lanes near the crash site.[11]

1.2.3 Roadway

At the crash location, the southbound direction of the I-35W tollway consisted of two lanes that totaled about 24 feet wide (each lane was 12 feet wide), bordered by a left paved shoulder that was about 4 feet wide and a right paved shoulder that was about 10 feet wide. At the edge of the left and right shoulders were, respectively, a 42-inch-high and a 36-inch-high concrete barrier.[12] In the area of the crash, the concrete barriers along both sides of the travel lanes were continuous and not configured with any spacings or gaps allowing for vehicle or pedestrian passage, making the toll lanes a constrained right of way. (See figures 2 and 3.)

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[9] Although TxDOT had no direct control over NTEMP S3 maintenance actions, TxDOT and NTEMP S3 did communicate about the winter storm before the crash. Before the onset of the storm, TxDOT held an "all hands" conference call with the companies operating the toll facilities in the affected region (including NTEMP S3) to coordinate their responses. TxDOT later told the NTSB that the purpose of the meeting was to be "on the same page" with the response approach but not to tell the companies "what to do."

[10] Lane-miles are calculated by multiplying the centerline mileage of a road by the number of lanes it has. Lane mileage provides a total amount of mileage covered on a road network.

[11] The crashes occurred on I-35W between Meacham Boulevard and Interstate 30, a distance of about 5.3 miles.

[12] Both barriers conformed to *Manual for Assessing Safety Hardware* test levels capable of redirecting a 36,000-kilogram (or 79,300-pound) tractor-van trailer and a 10,000-kilogram (or 22,000-pound) single-unit truck (American Association of State Highway and Transportation Officials [AASHTO] 2011, pp. 5–2 and 5–12).

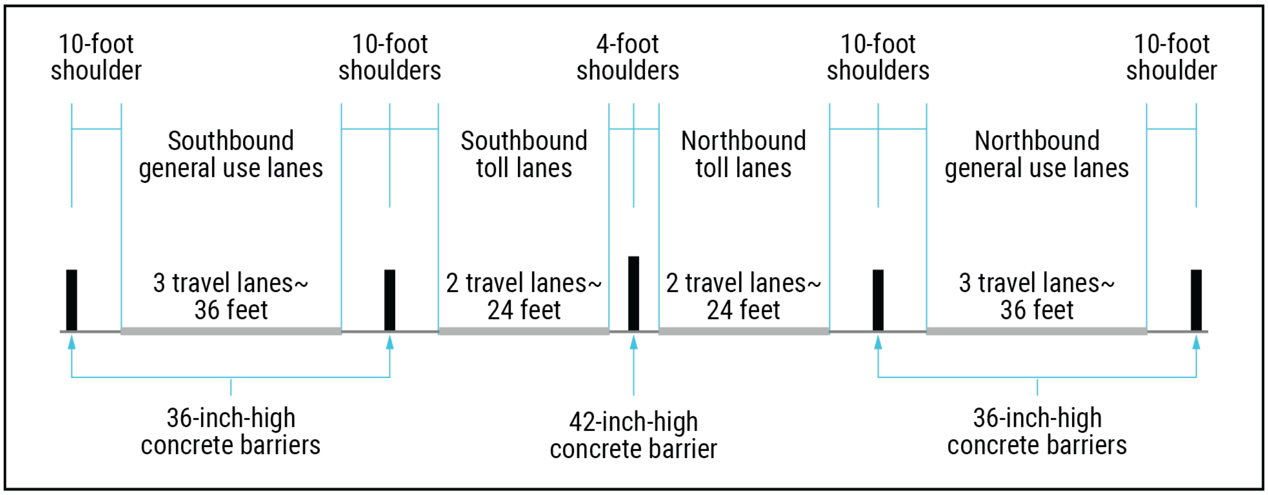

Figure 2. Configuration of north- and southbound travel lanes in crash area.

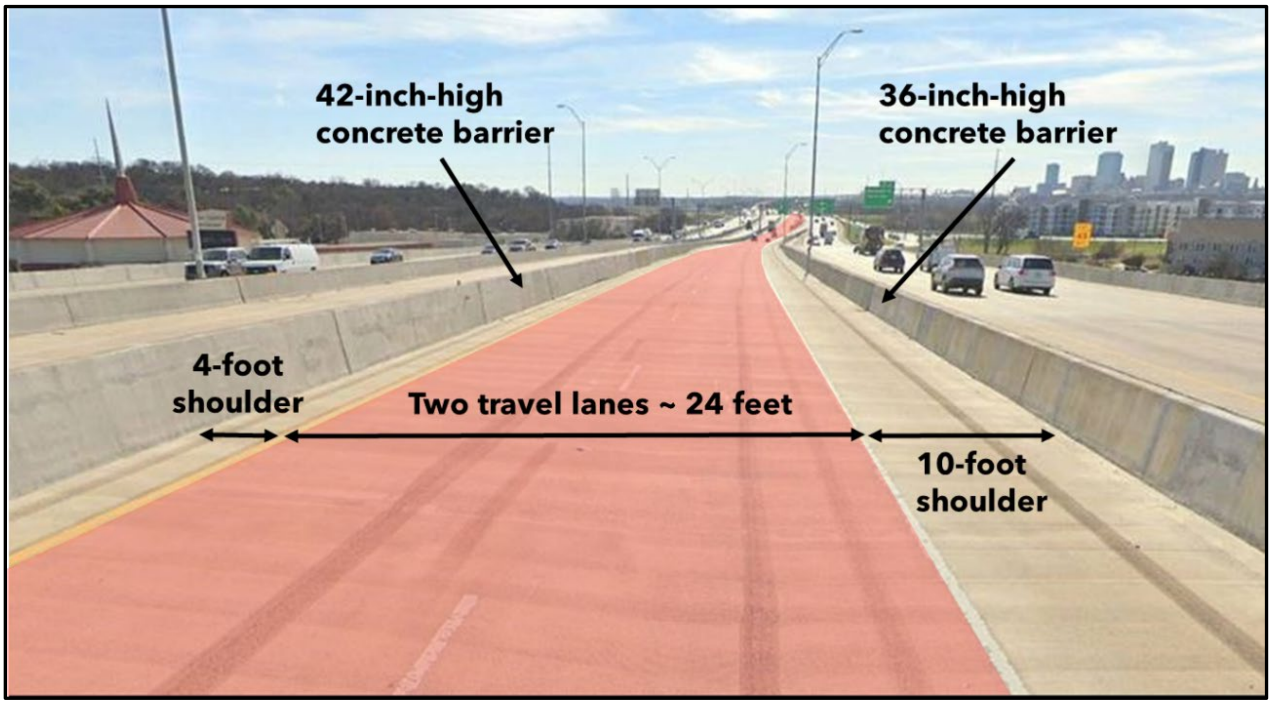

Figure 3. I-35W southbound toll lanes (highlighted in red) in area of crash site, looking south. Southbound general use lanes are on right side of image and northbound toll lanes are left of 42-inch-high concrete barrier. (Source: Google Earth Street view image from January 2020, adapted by NTSB.)

The crash occurred on an elevated portion of the roadway. The elevated structure preceding the crash location consisted of a hill crest with a 3% upgrade slope followed by a 3% downgrade slope.[13] The February 11, 2021, crashes began occurring about 1,000 feet past the hill crest on the downgrade slope. Based on the vertical alignment, the available sight distances for a passenger car and a truck-tractor traversing the crest of the vertical curve were about 950 and 994 feet, respectively. The American Association of State Highway and Transportation Officials (AASHTO) recommends a stopping sight distance of 866 feet for a 75-mph design speed on a 3% downgrade (AASHTO 2018).

The crash occurred during the hours of darkness, with roadway lighting illuminated. One or two 400-watt, high-pressure sodium luminaires were attached on top of several single poles in the vicinity of the crash. One single line of poles was mounted on top of the barrier separating the southbound toll lanes from the southbound general use lanes; another single line of poles was mounted on top of the barrier separating the northbound toll lanes from the northbound general use lanes.

As part of regular maintenance activities, NTEMP S3 had a contractor conduct a pavement friction assessment on I-35W in November 2019, using a locked-wheel skid friction tester on wet pavement. The pavement sections containing the crash location were found to have adequate friction values, and they required no remediation or further investigation.

1.2.4 Speed Limits and Signage

The posted regulatory speed limit for I-35W was 75 mph for the southbound and northbound toll lanes and 65 mph for the southbound and northbound general use lanes. In the 4 miles preceding the crash site, there were four regulatory speed limit signs and three advisory signs warning that “Bridge may ice in cold weather.” Before the crash, at 3:40 a.m. on February 11, dynamic message signs managed by NTEMP S3 along the southbound toll lanes began displaying the message, “ICY CONDITIONS EXIST/PLEASE USE CAUTION,” in response to a crash at another location.[14] Seven dynamic message signs located within 8.3 miles of the crash site displayed the same message. (See figure 4.)

[13] The TxDOT design parameters for the roadway allowed for slopes of up to 3%.

[14] The message “WINTER WEATHER ADVISORY” had been displayed beginning at 8:20 p.m. on February 10, 2021.

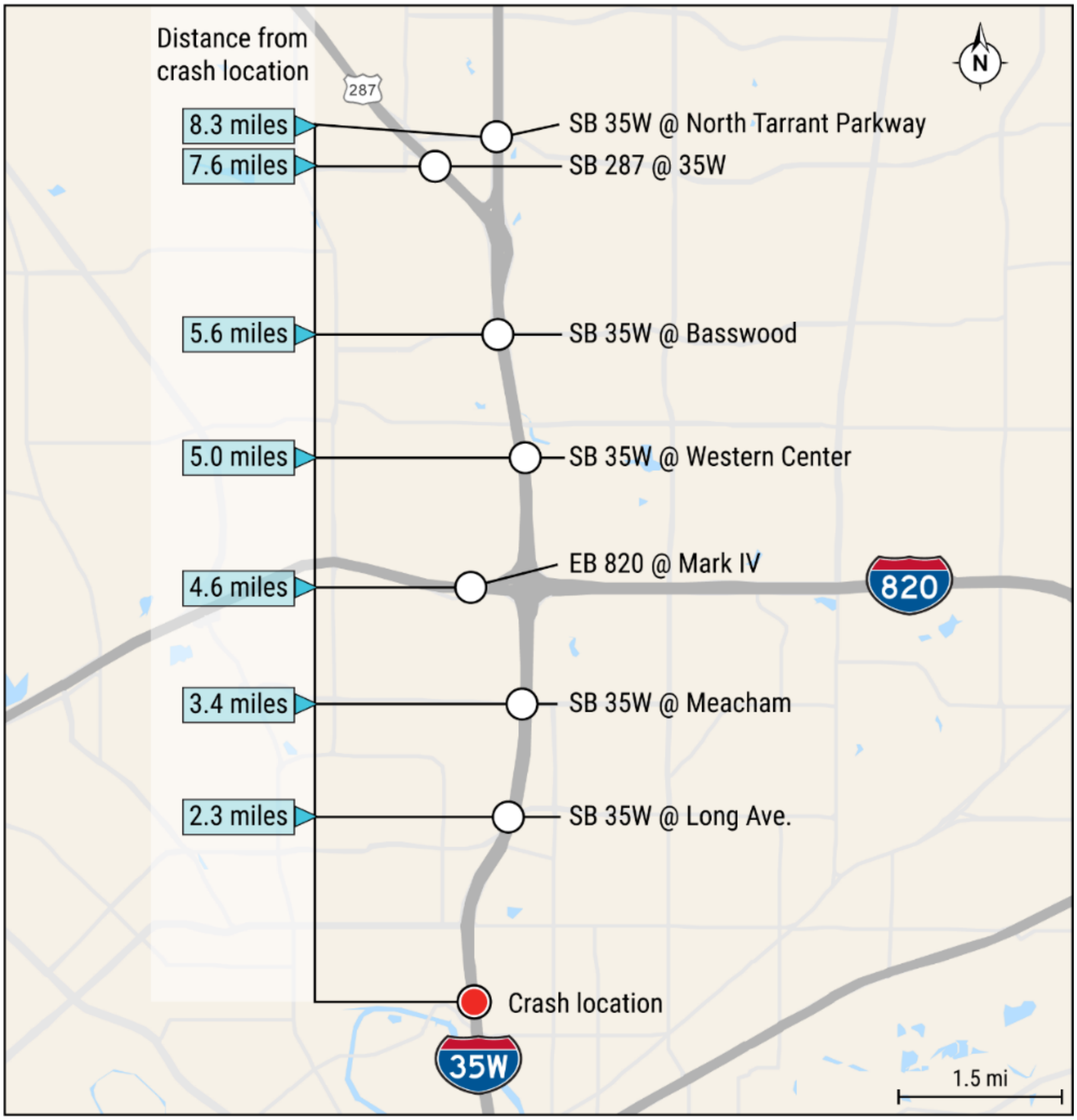

Figure 4. Map showing locations of dynamic message signs along, and on roads leading onto, southbound toll lanes. ("SB" indicates "southbound" and "EB" indicates "eastbound.")

The nearest dynamic message sign to the crash site was located about 2.3 miles north at the Long Avenue on-ramp. The sign was visible to traffic in both the southbound general use and toll lanes.

Speed limits in Texas are set by statute according to the type of road (*Texas Transportation Code*, Chapter 545, Subchapter H, Section 545.352).[15] TxDOT may alter statutory speed limits through the Texas Transportation Commission only after conducting an engineering and traffic investigation.[16] The engineering and traffic investigation must follow TxDOT's *Procedures for Establishing Speed Zones* (TxDOT 2015). TxDOT has no statutory authority to use variable speed limit signs or automated speed enforcement (speed safety cameras).[17]

1.3 Weather

The NWS Dallas/Fort Worth Weather Forecast Office issued several hazardous weather outlooks in the days preceding the crash. Beginning on February 9, 2021, the outlooks warned of freezing rain and ice accumulation on area roads, especially bridges and overpasses. The freezing precipitation was forecast to begin late on February 10 and to continue into February 11. In addition, the NWS issued winter weather advisories from February 10 through the time of the crash, warning of possible ice accumulations, mainly on elevated surfaces.

The crash occurred after about 36 consecutive hours of below-freezing temperatures. Official weather reporting sites in the area of the crash location reported light freezing precipitation and mist between 1:34 and 2:10 a.m. on February 11, with temperatures in the 20s °F. Light mist and fog were also reported from 2:53 to 4:53 a.m.[18] Conditions were favorable for the formation of black ice, and elevated roadway structures are particularly susceptible to such formations because they are exposed to the surrounding air on all sides and can quickly manifest

[15] For additional information, see the Texas Transportation Code, accessed February 16, 2023.

[16] NTEMP S3 is prohibited by section 8.1.7.3 of its facilities agreement with TxDOT from changing speed limits.

[17] Depending on the regulatory provisions for any given jurisdiction in the nation, roadway authorities may establish variable speed limits as appropriate speeds for conditions based on prevailing information about the roadway, like traffic speed, traffic volume, weather, and road surface conditions. Variable speed limits are displayed to drivers, typically using dynamic message signs. They can be implemented as regulatory or advisory speeds, depending on the policy and regulation for the jurisdiction.

[18] Precipitation also occurred after the multivehicle crash sequence began.

below-freezing temperatures within a few minutes of the air temperatures reaching such lows.[19]

NTSB postcrash interviews with first responders from the Fort Worth Police Department, Fort Worth Fire Department, and Metropolitan Area EMS Authority indicated that they found the pavement conditions slippery on both the toll and general use lanes when responding to the crash. Many responders characterized the slippery pavement conditions as an "ice rink" or a "sheet of ice." They also observed numerous people falling, slipping, and sliding and said that firefighters started putting down sand from sandbags to increase traction and make a walkway, so responders did not slip while attending to the victims.

1.4 Winter Weather Road Maintenance

1.4.1 NTEMP S3

General Practices. Before the onset of a winter weather event, NTEMP S3's practice was to pretreat the road by applying a liquid brine solution.[20] NTEMP S3 said that it typically applied brine solutions 24 to 72 hours in advance of a storm. NTEMP S3 indicated that, after the onset of a winter weather event, its personnel would apply subsequent chemical treatments in granular form on an as-needed basis.[21] The locations for these subsequent applications would be determined by personnel who patrolled and spot-checked the roadways, primarily though visual observation and by conducting brake checks.[22] Select NTEMP S3 employees also used handheld infrared thermometers. NTEMP S3 employees told NTSB investigators

[19] The NWS defines "black ice" as patchy ice on roadways or other transportation surfaces that cannot easily be seen. It is often clear (not white), making the black road surface visible underneath. It is most prevalent during the early morning hours, especially after snow melt on the roadways has had a chance to refreeze overnight when the temperature drops below freezing. Black ice can also form when roadways are slick from rain and temperatures drop below freezing overnight. Common locations for black ice formation include bridges, elevated overpasses, and spots on the road shaded by trees or other objects. Once formed, black ice is hard to detect and leads to hazardous driving conditions and an increased risk of crashes.

[20] NTEMP S3 used liquid Ice Slicer NM (also known as Ice Slicer CB), which is available as a commercial product. It consists of sodium chloride (90–98%), magnesium chloride (0.3–3.0%), potassium chloride (0.3–3.0%), and calcium chloride (0.3–3.0%).

[21] NTEMP S3 used Ice Slicer NM in granular form.

[22] In postcrash interviews, NTEMP S3 employees said that they would use "brake checks" to test whether the road was icy. They conducted the brake checks while driving their maintenance vehicles on the roadway; they would press the vehicle's brakes while underway to feel whether the vehicle slid or skidded on the road surface during braking.

that they prioritized the monitoring of bridges and overpasses while patrolling roadways before and during inclement weather. One NTEMP S3 road weather station was installed on a separate toll facility, Interstate 820, about 4 miles northeast of the crash location.

Practices Used Before This Crash. During the February 2021 winter storm, NTEMP S3 applied pretreatment about 44 hours before the multivehicle crash, using a brine solution with 23.3% salinity that was applied at a rate of about 44 gallons per lane-mile. During interviews, NTEMP S3 personnel told the NTSB that, on February 11, it had nine vehicles patrolling the I-35W corridor (including the area of the crash) in the 4 hours before the multivehicle crash. Fifteen technicians were on duty patrolling the corridor, performing spot-checks and, when needed, conducting spot treatments at locations where they found that ice had formed on the pavement. For example, at 3:00 a.m. that day, a separate crash occurred on northbound I-35W about 5 miles from the location of the subject multivehicle crash, and NTEMP S3 employees subsequently salted that area. At 4:40 a.m., NTEMP S3 employees identified moisture on the road about 2 miles south of the multivehicle crash location and salted that area. Once the treatment work was completed, the employees drove north on I-35W to reach the NTEMP S3 maintenance facility and passed through the crash area about 5:15 a.m. None of the crew personnel reported seeing any rain, freezing rain, or sleet in the area of the crash before 6:00 a.m.[23] The maintenance supervisor who was responsible for managing the corrective treatments and spot treatments of the icy conditions on I-35W also told the NTSB that, before the multivehicle crash, the southbound toll lanes in that area were spot-checked, but no moisture was detected. For this reason, granular salt was not applied at the crash location.

See table 1 for the timeline of weather, road maintenance, and related events that preceded the February 2021 multivehicle crash.

[23] See Highway Factors Supplemental Attachment *NTE Witness Interview Transcripts* in the public docket for this investigation (case number HWY21FH005).

Table 1. Timeline of weather and NTEMP S3 weather response actions preceding crash.

Date	Time*	Description
2/08/2021	10:32 a.m.	NTEMP S3 received first NWS alert for winter weather event, which advised of cold temperatures and possible precipitation. (NWS Dallas/Fort Worth weather forecast office issued several hazardous weather outlooks over the next 3 days.)
2/09/2021	3:40 a.m.	NWS began to advise of freezing rain and sleet beginning late February 10 and into February 11, along with below-freezing temperatures.
2/09/2021	10:12 a.m.	NTEMP S3 maintenance technicians pretreated the traffic lanes in the area of the crash with a liquid brine solution.
2/10/2021	8:20 p.m.	NTEMP S3 began displaying the message "WINTER WEATHER ADVISORY" on seven dynamic message signs near the crash site.
2/11/2021	1:34–2:10 a.m.	Light mist and freezing rain occurred.
2/11/2021	2:53–4:53 a.m.	Light mist and fog reported.
2/11/2021	3:40 a.m.	NTEMP S3 began displaying the message "ICY CONDITIONS EXIST/PLEASE USE CAUTION" on seven dynamic message signs near the crash site.
2/11/2021	5:15 a.m.	After treating a section of road 2 miles south of the eventual crash area, NTEMP S3 employees drove north on I-35W through the crash area and did not detect any moisture or ice.
2/11/2021	6:04 a.m.	Multivehicle crash sequence began in the southbound toll lanes of I-35W near the exit to Northside Drive.

* Times are approximate.

Winter Maintenance Training. Every year, NTEMP S3 holds a 1-day training event, known as the "Snow and Ice Rodeo." The event serves as both introductory training for new employees and refresher training for seasoned technicians, who review winter maintenance operations for roadway safety. In 2020, the "rodeo" consisted of classroom and practical training on the different types of equipment for ice treatment as well as how to load, unload, and operate the equipment. The training also included dry runs of the routes to be driven. All 15 technicians on duty the morning of February 11, 2021, had attended the 1-day training event held on October 22, 2020. Some employees indicated to the NTSB that the training had covered how to use visual observation and brake testing to spot-check roadways for moisture, ice, or both. Others stated that they did not receive any training in how to monitor or spot-check the roadway for moisture or ice.

1.4.2 TxDOT

The winter weather practices TxDOT used on the roadways it managed included application of liquid brine as a pretreatment, followed by subsequent applications of granular salt, as needed. TxDOT maintenance crews patrolled roadways in advance of inclement weather to detect moisture and to monitor air and road temperatures. TxDOT had roadway temperature devices installed on 67 of its vehicles. In other parts of the state, TxDOT used environmental sensor stations (ESSs) to measure multiple types of weather information, such as road temperature, road moisture, air temperature, wind speed, wind direction, precipitation, humidity, flood warning, and visibility.[24] Many of the TxDOT ESSs were located on elevated structures. In the Fort Worth District, TxDOT did not operate or maintain any ESSs.[25]

In response to winter weather events, TxDOT may consider road closures, in partnership with local law enforcement, emergency responders, and local governments. The joint decision is intended to be based on the safest path forward for the traveling public and the responders.

1.5 Additional Information

1.5.1 Video Study

NTSB investigators reviewed video recordings from three sources: (1) two traffic cameras near the crash location, (2) a forward-facing onboard image recorder on a combination vehicle that was traveling in the southbound toll lanes and was involved in a secondary collision during the crash sequence (the recorder provided two videos), and (3) a cell phone video from a bystander who was standing in the left shoulder of the southbound general use lanes just north of the crash location.[26]

The traffic camera videos showed that the initial crash began on the elevated structure. They showed that, about 6:04 a.m., a vehicle in the southbound toll lanes slid and struck the concrete barrier to the right. Then, other vehicles in the southbound toll lanes began to slide, spin, and strike the concrete barriers. About

[24] Five of the 25 TxDOT districts currently have road weather sensors (Lubbock, Houston, San Antonio, Pharr, and Laredo).

[25] TxDOT has no plans to install or operate any ESSs in the Fort Worth District. However, TxDOT says that it regularly considers the use of ESSs in TxDOT districts. In other areas, TxDOT has allowed private toll road operators to install ESS sites on state rights of way.

[26] For more detailed information on the video recordings associated with this crash, see the Video Specialist's Factual Report in the public docket for this crash (case number HWY21FH005).

6:13 a.m., a combination vehicle collided with the disabled vehicles from the previous impacts and came to a stop, blocking the southbound toll lanes. Then, other approaching vehicles slid and were unable to stop. As secondary crashes occurred, a queue of previously crashed vehicles formed, blocking through-traffic on the southbound toll lanes.

The two videos from the recorder on the commercial combination vehicle included date and time stamps and displayed a speed derived from a global positioning system (GPS). Per the recorder videos, in the minute preceding the secondary collision, the combination vehicle's speed did not exceed 66 mph, and it was not passed by any other vehicle. According to the NTSB video study for this investigation, stopped traffic became visible to the combination vehicle driver at 6:23:51 a.m., the combination vehicle began to slide at 6:24:03 a.m., and it collided with the queue of previously crashed vehicles beginning at 6:24:06 a.m. The displayed speed at the time the vehicle began to slide was 47 mph, although there was a 3-second lag in displayed vehicle speed. The onboard video also showed that the elevated road surface appeared shiny and reflective, the truck's windshield wipers were on, and there was precipitation on the windshield.

The bystander's cell phone video showed that the tops of the concrete barriers and the roadway surface appeared shiny and reflective, consistent with freezing precipitation on the surfaces. This 2-minute, 9-second cell phone video showed multiple vehicles sliding toward the previously crashed vehicles that were blocking the southbound toll lanes, vehicles sliding sideways down the toll lanes, and vehicles colliding with the queue of other crashed vehicles.

1.5.2 NTSB Survey of Private and State Toll Facilities

The NTSB conducted a survey of nine private and state-regulated toll facilities to determine their snow and ice removal pretreatment operations, roadway monitoring methods, and training processes.[27] The nine entities were a convenience sample of toll facilities in various regions of the country that experience cold and inclement weather. The NTSB compared the results from the survey to the treatment methods and training used by NTEMP S3.

[27] For more details, see appendix C and *Responses to Survey of Toll Facilities* in the NTSB public docket for this investigation (case number HWY21FH005). The nine facilities were located in Colorado, Illinois, Maryland, Massachusetts, South Carolina, Texas, and Virginia.

All nine of the private and state-regulated toll facilities surveyed indicated that they used a combination of liquid brine pretreatments and granular salt, as winter weather conditions warranted. Four of the nine toll facilities (Chicago Skyway, Massachusetts Turnpike, North Texas Tollway Authority, and Northwest Parkway in Colorado) had training materials that specifically focused on detection of moisture and icy road conditions, as well as on prioritizing locations where roadway treatments should be applied. Three of the nine surveyed entities (Intercounty Connector in Maryland, Massachusetts Turnpike, and North Texas Tollway Authority) used road weather information systems (RWISs) with either fixed sensor stations embedded in the roadway or mobile sensors mounted on a vehicle, while a fourth (Southern Connector in South Carolina) said that RWISs were used elsewhere in the state but not on the toll facility.[28]

1.5.3 NTEMP S3 Postcrash Actions

After the crash, NTEMP S3 undertook the following initiatives:

- Increased its fleet of maintenance vehicles equipped for winter maintenance.[29]
- Increased salt storage capacity by over 400 tons.
- Added the use of a new weather forecast vendor to provide more localized and customized forecasts and alerts, while continuing to use NWS forecasts. The new vendor also provides continuous access to a meteorologist and pavement temperature forecasting.
- Installed 18 weather sensors that capture air and pavement temperatures, as well as relative humidity. These were placed on elevated structures in areas where freezing is more likely to occur and were spaced at intervals less than 5 miles apart. When the sensors detect conditions such as freezing temperatures and icing (per certain established thresholds), they send an automatic e-mail notification to NTEMP S3.

[28] Road weather information systems (RWISs) consist of ESSs, a communication system for data transfer, and central systems to collect field data from numerous ESSs.

[29] The NTEMP S3 inventory of dump trucks was doubled, from 3 to 6; the number of pickup trucks was increased from 10 to 13; and the number of trucks outfitted to spray brine was more than tripled, from 3 to 10.

- Equipped all maintenance vehicles with infrared thermometers as well as GPS devices and controllers to make real-time information accessible through a computer dashboard and to allow technicians to obtain pavement temperature readings without having to stop and exit the vehicles. The GPS devices and controllers are linked to the treatment sprayers and spreaders to electronically capture operations data.
- Updated training materials to include the new technologies and processes that have been implemented. Also added online AASHTO Snow and Ice Pooled Fund Cooperative Program training courses to the training requirements for its staff.[30]

[30] For more information, see AASHTO Anti-Icing Training, accessed February 16, 2023.

2. Analysis

2.1 Introduction

The multivehicle crash that occurred in the southbound toll lanes of I-35W in Fort Worth began when several vehicles began to slide on the elevated roadway and struck the concrete barriers on either side of the toll lanes. As additional vehicles encountered the vehicles obstructing the roadway due to the earlier crashes, they were unable to stop on the icy roadway, leading to secondary crashes. As a result of the crash event, six people were fatally injured.

The following safety issues are discussed:

- Inadequate methods to monitor the condition of the roadway and elevated structures during inclement weather (section 2.2),
- Insufficient training for personnel responsible for snow and ice control on how to monitor moisture and icy conditions and when to apply suitable roadway treatments (section 2.3), and
- Need for technological countermeasures to help drivers and vehicles respond appropriately to inclement weather conditions (section 2.4).

2.2 Roadway Monitoring During Inclement Weather

Before the February 2021 storm that led to this crash, the NWS provided advance warning of the potential for freezing precipitation and repeatedly warned that ice accumulation on area roads, and particularly on bridges and elevated surfaces, could be expected. NTEMP S3 was aware of these NWS warnings and advisories in advance of the storm. Therefore, the NTSB concludes that NTEMP S3 had proper warning of the approaching winter weather and adequate opportunity to prepare for how the forecast freezing rain and sleet might affect the safety of the I35W roadway.

The roadway design in the I-35W crash area met applicable standards. The slope of the elevated structure met TxDOT design parameters, and the sight distance met AASHTO standards. Wet pavement friction testing conducted in 2019 showed that the pavement had adequate friction values and required no remediation.

2.2.1 NTEMP S3 Actions

Pretreatment. NTEMP S3 maintenance technicians pretreated the I-35W southbound toll lanes on February 9, 2021, at 10:12 a.m., about 44 hours (almost 2 days) before the crash, using a 23% salinity solution applied at a rate of about

44 gallons per lane-mile. The Federal Highway Administration (FHWA) *Manual of Practice for an Effective Anti-Icing Program* indicates that, for frost and black ice events, liquid (or prewetted solid) chemical application is an appropriate initial maintenance action (Ketcham and others 1996). In addition, the National Cooperative Highway Research Program (NCHRP) *Report 526 Snow and Ice Control: Guidelines for Materials and Methods* states that—

> A 23-percent solution of liquid NaCl [sodium chloride, or salt] applied at 40 to 60 gal/LM (or equivalent effective amount of other chemical) has proven to provide protection from these conditions that are nonprecipitation events….[31] In the absence of precipitation, these treatments are effective for at least 3 days and possibly up to 5 days depending on traffic volume (Blackburn and others 2004).

With respect to state guidance, the *TxDOT Snow and Ice Control Operations Manual* provides the following information:

> A pretreatment can be made before a storm, as long as the storm does not start out with above freezing temperatures and rain, washing the chemical away. Benefits from liquid pretreatments can include higher friction and better pavement conditions early in a storm (TxDOT 2017).

Because the pretreatment application salinity, rate, and timing were generally in accord with these policies, the NTSB concludes that NTEMP S3's pretreatment of roadway surfaces on February 9 in response to the initial winter weather warnings was reasonable and consistent with federal and state guidelines.

Messaging to Drivers. At 8:20 p.m. on February 10, 2021, NTEMP S3 began displaying a general message reading "WINTER WEATHER ADVISORY" on the seven dynamic message signs within 8.3 miles of the crash location. It updated this message to the more specific language of "ICY CONDITIONS EXIST/PLEASE USE CAUTION" at 3:40 a.m. on February 11, after a crash had occurred in the northbound general use lanes of I-35W about 5 miles north of the subject crash location. The dynamic message signage was consistent with TxDOT guidance (TxDOT 2017).

Deterioration of Roadway Conditions. On February 11, 2021, official weather reporting sites surrounding the crash location reported light freezing precipitation and mist between 1:34 and 2:10 a.m., with temperatures in the 20s °F. Temperatures remained below freezing. Conditions were favorable for the formation of black ice, and elevated structures are particularly susceptible because they are

[31] The "gal/LM" abbreviation stands for "gallons per lane-mile."

exposed to the surrounding air on all sides and can match below-freezing temperatures within minutes.

During the dark, early morning hours of February 11, NTEMP S3 employees were driving on the roadways and assessing them. They spot-treated some sections of roadway with salt, but they did not treat the elevated portion of I-35W where the multivehicle crash occurred.[32] About 5:15 a.m. (about 45 minutes before the multivehicle crash), NTEMP S3 maintenance crews drove north on I-35W and visually checked the road, but they detected no moisture and applied no salt.

Following the crash, Fort Worth Police Department, Fort Worth Fire Department, and Metropolitan Area EMS Authority staff indicated that they found the pavement conditions extremely slippery when responding to the crash, both on the toll and general use lanes. In addition, video evidence of the crashes involved in this event revealed that the roadway was shiny and reflective, consistent with frozen surfaces. The videos also showed vehicles sliding on the roadway, colliding with the queue of previously crashed vehicles, and slipping sideways down the roadway toward the main crash area.

Federal and state guidelines for effective snow and ice control on roads indicate that pretreatments applied before the onset of a winter weather event must be followed by subsequent chemical treatments when conditions deteriorate. The specific timing of subsequent applications is not specified, but it should be done as needed, based on the results of monitoring of roadway conditions. Specifically, the FHWA *Manual of Practice for an Effective Anti-Icing Program* states that pavement and weather conditions, as well RWIS data, should be monitored closely, and subsequent chemical applications should be made as needed (Ketcham and others 1996). TxDOT's *Snow and Ice Control Operations Manual* emphasized that the benefits of liquid pretreatment are generally short-lived and can be thought of as "buying time" in the early stages of a storm before subsequent chemical applications become effective (TxDOT 2017). TxDOT specifically notes that bridges and overpasses are known problem areas that call for prioritized monitoring.[33]

Effective monitoring of roadway conditions in inclement winter weather requires that known problem areas receive increased scrutiny. Because the NTEMP S3 employees did not detect and treat the ice on the elevated structure where the crash occurred when conditions deteriorated, the NTSB concludes that NTEMP S3's roadway monitoring process was deficient because, as precipitation and freezing temperatures continued and conditions deteriorated on the morning of

[32] At 4:40 a.m., NTEMP S3 employees identified moisture on the road about 2 miles south of the crash location; they salted that area.

[33] Other problem areas include steep grades, sharp curves, intersections, and ramps.

February 11, company personnel did not identify the elevated portion of I-35W where the crash took place as needing additional deicing treatment, which left the roadway surface icy, and drivers lost control of their vehicles.

2.2.2 Advanced Roadway Monitoring Technology

At the time of the crash, NTEMP S3 employees primarily relied on visual observation, brake checking, and use of handheld thermometers to detect moisture and icy conditions on roadways. More advanced weather sensing technology is readily available that can improve the detection of dangerous weather developments and hazardous road surface conditions. (NTEMP S3 had one road weather station, which was not on I-35W, at the time of the crash.) RWIS technology can accommodate sensors that measure multiple types of weather information, such as road temperature, road moisture, air temperature, wind speed, wind direction, precipitation, humidity, flood warning, and visibility. Thus, in addition to snow and ice detection, and depending on the types of sensors present, RWISs can be used to detect other inclement weather conditions, such as low visibility during fog, dust storms, high cross winds, and floods (Manfredi and others 2005). RWISs are widely used across the country (Murphy, Swick, and Guevara 2012) and, according to FHWA data, are present in almost every state.[34] Some states, such as Massachusetts, also use RWIS sensors mounted on vehicles. The Massachusetts Department of Transportation has found these portable sensors to be highly accurate (Tessier 2016).

Data provided by RWISs and their associated ESSs in real time can support decision-making by highway maintenance personnel, including where and when to deploy anti-icing and deicing chemicals, and when to warn motorists and/or close roadways. The NTSB concludes that, if ESSs had been installed near the crash location or portable sensors had been installed on the maintenance vehicles that were driven through the area before the crash, NTEMP S3 personnel would have had additional data that might have enabled them to determine that this elevated portion of the roadway needed deicing treatment.

Since the crash, NTEMP S3 has installed 18 weather sensors in the Dallas-Fort Worth area, including within 0.5 miles of the crash site, to monitor air and pavement temperature, as well as relative humidity. The sensors were strategically placed on elevated structures, where freezing is more likely to occur, and were spaced less than 5 miles apart, which is even closer together than is proposed in available guidance (Manfredi and others 2005).

[34] For additional information, see FHWA ESS map, accessed February 16, 2023.

The FHWA recommends using ESSs and RWISs for surveillance and monitoring to aid those making road weather management decisions.[35] The safety effectiveness of such systems has been documented for the state of Texas. A research report prepared by the Texas Transportation Institute, sponsored by TxDOT, included the following statement:

> The benefits of the system are almost immeasurable when considering the time saved and the prevention of loss of life that could occur.… The benefits include efficient reaction to environmental events and potentially saving life, property, and time (Benz, Fenno, and Goolsby 2001).

In addition, a study by Kwon and others (2015) developed statistical models concerning RWISs in the upper Midwest state of Minnesota. The study demonstrated that roads with RWISs had reduced crash frequency compared to roads without RWISs.

Of the interstate and non-interstate highway lane-miles in the Fort Worth District, NTEMP S3 maintains only a small portion (about 188 lane-miles) compared to the about 9,000 lane-miles that TxDOT maintains. TxDOT does not operate any ESSs in the district but uses them on bridges and elevated structures in other districts and reports that the sensors have improved safety in those areas.

TxDOT has indicated interest in these technologies and initiated a research program (begun before this crash) to develop and demonstrate weather-responsive management strategies, including the testing of vehicle-mounted weather sensors in real-world conditions with operational feedback.[36] According to TxDOT, the sensors have not yet been incorporated. Although Texas does not historically have a high rate of fatal crashes associated with adverse weather (Saha and others 2016), the fatal crash that resulted from the February 2021 winter storm highlights the need to have tools in place to detect and respond to adverse road conditions when bad weather does occur. The NTSB concludes that widespread deployment and use of ESSs would enable more efficient detection and monitoring of roadway conditions, as well as better responses to environmental events, likely reducing crashes and injuries during inclement weather.

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[35] For additional information, see Surveillance, Monitoring, and Prediction - FHWA Road Weather Management (dot.gov), accessed February 16, 2023.

[36] For more information, see *Develop and Demonstrate Weather-Responsive Management Strategies*, "RTI Project Agreement Between the Texas Department of Transportation and the University of Texas at Austin Center for Transportation Research, Project Number 0-7007," document date April 23, 2019.

Statewide, TxDOT has facilities agreements with several private and state-regulated toll facilities (in addition to NTEMP S3). Although TxDOT has allowed outside entities to install ESSs in the districts they manage, there is no statewide plan in Texas to prioritize locations for installation to ensure coverage. A coordinated approach and leadership from TxDOT on where ESSs should be installed statewide would benefit the safety of the traveling public as well as the efficiency of TxDOT and toll facility operations. Therefore, the NTSB recommends that the state of Texas implement a statewide plan to install ESSs in priority locations, including bridges and elevated structures, to enable timely response to hazardous road conditions due to inclement weather.

2.3 Training for Roadway Maintenance Personnel

Although NTEMP S3 has installed 18 weather sensors on elevated roadways in the Dallas-Fort Worth area, the roadway monitoring conducted by NTEMP S3 employees is still vital to determining the roadway condition. Before the crash, NTEMP S3 employees had a 1-day annual training event, known as the "Snow and Ice Rodeo." This training did not clearly emphasize roadway monitoring techniques to all participants. The 2020 event's agenda included what routes were to be driven but not the methods that employees should use to examine and assess the roadway's condition during a winter storm or other weather event. Some employees who took part in the "rodeo" told the NTSB that the training did address using visual observation and brake testing to effectively check roadways for moisture, ice, or both while others stated that they did not receive any training in these activities.[37] Based on conflicting reports from employees about whether methods for checking roadways for moisture or ice were addressed during the training, and the absence of these elements from the event's agenda, the 2020 rodeo did not fully train all NTEMP S3 employees on how to monitor a roadway's safety condition in winter weather. Therefore, the NTSB concludes that the training provided by NTEMP S3 was insufficient to prepare employees to monitor roadway conditions effectively during winter weather events.

The NTSB also compared NTEMP S3's training with that of nine private and state-regulated toll facilities that the NTSB surveyed. Four of the nine had training materials that specifically documented the topics of detecting moisture, identifying icy road conditions, and prioritizing locations where deicing treatments should be applied.

The NTSB has previously investigated a Texas crash involving the methods used by the workers responsible for maintaining the roadway during freezing and icy

[37] The employees who stated that they received no training were not the same ones who drove through the affected area on the morning of the crash.

conditions. A January 14, 2015, crash in Penwell, Texas, involved a prison bus that was traveling on Interstate 20 when it left the roadway and collided with a moving train. At the time of the crash, light mist was present, with no snow accumulation, and temperatures were below freezing. Icy conditions on the road had been reported, resulting in several single-vehicle crashes, including at least three median-crossover crashes and damage to the guardrail (NTSB 2016). As a result of the Penwell investigation, the NTSB found that TxDOT had not trained its personnel in accordance with the established snow and ice control guidelines and policy, and recommended that TxDOT train its personnel responsible for snow and ice control using AASHTO winter weather courses.[38] In response, TxDOT not only implemented the AASHTO training but also funded Texas Tech University to develop two comprehensive winter weather training courses, one for operations personnel (course MNT812) and one for managers (course MNT813).[39] These courses focus on topics of particular relevance in Texas rather than more general snow and ice control issues. Compared to the precrash training conducted by NTEMP S3, the modules and materials from these two Texas Tech training courses cover more topics in greater depth, such as priorities during route inspection; the importance of focusing on bridges, black ice, and melting/refreezing of ice on bridges; situations requiring judgment, such as barrier-separated lanes; and coordination between maintenance entities.

Postcrash, NTEMP S3 revised its employee training to include new technologies and processes for roadway monitoring, such as updated forecasting, use of the new road weather sensors to provide operators with real-time road conditions, and electronic controls to modernize salt-spreading operations. In addition, NTEMP S3 required employees to take the online AASHTO winter weather training, which includes best practices for roadway monitoring. The NTEMP S3's 2021 Snow and Ice Rodeo training included the topics of monitoring and reporting roadway conditions.

NTEMP S3's postcrash improvements in training should make it more capable of monitoring and addressing winter weather conditions on the roadways for which it is responsible. Additional focus on training by other private and state-regulated toll facilities in Texas could enhance their preparedness to maintain the safety of their roadways during winter weather events.

During a September 13, 2022, meeting, TxDOT representatives told the NTSB that the Texas Tech winter weather training programs have improved the readiness of

[38] See Safety Recommendation H-16-5, which was classified Closed—Acceptable Action in 2020.

[39] For more specific information on this training, see Winter Weather Management and Operations Curriculum, Texas Tech University, accessed February 16, 2023.

its employees to deal with winter weather. The TxDOT personnel particularly noted the usefulness of the emphasis on pavement pretreatment, followed by repeated treatment as necessary, as well as improvements in the calibration of materials and equipment. They also stated that providing separate courses for staff and management has been helpful.

The Texas Tech University training programs have been shared among all TxDOT districts, but they have not been distributed to private or state-regulated toll facilities in Texas. Although TxDOT does not dictate the training methods used by its contractors, it does coordinate with them on other aspects of winter weather response, such as messaging to the public. The NTSB concludes that coordination between TxDOT and the private and state-regulated toll facilities operating in Texas on best practices for training employees and managers responsible for snow and ice control would help ensure consistent use of effective procedures by all roadway maintenance entities in the state. Therefore, the NTSB recommends that the state of Texas provide the private and state-regulated toll facilities operating in the state of Texas with the winter weather training courses developed by Texas Tech University, or an equivalent training program, so that they can train their employees using the courses.

2.4 Technological Countermeasures in Inclement Weather

2.4.1 Speed Countermeasures

During wet conditions, icy conditions, or both, the available friction of the roadway is reduced, resulting in longer stopping distances than under dry conditions. In addition, a vehicle traveling at a higher speed, such as those on limited-access highways, requires a longer stopping distance than when traveling at lower speeds, and the driver must respond to a hazard more quickly to avoid a collision.[40] Higher speeds also lead to larger differences between a vehicle's precrash and postcrash velocity, which, in turn, leads to greater injury severity in a crash.

The circumstances of the crash, as well as video evidence, demonstrate that many of the 130 vehicles involved in this event were sliding and unable to stop on the

[40] (a) According to TxDOT, a limited-access highway is a roadway especially designed for through-traffic and over, from, or to which owners or occupants of abutting land or other persons have no right or easement of access. Interstate highways, parkways, and freeways are usually considered limited-access facilities. (b) Traveling too fast for conditions does not necessarily mean that a driver is exceeding the speed limit. The Fort Worth Police Department did not cite any of the involved drivers for excessive speed or driving too fast for conditions, and data from at least one truck showed that the truck was traveling no faster than 66 mph—9 mph below the 75-mph speed limit (without other vehicles passing it)—in the minute before it crashed.

icy road at the speeds they were traveling. In winter weather, safe driving speeds may be considerably below the maximum speed limit, which assumes a normal travel environment. In black ice conditions, like those present in this crash, it can be difficult to avoid secondary collisions. However, reduced speeds might have given these drivers more time to see the traffic and crash situation ahead and to take action to possibly avoid, or at least mitigate the severity of, secondary collisions. Reducing vehicle speed will decrease the energy and collision forces associated with each involved vehicle, reducing the overall severity of a multivehicle crash, if one occurs. Therefore, the NTSB concludes that, if the drivers had been traveling at slower speeds, more appropriate for the wintry conditions, they would have had more time to react as they approached the crash scene, which might have reduced the severity of the crash outcomes.

Driving too fast in inclement weather conditions is a prevalent problem. Data from the National Highway Traffic Safety Administration (NHTSA) National Center for Statistics and Analysis show that speeding, including traveling at a speed too fast for conditions, was a factor for 42% of drivers involved in fatal collisions on icy roads, compared with only 19% in dry conditions (NHTSA 2022). In addition, fatal chain-reaction crashes involving large numbers of vehicles are more likely to occur in adverse weather (Call, Wilson, and Shourd 2018; Wang, Liang, and Evans 2017). As in the Fort Worth crash, chain-reaction crashes often occur when vehicles cannot avoid secondary collisions due to either low visibility (for example, in heavy fog) or poor roadway conditions (such as snow, ice, or rain). Based on these data, the NTSB concludes that countermeasures are needed to make drivers more aware of safe speeds for conditions and to encourage them to reduce their speeds in adverse weather.

In Texas, the burden is on the driver to drive at a reasonable speed for the circumstances, regardless of the posted speed limit (*Texas Transportation Code* chapter 545, subchapter H, section 545.351). The *Texas Transportation Code* directs drivers to reduce speed under certain special conditions, including adverse weather, but it provides no guidance on what might constitute a reasonable speed reduction. The *Texas Driver Handbook* also states that speed should be reduced to correspond to conditions (Texas Department of Public Safety 2022, p. 45).

Thus, in Texas, a driver must determine on their own what constitutes a reasonable speed for conditions. Without additional guidance, some drivers may not be able to make such a determination.

On I-35W, the regulatory speed limit was 75 mph, as indicated by the posted signage. The regulatory speed limit is the maximum speed permitted for a section of highway, as established by law or regulation; consequently, it is enforceable. In the case of this crash, drivers on the I-35W southbound toll lanes could see dynamic message signs warning them of icy conditions and that they should use caution. The messaging of such signs, while helpful, was not enforceable or regulatory. The signs were advisory only and did not (1) identify a safe speed or (2) legally require drivers to slow to a new speed limit. In addition, by encouraging each driver to self-select their speed, this type of messaging may promote increased speed variance among drivers, which is associated with increased crash rates (FHWA 2018).

Conventional static speed limit signs do not account for less-than-ideal weather and therefore may not display an appropriate, reasonable, or safe speed limit under those conditions. By contrast, variable speed limits are specifically based on weather and road surface conditions. Variable speed limits are set by the highway authority in response to changing roadway conditions and, because the speeds can be established as regulatory rather than advisory speeds, the limits can be enforceable. Variable speed limits are communicated dynamically to drivers, usually by variable speed limit signs on the highway.

The FHWA has found that the use of variable speed limit signs—

> …during less-than-ideal conditions, such as heavy traffic and adverse weather, can improve safety by decreasing the risks associated with traveling at speeds that are higher than appropriate for the conditions and by reducing speed variance in traffic (FHWA 2017).

The FHWA published a volume of case studies (Goodwin 2003) on road weather management showing that variable speed limit signs have been successful in reducing vehicle speeds and crashes during inclement weather on, for example, the New Jersey Turnpike and a busy mountain pass in Washington State.

In another case, a 12-mile-long stretch of highway in Virginia that was prone to recurring fog events was repeatedly the site of multivehicle chain-reaction crashes involving more than 50 vehicles. A speed study found that, although drivers slowed somewhat during low visibility conditions, the average speeds still exceeded the safe speed calculated for the stopping sight distance (McCann and Fontaine 2016). To improve safety in the corridor, the Virginia Department of Transportation constructed a variable speed limit system that posted dynamic speed limits based on the visibility condition. When the variable speed limits were implemented during low visibility conditions, average vehicle speeds were reduced. Crash rates (per vehicle miles traveled) also decreased during the 11-month period studied after implementation of the variable speed limits (Gonzales and Fontaine 2018).

The NTSB investigated a 2003 crash in Hewitt, Texas, involving a motorcoach that was traveling in overcast weather with reduced visibility due to fog, haze, and heavy rain. The NTSB determined that the speed limit on the roadway exceeded the design speed and, combined with the wet pavement conditions, did not provide drivers with enough time to stop their vehicles (NTSB 2005). Following the investigation, we issued Safety Recommendation H-05-20 to TxDOT, as follows:

> Install variable speed limit signs or implement alternate countermeasures at locations where wet weather can produce stopping distances that exceed the available sight distance. (H-05-20)

In 2013, the Texas legislature passed House Bill 2204, which granted TxDOT the ability to establish a variable speed limit pilot program.[41] The Texas pilot program on variable speed limits demonstrated safety benefits (Kuhn and others 2016). For example, the pilot locations had fewer crashes in adverse weather and under poor surface conditions (such as when roads were wet or affected by ice or snow) during the variable speed limit program. The pilot program expired in February 2015. Since then, TxDOT has repeatedly tried to obtain the necessary authority from the legislature to install variable speed limit systems, as recommended in Safety Recommendation H-05-20. However, this authority has not been granted; consequently, TxDOT currently cannot implement variable speed limits on a permanent basis. The NTSB classified Safety Recommendation H-05-20 Closed—Unacceptable Action in 2020.

The NTSB concludes that, had variable speed limit signs that changed the regulatory speed limit been used to require drivers to slow to a speed more appropriate for the winter weather conditions, the severity of the multivehicle crash could have been reduced. The NTSB therefore recommends that the state of Texas enact legislation to allow TxDOT to install variable speed limit signs on Texas roadways.

Another proven countermeasure to reduce vehicle speeds is automated speed enforcement, also known as speed safety cameras.[42] Data indicate that the effectiveness of variable speed limits can be improved with the use of automated enforcement (FHWA 2017). As noted in the NTSB's 2017 safety study on *Reducing Speeding-Related Crashes Involving Passenger Vehicles*, a review of 28 speed safety camera studies found that the cameras reduced crashes 8–49% (NTSB 2017). Speed safety cameras can also operate at locations where traditional roadside traffic stops may be dangerous or infeasible (FHWA and NHTSA 2008). Enforcement conducted by police personnel in winter weather conditions is challenging, and hazardous road conditions can increase the likelihood of officers being involved in a crash or incident

[41] As previously noted, TxDOT is a statutory agency, created by the Texas legislature, and it has only those powers delegated to it through statute. TxDOT has no independent authority to establish variable speed limits or signs (or speed safety cameras for enforcement purposes).

[42] For more information, see the FHWA webpage on Proven Safety Countermeasures, accessed February 16, 2023.

while conducting on-road enforcement due to low visibility, poor traction, and other weather-related issues. Speed safety cameras can be used to enforce reduced speeds in winter weather conditions automatically and safely.

As a result of our 2017 safety study, the NTSB issued several recommendations aimed at reducing speed-related crashes, including Safety Recommendation H-17-31 to the seven states—including Texas—that, at the time, prohibited automated speed enforcement, as follows:[43]

> Amend current laws to authorize state and local agencies to use automated speed enforcement. (H-17-31)

Instead of encouraging their use, in June 2019, the state of Texas enacted a law that fully banned the use of both automated speed enforcement and red-light cameras. Therefore, in 2021, the NTSB classified Safety Recommendation H-17-31 Open—Unacceptable Response for Texas.

In our investigation of the 2020 Mt. Pleasant Township, Pennsylvania, crash (NTSB 2022), we conducted a speed study using an advisory variable speed limit sign and found that motorists drove slower when law enforcement was visually present. Speed safety cameras similarly provide notice and threat of enforcement, thereby further cueing motorists, such as those involved in the Fort Worth crash, to reduce their speed when variable speed limit signs are activated. Moreover, the FHWA has stated that, "For any VSL [variable speed limit] to be successful in effectively managing speed and reducing crash risk, there must be a clear vision of how the system will operate and be enforced…." (FHWA 2012, p. 19). The NTSB concludes that automated speed enforcement (such as through use of speed safety cameras) is an effective countermeasure to reduce crashes, fatalities, and injuries related to speeding and traveling at speeds too fast for conditions. The NTSB therefore reiterates Safety Recommendation H-17-31 to the state of Texas.

2.4.2 Connected Vehicle Technology

In addition to countermeasures that would require reduced speed in inclement weather, another tool—connected vehicle technology—could have benefitted the drivers involved in the multivehicle crash. Connected vehicle technology is also described as vehicle-to-everything (V2X) technology, an umbrella term encompassing the various elements through which vehicles can communicate. V2X technology enables commercial and passenger vehicles to communicate with each other, with the infrastructure, and with other road users, such as motorcyclists,

[43] The seven states were Maine, Mississippi, New Hampshire, New Jersey, Texas, West Virginia, and Wisconsin.

cyclists, and pedestrians. V2X-equipped vehicles securely send and receive vehicle performance information such as speed, position, braking, stability control system activation, and direction of travel, among other data. The technology acts as another sensor, or source of information, which can be incorporated into the vehicle's own collision avoidance system, and which warns a driver of an upcoming hazard. Significantly, this technology is not limited by line of sight and therefore is not affected by curves, visibility, or crash scenarios that are challenging for a vehicle's collision avoidance systems or a driver to detect. V2X communications can therefore provide information about a threat outside the driver's and collision avoidance systems' field of view much earlier than radar or camera sensors, which extends the range of hazard detection and warns the driver before the hazard is even visible to them.

Had the vehicles involved in the Fort Worth crash been equipped with V2X technology, it would have allowed the sliding vehicles to issue warnings of electronic stability control activation (an indication of icy conditions) to trailing vehicles, allowing the drivers of those vehicles more time and a better opportunity to change their driving behavior before encountering the icy conditions. Also, the vehicles that crashed early in the sequence could have further communicated to approaching vehicles, before the drivers of those vehicles could see the crashes, that the vehicles ahead were stopped and blocking the roadway. This messaging would have conveyed warning of a specific, imminent hazard to drivers, in contrast to a more general warning of icy conditions. It should be noted that not all of the 130 vehicles involved in this event would have needed to be equipped with V2X to realize safety benefits. Although vehicles approaching the crash area would have needed to be equipped to receive the warnings to benefit, the overall crash severity would still have been reduced if even some of the vehicles involved early in the crash sequence were equipped to send out an alert. The NTSB concludes that connected vehicle technology, if installed on at least some of the vehicles involved in the crash, could have provided information about the icy road conditions and the sliding and stopped vehicles, so that drivers of approaching V2X-equipped vehicles would have been warned of the imminent hazard and might have avoided or mitigated the secondary crashes.

The NTSB has long advocated for connected vehicle technology. In 2013, in our report on the investigation of the 2012 collision between a school bus and a truck at an intersection near Chesterfield, New Jersey (NTSB 2013), the NTSB issued the following two safety recommendations to NHTSA:

> Develop minimum performance standards for connected vehicle technology for all highway vehicles. (H-13-30)
>
> Once minimum performance standards for connected vehicle technology are developed, require this technology to be installed on all newly manufactured highway vehicles. (H-13-31)

To date, NHTSA has made little progress toward implementing the recommendations, and both are currently classified Open—Unacceptable Response.

Although some V2X applications are available and ready to deploy and the technologies' lifesaving benefits continue to be demonstrated, the future deployment of connected vehicles requires regulatory certainty and a spectrum free from harmful interference. In May 2021, the Federal Communications Commission (FCC) issued a rule that decreased the spectrum allocated to V2X by 60 percent and introduced potentially harmful interference by allowing unlicensed wi-fi devices to operate in surrounding communication bands. The NTSB, US Department of Transportation (USDOT) agencies, and the automotive industry have repeatedly expressed concerns about the potential for harmful interference. In 2022, in our report on the investigation of the 2020 Mt. Pleasant Township, Pennsylvania, crash, the NTSB concluded that the FCC's regulatory action, which decreases the size of the communication spectrum available for the intelligent transportation system and allows harmful interference from unlicensed devices, threatens the future deployment of connected vehicle technology. Other critical factors negatively affecting V2X deployment include the USDOT's failure to lead and create an environment of regulatory certainty and automakers' reluctance to invest in such an uncertain regulatory environment. Consequently, the NTSB concluded that USDOT leadership is needed to establish regulatory certainty and resolve critical issues related to V2X (NTSB 2022). As a result, the NTSB issued the following safety recommendations in the Mt. Pleasant report:

> *To the USDOT*: Implement a plan for nationwide connected vehicle technology deployment that (1) resolves issues related to interference from unlicensed devices, such as those that use wi-fi; (2) ensures sufficient spectrum necessary for advanced connected vehicle applications; and (3) defines communication protocols to be used in future connected vehicle deployment. (H-22-1)

> *To the FCC*: Implement appropriate safeguards to protect vehicle-to-everything communications from harmful interference from unlicensed devices, such as those that use wi-fi. (H-22-6)

Both safety recommendations are currently classified Open—Await Response.

Because the Fort Worth crash is another instance in which connected vehicle technology could have reduced the severity of the crash, the NTSB reiterates Safety Recommendations H-13-30 and -31 to NHTSA, H-22-1 to the USDOT, and H-22-6 to the FCC.

3. Conclusions

3.1 Findings

1. North Tarrant Express Mobility Partners Segments 3 had proper warning of the approaching winter weather and adequate opportunity to prepare for how the forecast freezing rain and sleet might affect the safety of the Interstate 35 West roadway.

2. North Tarrant Express Mobility Partners Segments 3's pretreatment of roadway surfaces on February 9 in response to the initial winter weather warnings was reasonable and consistent with federal and state guidelines.

3. North Tarrant Express Mobility Partners Segments 3's roadway monitoring process was deficient because, as precipitation and freezing temperatures continued and conditions deteriorated on the morning of February 11, company personnel did not identify the elevated portion of Interstate 35 West where the crash took place as needing additional deicing treatment, which left the roadway surface icy, and drivers lost control of their vehicles.

4. If environmental sensor stations had been installed near the crash location or portable sensors had been installed on the maintenance vehicles that were driven through the area before the crash, North Tarrant Express Mobility Partners Segments 3 personnel would have had additional data that might have enabled them to determine that this elevated portion of the roadway needed deicing treatment.

5. Widespread deployment and use of environmental sensor stations would enable more efficient detection and monitoring of roadway conditions, as well as better responses to environmental events, likely reducing crashes and injuries during inclement weather.

6. The training provided by North Tarrant Express Mobility Partners Segments 3 was insufficient to prepare employees to monitor roadway conditions effectively during winter weather events.

7. Coordination between the Texas Department of Transportation and the private and state-regulated toll facilities operating in Texas on best practices for training employees and managers responsible for snow and ice control would help ensure consistent use of effective procedures by all roadway maintenance entities in the state.

8. If the drivers had been traveling at slower speeds, more appropriate for the wintry conditions, they would have had more time to react as they approached the crash scene, which might have reduced the severity of the crash outcomes.

9. Countermeasures are needed to make drivers more aware of safe speeds for conditions and to encourage them to reduce their speeds in adverse weather.

10. Had variable speed limit signs that changed the regulatory speed limit been used to require drivers to slow to a speed more appropriate for the winter weather conditions, the severity of the multivehicle crash could have been reduced.

11. Automated speed enforcement (such as through use of speed safety cameras) is an effective countermeasure to reduce crashes, fatalities, and injuries related to speeding and traveling at speeds too fast for conditions.

12. Connected vehicle technology, if installed on at least some of the vehicles involved in the crash, could have provided information about the icy road conditions and the sliding and stopped vehicles, so that drivers of approaching vehicle-to-everything-equipped vehicles would have been warned of the imminent hazard and might have avoided or mitigated the secondary crashes.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the multivehicle crash in Fort Worth, Texas, was ice accumulation on the surface of the elevated roadway, which made drivers lose control of their vehicles, which then slid into road barriers and other vehicles. Contributing to the unsafe roadway condition was the failure of North Tarrant Express Mobility Partners Segments 3 to effectively monitor and address roadway conditions along Interstate 35 West during and after periods of freezing rain and mist. Contributing to the severity of the crash outcome was drivers traveling at speeds too fast for the winter weather conditions.

4. Recommendations

4.1 New Recommendations

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

To the state of Texas:

Implement a statewide plan to install environmental sensor stations in priority locations, including bridges and elevated structures, to enable timely response to hazardous road conditions due to inclement weather. (H-23-1)

Provide the private and state-regulated toll facilities operating in the state of Texas with the winter weather training courses developed by Texas Tech University, or an equivalent training program, so that they can train their employees using the courses. (H-23-2)

Enact legislation to allow the Texas Department of Transportation to install variable speed limit signs on Texas roadways. (H-23-3)

4.2 Previously Issued Recommendations Reiterated in This Report

The National Transportation Safety Board reiterates the following safety recommendations.

To the US Department of Transportation:

Implement a plan for nationwide connected vehicle technology deployment that (1) resolves issues related to interference from unlicensed devices, such as those that use wi-fi; (2) ensures sufficient spectrum necessary for advanced connected vehicle applications; and (3) defines communication protocols to be used in future connected vehicle deployment. (H-22-1)

To the National Highway Traffic Safety Administration:

Develop minimum performance standards for connected vehicle technology for all highway vehicles. (H-13-30)

Once minimum performance standards for connected vehicle technology are developed, require this technology to be installed on all newly manufactured highway vehicles. (H-13-31)

To the Federal Communications Commission:

Implement appropriate safeguards to protect vehicle-to-everything communications from harmful interference from unlicensed devices, such as those that use wi-fi. (H-22-6)

To the state of Texas:

Amend current laws to authorize state and local agencies to use automated speed enforcement. (H-17-31)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JENNIFER HOMENDY
Chair

MICHAEL GRAHAM
Member

BRUCE LANDSBERG
Vice Chairman

THOMAS CHAPMAN
Member

Report Date: February 27, 2023

Appendixes

Appendix A: Investigation

The National Transportation Safety Board (NTSB) was notified of the Fort Worth, Texas, crash on February 11, 2021, and dispatched a partial investigative team (after COVID-related travel restrictions were relaxed in that region), consisting of the investigator-in-charge and the highway factors investigator. The NTSB also established a group to investigate highway factors.

Parties to the investigation were the Texas Department of Transportation, North Tarrant Express Mobility Partners Segments 3, the Fort Worth Police Department, the Fort Worth Fire Department, and the Metropolitan Area EMS Authority.

Appendix B: Consolidated Recommendation Information

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

For each recommendation–

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

(2) a description of the Board'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 state of Texas

H-23-1

Implement a statewide plan to install environmental sensor stations in priority locations, including bridges and elevated structures, to enable timely response to hazardous road conditions due to inclement weather.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.2.2. Information supporting (b)(1) can be found on pages 19–21; and (b)(2) and (b)(3) are not applicable.

H-23-2

Provide the private and state-regulated toll facilities operating in the state of Texas with the winter weather training courses developed by Texas Tech University, or an equivalent training program, so that they can train their employees using the courses.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3. Information supporting (b)(1) can be found on pages 21–23; and (b)(2) and (b)(3) are not applicable.

H-23-3

Enact legislation to allow the Texas Department of Transportation to install variable speed limit signs on Texas roadways.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4.1. Information supporting (b)(1) can be found on pages 23–26; and (b)(2) and (b)(3) are not applicable.

Appendix C: Survey of Other Private and State-Regulated Toll Facilities

Toll Facility	Location	Private or State-Regulated	Year Facility Opened to Traffic	Pretreatment and Subsequent Treatments Used	Methods/Technologies to Monitor Moisture and Ice Formation
Chicago Skyway	Chicago, IL	Private	1958	Mixture of sodium chloride (salt) and liquid calcium chloride depending on temperature and type of precipitation.	Chicago Skyway is prepared for "dawn patrol" by November 1. Chief operating officer determines the actual starting time for dawn patrol based on observed weather conditions.
Dulles Greenway	Sterling, VA	Private	1995	Pretreatment options include magnesium chloride and depend on the weather and roadway conditions.	No sensor detection systems are used. Employees are trained on spot-checking bridge/roadway/toll plaza temperature.
Intercounty Connector	Montgomery and Prince George's County, MD	State-regulated	2011	Salt brine and salt	At the beginning of the winter season, two trained maintenance technicians are assigned to work on "frost patrol," which monitors on-site roadway and weather conditions from 12:00 a.m. until 8:00 a.m. RoadWatch gauges are used on all vehicles that measure air/road temperature. Toll facility uses two roadway-embedded weather sensors that record wind speed, wind direction, air temperature, dew point, relative humidity, precipitation type, and road conditions.
Massachusetts Turnpike	Boston, MA	State-regulated	1957	Pretreatment is 85% saturated sodium chloride solution, plus 15% of 28% liquid magnesium chloride.	Road weather information systems (RWISs) (provided by Vaisala) coupled with dedicated weather forecaster who provides a maintenance decision support system.

Toll Facility	Location	Private or State-Regulated	Year Facility Opened to Traffic	Pretreatment and Subsequent Treatments Used	Methods/Technologies to Monitor Moisture and Ice Formation
North Texas Tollway Authority	Plano, TX	Political subdivision of the state of Texas	Portions opened between 1968 and 2018	Brine used as pretreatment; each event is assessed independently for use. Materials used during winter weather event: sand, salt, magnesium chloride, and calcium chloride.	Authority uses permanent pavement sensors, RWIS, which can be monitored using an Internet-based website at select location. In addition, staff patrols the roadways and monitors conditions.
Northwest Parkway	Broomfield, CO	Private	2002	Northwest Parkway uses Ice Slicer granular and Apex liquid supplied by Envirotech.	High priority areas include bridges, all ramps, and the toll plaza area. Snow plowed until it reaches a depth or consistency that cannot be removed by a controlled application of Ice Slicer or liquid deicers. No roadway sensors are used at this time.
Pocahontas Parkway	Richmond, VA	State-regulated through concession agreement	2002	Liquid solution – typically of salted brine. The quantity of anti-icing liquid is contingent on the severity of the storm.	Pocahontas Parkway team checks the weather forecast daily using weather mobile applications and nearby weather stations. Supervisors and maintenance technicians have access to handheld laser temperature gauges. The gauges are used to monitor the temperature of the road asphalt and concrete bridge decks throughout the parkway.
Southern Connector	Piedmont, SC	Public/private partnership, operated by non-profit organization	2001	Snow and ice operations primarily consist of brine applications, sodium chloride applications, or applications of a mixture of sand and sodium chloride. The specific application is	South Carolina Department of Transportation has RWISs throughout the state to monitor pavement and weather conditions, but none of these RWISs are located on the toll facility. The information collected from these systems—along with weather forecast information, combined with firsthand information from employees

Toll Facility	Location	Private or State-Regulated	Year Facility Opened to Traffic	Pretreatment and Subsequent Treatments Used	Methods/Technologies to Monitor Moisture and Ice Formation
				determined by the conditions at hand.	physically evaluating routes—is used to confer appropriate treatments and times.
State Highway 130 Segments 5 and 6	Buda, TX	Operated by private company but state-regulated	2012	Crews begin applying brine at the start of precipitation, while temperatures are above freezing; locations are continually treated and monitored; when ice is detected, crews begin continuous salt application until weather event is over.	Authority does not intend on using monitoring devices. As weather events are identified, crews proactively treat and monitor the road.

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