NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF HIGHWAY SAFETY
WASHINGTON, D.C.

HIGHWAY FACTORS GROUP CHAIRMAN'S FACTUAL REPORT

A. CRASH INFORMATION

Location:	Interstate 70/76 (I-70/76), Pennsylvania Turnpike at mile-marker 86.1 westbound, Mount Pleasant Township, in Westmoreland County, Pennsylvania
Vehicle #1:	2005 Van Hool 57-passenger motorcoach C2045
Operator #1:	58-year-old male (fatally injured)
Occupants:	59 passengers
	(2 fatalities, 57 various injuries)
Carrier:	Z&D Tour Inc., Rockaway, NJ
Vehicle #2:	2018 Freightliner Cascadia truck-tractor towing a 2019, 53-foot Hyundai Translead semitrailer
Operator #2:	35-year-old male (not injured)
Passenger:	35-year-old-male (minor injury)
Carrier:	Fed Ex Ground, Moon Township, PA
Vehicle #3:	2018 Freightliner Cascadia truck-tractor towing a 2018, 53-foot Stoughton semitrailer
Operator #3:	53-year-old male (fatally injured)
Passenger:	48-year-old male (fatally injured)
Carrier:	United Parcel Service, Harrisburg, PA
Vehicle #4:	2007 Mercedes Benz C280 sedan
Operator #4:	46-year-old male (not injured)
Passenger:	20-year-old-male (not injured)
Passenger:	20-year-old-male (not injured)
Vehicle #5:	2018 Freightliner Cascadia truck-tractor towing a 2020, 28.5-foot Stoughton semitrailer
Operator #5:	62-year-old male (not injured)

Passenger:	41-year-old male (not injured)
Carrier:	United Parcel Service, Willow Grove, PA
Date:	January 5, 2020
Time:	Approximately 3:30 a.m. local time
NTSB #:	**HWY20MH002**

B. HIGHWAY FACTORS GROUP

Dan Walsh, P.E., Senior Highway Factors Investigator, Group Chairman
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C. CRASH SUMMARY

For a summary of the crash, refer to the *Crash Summary Report* in the docket for this investigation.

D. DETAILS OF THE HIGHWAY FACTORS INVESTIGATION

The *Highway Factors Factual Report* begins with a discussion on prefatory data that includes the crash location, construction history, average daily traffic volumes, vehicle classification count, and traffic and fatal accident summary. The report also focuses on roadway data that includes speed limit, dynamic message signs, horizontal alignment, vertical alignment, typical section, rumble strips, highway markings, highway lighting, signage prior to the crash, friction numbers, and rutting in the westbound travel lanes. The report documents the maintenance and weather data that includes Pennsylvania Turnpike remote weather station, Donegal Maintenance Facility, specifications for the single axle salt truck used in applying salt in the westbound direction of I-70/76 in the vicinity of the crash, witness interviews of Pennsylvania Turnpike Commission (PTC) truck drivers and supervisors, PTC snow and ice removal procedures, and other states policies for snow and ice removal procedures. The report summarizes tests conducted after the crash and PTC actions taken after the crash. The report provides a discussion regarding Pennsylvania's 2017 Strategic Highway Safety Plan (SHSP). Finally, the report concludes with documentation of speed studies performed by the PTC.

1. Prefatory Data

1.1. Crash Location

The crash occurred in the westbound travel lanes of the Pennsylvania Turnpike, Interstate 70/76 (I-70/76) at milepost (MP) 86.1 near Mount Pleasant Township., in Westmoreland County, Pennsylvania. **Figure 1** is a crash map that illustrates the crash location was approximately 36 miles southeast of Pittsburgh. **Figure 2** is a Pennsylvania Turnpike System Map illustrating the approximate crash location.

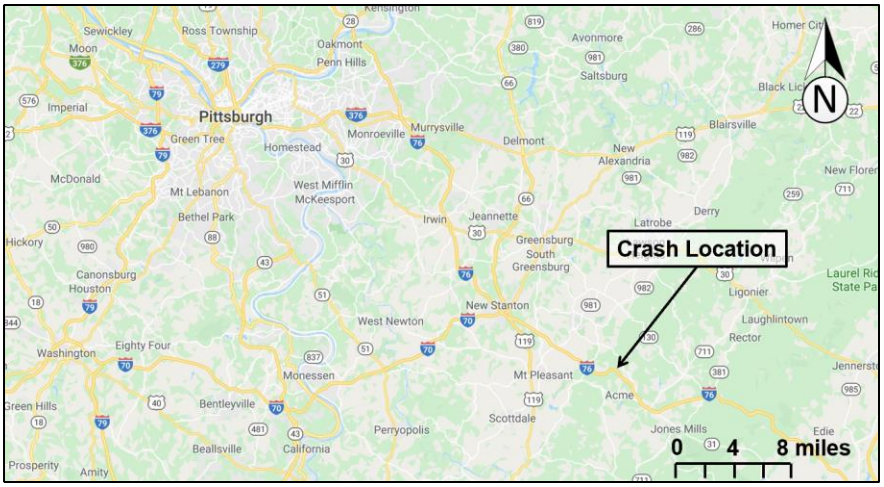

Figure 1 – Crash map (Source: Google Maps revised).

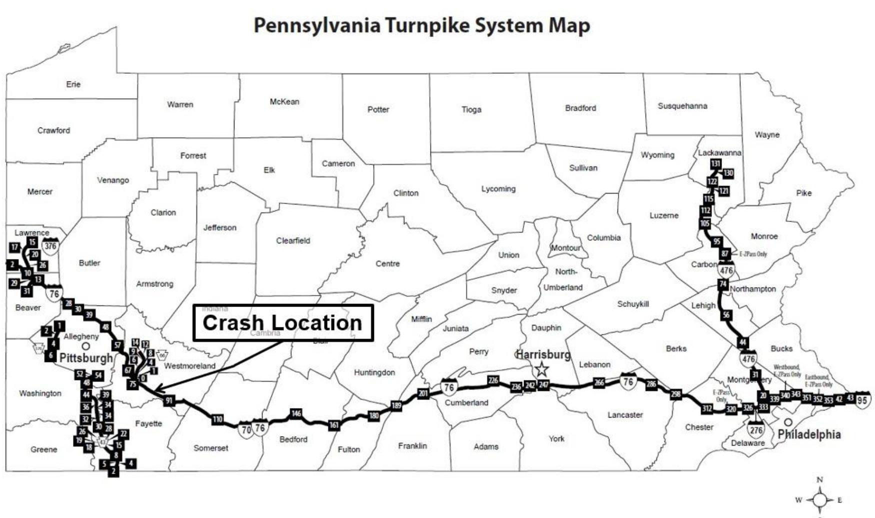

Figure 2 – Pennsylvania Turnpike System Map (Source: Pennsylvania Turnpike Commission).

1.2. Construction History of Pennsylvania Turnpike

This section of the Pennsylvania Turnpike, in the vicinity of the crash, was originally designed in 1938 and built in 1939-1940 and then reconstructed and widened in 2005. A one-half inch microsurface material was applied during the 2011 construction season. A recent resurfacing project removed the one-half inch microsurface material and the two-inch wearing course. Subsequently, a new two-inch stone matrix wearing course material was placed and completed in the westbound travel lanes in the vicinity of the crash in September 2019.

1.3. Average Daily Traffic Volumes

Table 1 summarizes the average daily traffic volumes on the Pennsylvania Turnpike in the vicinity of the crash from 2015 to 2019.

Table 1 – Average daily traffic volumes in the vicinity of the crash.

Year	Eastbound	Westbound	Total
2019	19,382	17,965	37,347
2018	19,474	18,114	37,588
2017	19,665	18,221	37,886
2016	19,483	17,979	37,462
2015	19,278	18,085	37,363

1.4. Vehicle Classification Count

At the request of NTSB investigators, the PTC performed a 24-hour vehicle classification count study in the vicinity of the crash on Sunday, March 1, 2020. Sunday was specifically selected as the day to conduct the study because it coincided with the same day of the week as the crash. **Table 2** summarizes the 24-hour classification count study for vehicles travelling in the westbound direction of travel at MP 86.1.

Table 2 – 24-hour classification count study for vehicles travelling in the westbound direction of I-70/76 at MP 86.1 on Sunday, March 1, 2020.

Vehicle Classification	Vehicle Count	Percent	Category
Class 1 Motorcycles	2	0.0%	Motorcycles
Class 2 Passenger Cars	12,315	73.5%	Passenger Cars
Class 3 Other Two-Axle, Four-Tire Single Unit Vehicles	1,938	11.6%	Pickups and Vans
Class 4 Buses	45	0.3%	Motorcoaches
Class 5 Two-Axle, Six-Tire, Single-Unit Trucks	170	1.0%	Single-Unit Trucks
Class 6	53	0.3%	

Three-Axle Single-Unit Trucks			(1.3%)
Class 7 Four or More Axle Single-Unit Trucks	5	0.0%	
Class 8 Four or Fewer Axle Single-Trailer Trucks	6	0.0%	Single-Trailer Trucks (12.4%)
Class 9 Five-Axle Single-Trailer Trucks	2,074	12.4%	
Class 10 Six or More Axle Single-Trailer trucks	1	0.0%	
Class 11 Five or Fewer Axle Multi-Trailer Trucks	118	0.7%	Multi-Trailer Trucks (0.9%)
Class 12 Six-Axle Multi-Trailer Trucks	30	0.2%	
Class 13 Seven or More Axle Multi-Trailer Trucks	0	0.0%	
Totals	**16,757**	**100%**	

1.5. Traffic Accident History

Table 3 summarizes the traffic accident history on the left-hand horizontal curve just prior to the crash location in the westbound direction for the last 5 years. The traffic accident summary in this segment indicated only 3 accidents and none of the accidents involved wet or slippery road conditions. There were no injuries as a result of the 3 accidents.

Table 3 – Traffic accident summary on the left-hand horizontal curve just prior to the crash location in the westbound direction of I-70/76 for the last 5 calendar years (2014 through 2019).

Date	Time	Direction	Description	Injured
7/18/2014	8:10 p.m.	WB	Unit 1 was traveling westbound on I-70/76 when a piece of debris flew up and struck the front causing minor damage.	0
10/31/2015	12:50 p.m.	WB	Unit 1 operator lost control of vehicle after the front driver side tire blew out.	0
6/23/2019	5:35 a.m.	WB	The right front undercarriage of Unit 1 struck a boulder on the roadway.	0

2. Roadway Data

2.1. Speed Limit

The posted regulatory speed limit for the Pennsylvania Turnpike was 70 miles per hour (mph). An advisory speed sign of 55-mph[1] was posted approximately 2,112 feet prior to the crash site as illustrated in **Figure 3**.[2] Numerous advisory speed signs of 55-mph were posted along the Pennsylvania Turnpike warning motorists to reduce their speed before entering horizontal curves.

Figure 3 – Advisory speed sign of 55-mph was posted approximately 2,112 feet prior to the crash site.

2.2. Dynamic Message Signs

Table 4 summarizes the dynamic message sign (DMS) locations and messages that had been displayed in the westbound direction of the Pennsylvania Turnpike prior to the crash. The DMS signs began displaying these messages at approximately 10 p.m. on January 4, 2020, about 5.5 hours before the crash.

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[1] The 55-mph advisory speed is not a regulatory speed limit. Pennsylvania State Police cannot cite the driver for speeding since the 55-mph advisory speed is not regulatory. However, Pennsylvania State Police can cite the driver for driving too fast for conditions. The 55-mph advisory sign is intended as warning for passenger cars and trucks to slow down to a lower speed, from 70-mph to 55-mph, before entering horizontal curves.

[2] Refer to NTSB – Office of Research and Engineering *Video Study Report* in the docket regarding motorcoach speed estimate and deceleration rate of the FedEx Ground truck.

Table 4 – Dynamic message sign (DMS) locations and messages that had been displayed in the westbound direction of the Pennsylvania Turnpike prior to the crash.

<table>
<tr><th>DMS Milepost Location</th><th>Distance to Crash (miles)</th><th>Direction</th><th colspan="2">Message</th></tr>
<tr><td>92.7</td><td>6.6</td><td>Westbound</td><td rowspan="5">Winter Weather Conditions</td><td rowspan="5">Use Caution</td></tr>
<tr><td>113.8</td><td>27.7</td><td>Westbound</td></tr>
<tr><td>123.6</td><td>37.5</td><td>Westbound</td></tr>
<tr><td>149.4</td><td>63.3</td><td>Westbound</td></tr>
<tr><td>163.0</td><td>76.9</td><td>Westbound</td></tr>
</table>

2.3. Horizontal Alignment

The horizontal alignment immediately prior to the crash location consisted of a 1,296-foot radius curve to the left for motorists travelling in the westbound direction of the Pennsylvania Turnpike.[3] **Figure 4** illustrates the 1,296-foot radius curve immediately prior to the crash location and the approximate location of the advisory sign alerting motorists to reduce their speed to 55-mph before entering the horizontal curve.

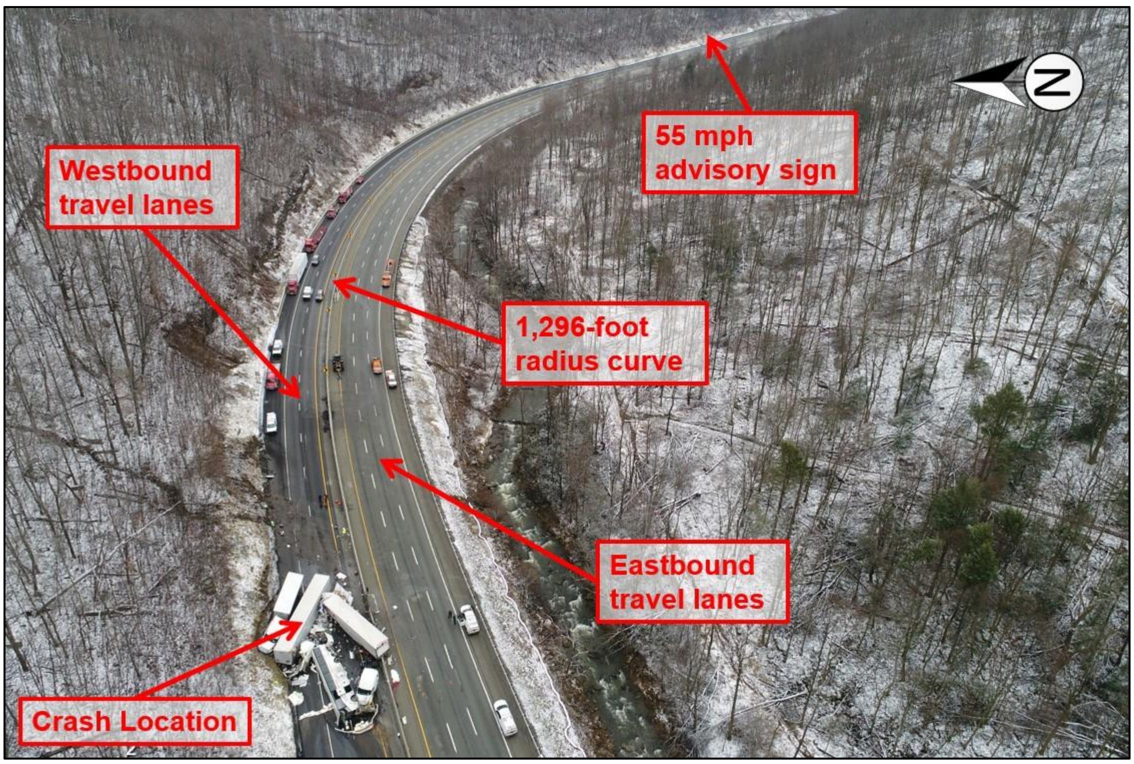

Figure 4 – 1,296-foot radius curve to the left for motorists travelling in the westbound direction of the Pennsylvania Turnpike prior to the crash location.

[3] The super-elevation rate in the westbound direction transitions from a full 8% super-elevation rate sloping toward the median to a 2% super-elevation rate sloping toward the shoulders in the area of the motorcoach crash. Additional information on the horizontal curve and super-elevation rate can be found in the *Technical Reconstruction Group Chairman's Factual Report*.

2.4. Vertical Alignment

The vertical alignment in the vicinity of the crash consisted of a downgrade slope negative (-) 3.008% grade for motorists travelling in the westbound direction.

2.5. Typical Section

The typical section for the Pennsylvania Turnpike in the vicinity of the crash consisted of 2 westbound travel lanes. Each of the westbound travel lanes was approximately 12-feet wide. The total width of the 2 westbound travel lanes was approximately 24 feet wide.[4]

A paved shoulder existed adjacent to the rightmost travel lane and leftmost travel lane in the westbound direction of travel. The paved shoulder adjacent to the rightmost travel lane was approximately 12-feet wide. The paved shoulder adjacent to the leftmost travel lane was approximately 8-feet wide.

A 52-inch-tall concrete barrier existed in the median, that separated the westbound travel lanes and the eastbound travel lanes. A 52-inch-tall concrete barrier also existed adjacent to the outside paved shoulder in the westbound direction of travel along the 1,296-foot radius curve. The 52-inch-tall concrete barrier adjacent to the outside paved shoulder in the westbound direction of travel terminated approximately 377 feet prior to the crash location.

The PTC provided the following information regarding the location of the 52-inch-tall concrete barrier adjacent to the outside paved shoulder in the westbound direction:[5]

> *"The location of the single face barrier along the back edge of shoulder was selected due to the characteristics of the slope off the back edge of shoulder, not the curvature of the roadway. In general, the barrier was installed at locations where the cut slope is steeper than 1.5:1 and or in areas of rock outcroppings."*

Drainage grates were located along the back edge of the outside paved shoulder to capture stormwater runoff from the cut slopes. The outside paved shoulder adjacent to the rightmost travel lane was sloped at a 2% downward rate toward the cut slopes preventing stormwater runoff from encroaching into the travel lanes. Drainage grates were also located along the back edge of the inside shoulder adjacent to the 52-inch-tall concrete barrier in the median. The drainage grates were connected by 30-inch and 18-inch corrugated metal pipes located under the westbound and eastbound travel lanes for the purpose of stormwater runoff conveyance to a nearby stream located south of the Pennsylvania Turnpike.

2.6. Rumble Strips

Grooved longitudinal rumble strips existed in the paved shoulder adjacent to the rightmost travel lane and leftmost travel lane in the westbound direction of travel. The rumble strip

[4] In the eastbound direction (not the direction in which the crash occurred) 3 travel lanes existed. In the eastbound direction, there was a long upward slope that extended from MP 82.7 to MP 93.0. For this reason, the PTC installed a third lane (right lane) for trucks and other slow-moving traffic. Signs existed in the eastbound direction that indicated "Left Lane No Trucks".

[5] Email received from the PTC dated March 9, 2020.

dimensions were approximately 16-inches long and 7-inches wide. The rumble strips were spaced approximately 12-inches apart measured from the centerline of the rumble strip. The depression of the rumble strip into the pavement was approximately 1/2-inch. The rumble strips were offset from the edge of traveled way by approximately 4-inches.

2.7. Highway Markings

The highway marking separating the paved shoulder from the rightmost travel lane consisted of a temporary 4-inch wide solid white polyurea line.[6] The highway markings separating the 2 westbound travel lanes consisted of temporary 4-inch wide broken white polyurea lines that were each 10 feet long and had 30 foot spacing between them.[7] The highway marking separating the paved shoulder from the leftmost travel lane consisted of a 6-inch-wide solid yellow permanent preformed patterned line.

2.8. Highway Lighting

No highway lighting was available in the westbound and eastbound direction of the Pennsylvania Turnpike in the vicinity of the crash.

2.9. Regulatory and Warning Signs Prior to the Crash

Table 5 summarizes the regulatory and warning signs located in the 4 miles leading up to the crash in the westbound travel lanes of the Pennsylvania Turnpike.

Table 5 – Regulatory and warning signs located in the 4 miles leading up to the crash in the westbound travel lanes of the Pennsylvania Turnpike.

Signage	Number and Description of Signage	Milepost (Crash Site MP 86.1)	Distance from Signage to Crash	Signage Measurements
	1 – Hill Sign 1 – Next 2 Miles Sign	MP 86.15	264 feet	48” x 48” 30” x 24”
	14 – Shoulder Chevron signs	MP 86.15 to MP 86.40	264 feet to 1,584 feet	36” x 48”
	1 – Left Winding Road Sign	MP 86.50	2,112 feet	48” x 48” 30” x 30”

[6] Polyurea highway markings are common and used for the initial coating and as a repair/maintenance coating because of its increased reflectivity, fast curing ability, impact resistance, and elongation and tensile strength. The temporary lines were used as part of the recent resurfacing project completed in September 2019.

[7]The permanent solid and broken white lines would be 6-inches wide. The permanent broken white lines would be 15 feet long and have 25-foot spacing between them.

	1 – 55 MPH Advisory Speed Sign			
	7 – Median Chevron signs	MP 86.70 to MP 86.82	3,168 feet to 3,802 feet	36” x 48”
	1 – Fallen Rocks Sign	MP 87.0	4,752 feet	48” x 48”
	1 – Hill Sign 1 – Next 3 Miles Sign	MP 87.17	5,650 feet (1.07 miles)	48” x 48” 30” x 24”
	1 – Right Winding Road Sign 1 – 55 MPH Advisory Speed Sign	MP 87.30	6,336 feet (1.2 miles)	48” x 48” 30” x 30”
	1 – Hill Sign 1 – Next 4 Miles Sign	MP 88.15	10,824 feet (2.05 miles)	48” x 48” 30” x 24”
	1 – Hill Sign 1 – Next 5 Miles Sign	MP 89.16	16,157 feet (3.06 miles)	48” x 48” 30” x 24”
	1 – Keep Right Except to Pass Sign	MP 89.30	16,896 feet (3.2 miles)	48” x 60”
	1 – 70 MPH Speed Limit Sign	MP 89.90	20,064 feet (3.8 miles)	48” x 60”
	1 – Right Reverse Curve Sign	MP 90.05	20,856 feet (3.95 miles)	48” x 48” 30” x 30”

	1 – 60 MPH Advisory Speed Sign			

2.10. Friction Numbers and Rutting in Westbound Travel Lanes

Tables 6 and 7 summarizes the friction numbers and rutting in the right lane of the westbound travel lanes of the Pennsylvania Turnpike in the vicinity of the crash. The PTC conducted the friction and rutting tests on October 14, 2019, after completion of a recent resurfacing project, performed in September 2019, that placed a new two-inch wearing course in the westbound travel lanes in the vicinity of the crash.

The PTC followed Pennsylvania Department of Transportation (PennDOT) guidance[8] regarding evaluation of ribbed and smooth tire test results which indicated the following:[9]

> *"Actions should be recommended for those sections that meet ribbed tire test results that yield skid numbers of 35 or less; or smooth tire test results that yield skid numbers of 20 or less."*

Table 6 – Friction numbers in the right lane of the westbound travel lanes of the Pennsylvania Turnpike in the vicinity of the crash.[10]

Milepost		Friction Numbers	
From	**To**	**L-Ribbed**	**R-Smooth**
85.0	85.1	45.95	44.5
85.1	85.2		44.65
85.2	85.3	44.25	
85.3	85.4		39.1
85.4	85.5	43.35	
85.5	85.6	43.5	38.8
85.6	85.7		41.5
85.7	85.8	43.45	
85.8	85.9		32.75
85.9	86.0	45.55	40.05
86.0	86.1	48	
86.1	86.2		39.75
86.2	86.3	44.25	
86.3	86.4		41.25

[8] Pennsylvania Department of Transportation District Highway Safety Guidance Manual, Section 5.6.18 Wet Pavement Crashes, May 2019.

[9] The Pennsylvania Department of Transportation rating system are for passenger cars only and do not set minimum frictional quality standards for commercial vehicle tires on wet pavement.

[10] The PTC used a locked-wheel skid friction tester that meets all specifications set forth in ASTM E-274, Standard Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire. Tests were performed using an ATSM E-501 ribbed testing tire in the left wheel path and an ASTM E-524 smooth testing tire in the right wheel path of the right lane. Tests were performed at a constant speed of 40 mph as the locked test wheels are dragged over a wetted pavement surface. ASTM International is a group of scientists and engineers that develop standard test methods, formerly known as the American Society for Testing and Materials.

86.4	86.5	43.9	41.8
86.5	86.6	40.9	
86.6	86.7		41.8
86.7	86.8	43.25	
86.8	86.9		35.1
86.9	87.0	42.85	42.15
87.0	87.1	43.5	

Table 7 – Rutting in the right lane of the westbound travel lanes of the Pennsylvania Turnpike in the vicinity of the crash.[11]

Milepost			Rutting			
From	To	Rut Distance (miles)	LWP Avg Rut (inch)		RWP Avg Rut (inch)	
85.0	85.1	0.1	0.18	Very Good	0.18	Very Good
85.1	85.2	0.1	0.16	Very Good	0.16	Very Good
85.2	85.3	0.1	0.13	Very Good	0.10	Very Good
85.3	85.4	0.1	0.11	Very Good	0.10	Very Good
85.4	85.5	0.1	0.16	Very Good	0.15	Very Good
85.5	85.6	0.1	0.15	Very Good	0.23	Good
85.6	85.7	0.1	0.15	Very Good	0.18	Very Good
85.7	85.8	0.1	0.16	Very Good	0.17	Very Good
85.8	85.9	0.1	0.15	Very Good	0.20	Good
85.9	86.0	0.1	0.19	Very Good	0.16	Very Good
86.0	86.1	0.1	0.15	Very Good	0.21	Good
86.1	86.2	0.1	0.15	Very Good	0.22	Good
86.2	86.3	0.1	0.15	Very Good	0.21	Good
86.3	86.4	0.1	0.16	Very Good	0.17	Very Good
86.4	86.5	0.1	0.17	Very Good	0.18	Very Good
86.5	86.6	0.1	0.17	Very Good	0.16	Very Good
86.6	86.7	0.1	0.15	Very Good	0.13	Very Good
86.7	86.8	0.1	0.13	Very Good	0.14	Very Good
86.8	86.9	0.1	0.15	Very Good	0.14	Very Good
86.9	87.0	0.1	0.16	Very Good	0.16	Very Good
87.0	87.1	0.1	0.14	Very Good	0.15	Very Good

[11] Classification of rut depths accessed on the internet at the following link: http://www.teed.ee/en/services/testing-and-measurement/measurements/road-profile/rut-depth-measurements/. Pavements with rut depths of less than .20 inches are considered to be very good. Pavements with rut depths of .20 - .40 inches are considered to be good. Pavements with rut depths of .40 - .80 inches are considered to be fair. Pavements with rut depths of .80 – 1.2 inches are considered to be poor. Pavements with rut depths greater than 1.2 inches are considered to be very poor.

3. Maintenance and Weather Data

3.1. PTC Remote Weather Station

Table 8 summarizes the weather information from the PTC remote weather station located at MP 99.65 from January 4, 2020, at 6 p.m. through January 5, 2020, at 4 a.m.

Table 8 – Weather information from the PTC remote weather station located at MP 99.65 from January 4, 2020, at 6 p.m. through January 5, 2020, at 4 a.m.

Date	Time	Air Temperature (F)	Precipitation Intensity	Precipitation Accumulation (inches per 24-hour)[12]
1/4/2020	6 p.m.	33	None	0.24
1/4/2020	7 p.m.	32	Slight	0.23
1/4/2020	8 p.m.	31	Slight	0.24
1/4/2020	9 p.m.	30	Slight	0.22
1/4/2020	10 p.m.	30	Slight	0.21
1/4/2020	11 p.m.	29	Slight	0.21
1/4/2020	12 p.m.	28	Slight	0.20
1/5/2020	1 a.m.	26	Slight	0.20
1/5/2020	2 a.m.	25	Slight	0.22
1/5/2020	3 a.m.	24	Slight	0.21
1/5/2020	4 a.m.	24	Slight	0.21

3.2. Donegal Maintenance Facility

The total distance of the I-70/I-76/I-276 Pennsylvania Turnpike East/West Mainline was approximately 356 miles, beginning at MP 0 to MP 356. **Table 9** summarizes the maintenance facility names and their responsibility limits along the I-70/I-76/I-276 Pennsylvania Turnpike. The Donegal Maintenance Facility was responsible for the maintenance of the I-70/I-76 Pennsylvania Turnpike from MP 75.2 through MP 100. The crash occurred at MP 86.1 westbound.

Table 9 – Maintenance facility names and their responsibility limits along the I-70/I-76/I-276 Pennsylvania Turnpike.

Maintenance Facility Names	Responsibility Limits
Homewood	MP 0 to MP 24.8
Gibsonia	MP 24.8 to MP 49.3
Harrison City	MP 49.3 to MP 75.2
Donegal	MP 75.2 to MP 100.0 (Crash site MP 86.1)
Somerset	MP 100.0 to MP 122.2
Kegg	MP 122.2 to MP 145.5

[12]The precipitation accumulation in inches per 24-hour are rolling averages for precipitation.

Everett	MP 145.5 to MP 168.4
Burnt Cabins	MP 168.4 to MP 201.3
Newville	MP 201.3 to MP 226.4
New Cumberland	MP 226.4 to MP 253.3
Mt. Gretna	MP 253.3 to MP 276.2
Bowmansville	MP 276.2 to MP 302.7
Devault	MP 302.7 to MP 326.3
Plymouth Meeting	MP 326.3 to MP 339.1
Trevose	MP 339.1 to MP 356.42 and MP H-40.83 to MP H-43.33

Table 10 summarizes the truck numbers and their responsibility limits for applying salt on the I-70/I-76 Pennsylvania Turnpike from January 4 and 5, 2020 in the Donegal Maintenance Facility. Truck number 75-728 was responsible for applying salt from MP 83.5 to MP 88.8, a distance of approximately 5.3 miles.

Table 10 – Truck numbers and their responsibility limits for applying salt on the I-70/I-76 Pennsylvania Turnpike from January 4 and 5, 2020 in the Donegal Maintenance Facility.

Truck Numbers	Responsibility Limits
75-731	MP 75.2 to MP 83.5
75-728	MP 83.5 to MP 88.8 (Crash site MP 86.1)
75-729	MP 88.8 to MP 94.3
75-669	MP 94.3 to MP 100.0

Table 11 summarizes the four passes that truck number 75-728 made prior to the crash in the westbound direction in the vicinity of MP 86.1 on January 4 and 5, 2020 that includes time and day, salt per lane mile, and lane in which the truck was traveling.[13]

Table 11 – Four passes that truck number 75-728 made prior to the crash in the westbound direction in the vicinity of MP 86.1 on January 4 and 5, 2020.

Truck Number	MP / Direction	Time / Day	Salt per Lane Mile	Lane
75-728	86.1 / WB	11:48 p.m. 1/4/2020	450 pounds	Left
75-728	86.1 / WB	1:48 a.m. 1/5/2020	300 pounds	Right
75-728	86.1 / WB	2:20 a.m. 1/5/2020	300 pounds	Left
75-728	86.1 / WB	3:20 a.m. 1/5/2020	300 pounds	Right

[13] Each truck is equipped with a telematics system that includes a vehicle tracking device that allows the sending, receiving, and storing of telemetry data.

3.3. Specifications for Single Axle Salt Truck Number 75-728

Figure 5 illustrates Pennsylvania Turnpike Commission single axle truck number 75-728, the truck used in applying salt in the westbound direction of I-70/76 in the vicinity of the crash. The truck has a straight blade plow in the front and the salt is dispensed in the back of the truck through a gate, controlled by the driver using a valve. The salt falls on to a spinner in which the setting is also controlled by the driver. The spinner setting in the vicinity of the crash was set at 40 which means the salt hits the entire lane in which the truck is traveling and portions of the shoulder and adjacent lane.[14] The application rate of salt was set at 450 pounds per lane mile at approximately 11:00 p.m. on January 4, 2020 and was changed to 300 pounds per lane mile at approximately 1:00 a.m. on January 5, 2020.[15]

A typical Pennsylvania Turnpike Commission single axle truck holds approximately 10 cubic yards of salt. The gross vehicle weight of the single axle truck was approximately 43,000 pounds. The usable capacity of the fuel tank was approximately 70 gallons. A 7-inch-wide color touch screen controller display was available to the driver capable of operating the spinner setting and application rate.

Figure 5 – PTC single axle truck number 75-728, the truck used in applying salt in the westbound direction of I-70/76 in the vicinity of the crash.

3.4. Witness Interviews of PTC Truck Drivers and Supervisors

NTSB investigators conducted witness interviews with the PTC truck drivers and supervisors who were responsible for applying salt on the I-70/I-76 Pennsylvania Turnpike on January 4 and 5, 2020 in the Donegal Maintenance Facility. A copy of the entire transcribed document for each witness interview can be found in the docket for this investigation.

Specific information taken from the witness interviews included the following:

[14] The spinner setting can be set from 0 to 99. A spinner setting of 40 with a truck speed of 25 to 30 mph means the salt hits the entire lane in which the truck is traveling and portions of the shoulder and adjacent lane.

[15] The application rate of salt can be set from 0 to 999 pounds per lane mile.

“***Brittany Clark – Truck Driver Operator, Donegal Maintenance – Date of Interview: Friday, January 10, 2020***[16]

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BY MR. WALSH:

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Q. Did you encounter any difficulties with the treatment operation on I-70 in the vicinity of the crash?
A. No. No.
Q. Did you, did you see any black ice or slippery conditions on I-70 in the vicinity of the crash?
A. No.
Q. Did you see any black ice or slippery conditions anywhere on I-70 --
A. No.

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MR. ACCETTA: I know, I think, Dan had asked, but as you approached and saw the accident on the eastbound lanes, what was the road surface like that you remember?
MS. CLARK: Wet.

Chris Clark – Truck Driver Operator, Donegal Maintenance – Date of Interview: Friday, January 10, 2020[17]

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Q. Did you encounter any difficulties with the treatment operation that night?
A. No. I mean, just hard at work hitting it. I mean, there's nothing you can do, just keep chasing it.
Q. Did you see any black ice or slippery conditions on I-70 on the day of the crash?
A. No.

John Patrick – Section Foreman, Donegal Maintenance – Date of Interview: Friday, January 10, 2020

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BY MR. WALSH:

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[16] Truck driver operator of truck number 75-728.
[17] Truck driver operator of truck number 75-718.

Q. What was the weather report leading up to the crash?
A. They were calling for -- AccuWeather was calling for a

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dusting up to an inch in the highest elevation, through Sunday morning.

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Q. Okay. What treatment was determined by the Donegal Maintenance Facility in response to this weather report?
A. I don't have my numbers in front of me, but they -- if I remember correctly, Brittany's truck threw two loads prior to the event -- to the accident, so I don't know if they told you, but roughly, if you would run your truck, working it hard, you can get 10 tons off in an hour. Usually, for every hour on an 07, which is a spreader, that's one load of salt. Can you get if off quicker? Yeah, but you'll make a mess. You're just going to pound salt. So that's the rule of thumb's an hour. So she had, in the -- from 11:00 until 3:30, she had thrown two loads of salt, if I remember what she told me. Lee had one off, and I don't remember what Chris had off, because he did go down through her section once.
Q. So the treatment was salt?
A. Just salt, yes.

Lee Silvis – Truck Driver Operator, Donegal Maintenance – Date of Interview: Friday, January 10, 2020[18]

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Q. Okay. Did you encounter any difficulties with the treatment operation on I-70 in the vicinity of the crash?
A. No, sir.
Q. Did you see any black ice or slippery ice --
A. No.
Q. -- icing conditions on I-70?
A. No, sir.

Todd Tilson – Superintendent, Donegal Maintenance – Date of Interview: Friday, January 10, 2020

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Q. Okay. In terms of your training of your maintenance

[18] Truck driver operator of truck number 75-731.

operators, what training do they need to go through to become a maintenance operator?

A. We send them to our training facility and they get truck and loader training, which will include plows, spreaders, on how to just drive the truck, back the truck up, how to drop the plowing spreader, how to adjust your spreader for the different applications and rates. So they get a general thing with the whole trucks and their functions on it, and then we typically -- when they're a brand-new hire we will put them with a seasoned veteran and leave them watching a seasoned veteran out there, and then we'll leave them to drive and put somebody with them until the foreman, the assistant foreman, or whomever feels that they're comfortable to go on their own.

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Q. Have you had any problems in the past with operators not spreading the material that's in their truck? I mean, any --

A. No.

Q. -- have any issues with that in the past?

A. No. Our issue is, from a supervisor standpoint, they put down a lot of material and they're pushing with the MS4, the environmental. So there's a lot of material that the turnpike puts down. So we've never had a problem with them not putting it down.

Q. Not a problem with theft or any issues like that?

A. No.

Q. What other treatments do you use besides salt?

A. We -- our typical winter treatments for the roadway would consist of salt, anti-skid material, salt brine, and a liquid calcium.

Mark Zambanini – Maintenance Utility Worker, Donegal Maintenance – Date of Interview: Friday, January 10, 2020

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BY MR. WALSH:

Q. Did you see any black ice or slippery conditions on I-70 in the vicinity of the crash during your run?

A. None. None.

Q. Did you see any black ice or slippery conditions anywhere on I-70 during your run?

A. None."

3.5. PTC Snow and Ice Removal Procedures

Table 12 summarizes the PTC weather levels determined by maximum forecast range.[19] The weather levels for snow and ice accumulation events were broken into 4 basic events: Level 1 Basic Event, Level 2 Medium Event, Level 3 Major Event, and Level 4 Extreme Event. The slight precipitation of 0.20 to 0.24 inches per 24-hour would not meet any of the classifications in **Table 12.**

Table 12 – PTC weather levels determined by maximum forecast range.

Weather Event	Level 1 Basic Event	Level 2+	Level 2 Medium Event	Level 3 Major Event	Level 4 Extreme Event
Snow	> ½ inch per hour OR > 2 inches in 12 hours	Requires Pre-Event Meeting	> 1 inch per hour OR > 5 inches in 12 hours OR > 7 inches in 24 hours	> 2 inches per hour OR > 12 inches in 24 hours OR < ½ mile visibility	> 3 inches per hour OR > 18 inches in 24 hours OR < ¼ mile visibility OR Unplowed 5 inches
Ice Accumulation	N/A	Requires Pre-Event Meeting	< ¼ inch accumulation OR Formation on ramps, roadway, or bridges	> ¼ inch accumulation OR Enough accumulation to cause damage to trees or powerlines	> ½ inch accumulation OR Powerlines, trees or other objects coming down due to ice

Table 13 summarizes the PTC weather level travel restrictions determined by maximum forecast range.

[19] Weather Event Management Playbook, Pennsylvania Turnpike Commission, August 2017, Version 1.2, page 8.

Table 13 – PTC weather level travel restrictions determined by maximum forecast range.

Weather Event	Level 1 Basic Event	Level 2 Medium Event	Level 3 Major Event	Level 4 Extreme Event
Snow	N/A	Consider Speed Restrictions	• Consider Speed Restrictions • Consider Closing Slip Ramps • Single Lane Entry • Ban At-Risk Vehicles	• Consider Speed Restrictions • Consider Closing Slip Ramps • Single Lane Entry • Ban At-Risk Vehicles • Potential Turnpike Closure
Ice Accumulation	N/A	Consider Speed Restrictions	• Consider Speed Restrictions • Consider Closing Slip Ramps • Single Lane Entry • Ban At-Risk Vehicles	• Consider Speed Restrictions • Consider Closing Slip Ramps • Single Lane Entry • Ban At-Risk Vehicles • Potential Turnpike Closure

The following information was taken from the PTC Maintenance Manual:[20]

"2.1 Introduction

The overall objective in Turnpike maintenance planning is to establish an adequate maintenance program capable of accommodating all travel in an orderly, safe and efficient manner. Roads and structures must be maintained with the least amount of inconvenience to the traveling customer, the greatest degree of safety and with full consideration of the property owners adjacent to the Turnpike.

[20] PTC Maintenance Manual, Final September 23, 2013.

3.5 Winter Activities during December, January, February and March

3.5.1 Objectives and Definitions

The primary maintenance objective during the winter months is to keep all turnpike roadways in a safe and passable condition. Operations will proceed as quickly and efficiently as possible but within the limitations imposed by weather conditions, availability of resources, environmental concerns and employee safety requirements.

*A **spreading storm** is a winter storm having a minimal accumulation of snow, sleet, or freezing rain or a combination of the three. Application and reapplication of deicing and/or anti-skid materials will occur when warranted during the course of the storm. Plowing may be required to clear snow or slush from the highway during the storm and/or after the storm has ended.*

*A **plowing storm** is a winter storm having greater accumulation of snow, sleet or freezing rain or a combination of the three. Plowing will be the predominant activity to remove snow and/or ice from the highway. Application of deicing and/or anti- skid materials will normally occur at the beginning of the storm to prevent the bonding of snow and/or ice to the pavement surface. Reapplication of deicing materials and/or anti-skid may be needed during the storm as warranted to ensure traction by vehicles and/or to prevent bonding of snow and/or ice to the pavement surface.*

3.5.4 Material Applications and Storm Plowing Procedures

Spreading Operation

- *Roads may be treated with straight salt or a chemical enhancer.*
- *A salt/anti-skid mix can be used when conditions are such that straight chemical applications are not effective due to lower temperature or additional traction is needed.*
- *Although the decision to use a straight chemical application or a salt/anti-skid mix is basically a field decision, following the recommended application rates will help to provide a consistent level of service while conserving materials.*
- *Liquid enhancers may be used as pre-wetting agents to augment the activation of the salt. Sodium chloride (salt brine) should primarily be used as the pre-wetting agent when the temperature is above 15 degrees. When the temperature falls below 15 degrees, calcium chloride should be used as the pre wetting agent. With both materials, the recommended application rate is between 6 and 12 gallons per ton.*
- *Ultimately, field personnel must decide the final selection of deicing materials or a combination of materials based on availability and experience.*

Anti-icing

Anti-icing is the application of a chemical freezing point depressant to prevent bonding between frozen precipitation or frost and a pavement surface. At temperatures below 15ºF, falling snow is generally dryer which allows it to blow over the roadway surface. Under these conditions, anti-icing is not recommended. The decision to perform anti- icing may be made by using the PTC's Anti-Icing Decision Tree contained in Appendix J.

Appendix E

Roadway Condition Descriptions

In order to attain a common understanding of winter road conditions, the following conditions and definitions have been established. These condition descriptions represent the predominate condition of the road being reported.

Condition	***Description***	***Photograph***
Condition 1*: Clear - Dry/wet pavement surface is maintained at all times.*	*This condition represents time periods when the pavement and air temperatures are above freezing with or without precipitation. This condition may also exist when temperatures are at or below freezing and traffic is able to maintain speeds at or near posted limits. (An example would be during the cleanup phase of a minor event when roads are wet and reports indicate they are freezing dry with traffic speeds returning to normal.)*	
Condition 2*: Wet with Freezing Conditions - Wet pavement surface is the general condition with air temperatures near or below freezing. There are occasional areas having snow or ice accumulations resulting from drifting, sheltering, cold spots, frozen melt-water, etc.*	*This condition should be utilized during periods of precipitation when air and/or pavement temperatures are at 34 degrees and are expected to drop to freezing or below freezing during the course of the storm. This condition should also be used when wet or light snow cover conditions are expected to persist for two or more hours with freezing temperatures.*	

***Condition 3**: Snow and/or Slush Covered - Accumulations of loose snow or slush are regularly found on the pavement surface. Light to moderate snow cover may be present in some areas (up to 2 inches on secondary routes).*	*Some snow packed and/or icy conditions may be present but do not represent predominate road conditions on the interstates. Reduced travel speeds may be required due to slick road conditions.*	
***Condition 4**: Snow Packed / Significant Snow Cover - The pavement surface has continuous stretches of packed snow with or without loose snow on top of packed snow and ice. Significant snow accumulations are present in some areas (2 – 5 in).*	*This condition may become prevalent during periods of heavy snowfall. Speed limit reductions and vehicle restrictions should be considered when this becomes the predominate condition on the roadway.*	
***Condition 5**: Icy - The pavement surface is predominantly covered with ice and packed snow. There may be loose snow or sleet on top of the icy or packed snow surface.*	*This condition may be the result of sleet, freezing rain, snow melt or refreeze. Reduced travel speeds may be necessary and motorist should be advised to limit travel or travel at significantly reduced speeds until conditions improve.*	
***Condition 6**: Impassable - The road is temporarily impassable to most or all vehicles. This may be the result of severe weather (low visibility, blowing snow, etc.) or road conditions [drifting, excessive unplowed snow (5+ inches), avalanche potential or actuality, glare ice, etc.]*		

Appendix H

Application Rates

PTC's Application Rates Guideline			
Scenario	*Surface Temperature (F)*	*Application Rate (#'s / Lane Mile)*	*Pre-Wet Agent*
1	*30° & Up*	*250 #'s*	*NaCl*
2	*20° to 29°*	*300 #'s*	*NaCl*
3	*19° & Below*	*350 #'s*	*CaCl*
Note:	*Anti-Skid can be used when snow pack or icing conditions are encountered or when the temperature falls below 0° F. Mix Ratio should be 50 / 50 and the application rates should be between 350 #'s and 700 #'s per Lane Mile."*		

3.6. Other States Policies for Snow and Ice Removal Procedures

NTSB staff researched other states policies for snow and ice removal procedures, including the PennDOT, and the neighboring states of Pennsylvania that included the Ohio Turnpike and Infrastructure Commission, New York State Thruway Authority, New Jersey Turnpike Authority, and Maryland Transportation Authority.

3.6.1. Pennsylvania Department of Transportation (PennDOT)

The following information was taken from the PennDOT Winter Services Maintenance Manual:[21]

"4.5 Winter Activities During December, January, February and March

4.5.1 Objectives and Definitions

The primary maintenance objective during the winter months is to keep all state roads in a safe and passable condition. Operations will proceed according to priorities of routes as quickly and efficiently as possible, but within the limitations imposed by weather conditions, availability of resources, environmental concerns, and employee safety requirements.

Plowing operations are generally initiated after one to two inches of snow have fallen and continue until the storm has ended.

4.5.3 Levels of Service

First priority routes (interstates and limited access highways and ramps) shall be maintained in an operable condition with a minimum of two traffic lanes passable in each direction after the cessation of significant snowfall/freezing rain.

[21] PDOT Maintenance Manual, Chapter 4: Winter Services, revised April 2019.

The planned schedule to service the interstate system shall be based on an average interval of two hours to manage a moderate snowstorm. Plowing and spreading should continue until traffic lanes are mostly free of snow and ice full width and shoulder area plowed as soon as practical after a storm has ended.

First & Second Priority Routes Anti-Skid/Salt Mix Application Rate Guidelines								
	100% Salt lb / snow lane mile		***25 / 75 (Anti-Skid/Salt Mix) lb / snow lane mile***		***50 / 50 (Anti-Skid/Salt Mix) lb / snow lane mile***		***75 / 25 (Anti-Skid/Salt Mix) lb / snow lane mile***	
Surface Temp. (F)	***Dry***	***Pre wet***	***Dry***	***Pre wet***	***Dry***	***Pre wet***	***Dry***	***Pre wet***
Above 25	*120*	*100*	*140**	*120**	*170**	*150**	*200**	*180**
15 – 25	*210*	*170*	*230*	*180*	*250*	*200*	*310*	*270*
10 – 14	**	**	*250*	*200*	*300*	*250*	*350*	*300*
Below 10	**	**	**	**	**	**	**	**

This chart is general statewide guidance and per snow lane mile. If treating down the center of a highway, application rates should be doubled. Consider lowering rates on subsequent passes. Detailed federal guidance by type of event is located in PUB 23A Appendix H. Local decision on type of roadway and ice and snow conditions will dictate application rate decisions.

* *Consideration should be made not to use antiskid mixes for events with temperatures 25 degrees and rising.*
** *Straight salt not recommended below 14 degrees.*

4.5.5 Material Applications, Plowing Procedures and Other Winter Activities

***Sodium Chloride** – The use of sodium chloride (common salt) combined with snow plowing is the most effective, most economical and safest snow and ice control method currently available. Salt is most effective for melting purposes at temperatures above 20 degrees F., with reduced melting ability as the temperature drops. In general, the purpose of salt is to (1) reduce adherence of snow to the pavement, (2) keep the snow in a "mealy" condition and thereby permit nearly full removal by plowing, and (3) prevent the formation of ice or snow ice (hard pack). Salt is not intended to take the place of snowplows. It is economically and environmentally unacceptable to attempt to melt snow accumulations that are plowable.*

***Calcium Chloride** – Calcium chloride is a chemical which melts ice at lower temperatures than sodium chloride. Flake calcium chloride is used as an additive to abrasives (anti-skid) to prevent freezing in stockpiles, to thaw culverts and catch basins, to help hold the abrasive in place on the pavement and on rare occasions to trigger sodium chloride action. Liquid calcium chloride at 32% strength can be used to pre-wet solid sodium chloride to trigger the chemical reaction at low temperatures. The addition of liquid calcium chloride also is beneficial in retaining* *de-icing material on the roadway by increasing the adhesion of the material to the roadway.*

Abrasives *– Abrasives (fine mineral aggregates) are used primarily for immediate traction on hills, curves, intersections, railroad crossings and other areas and to minimize the use of salt. This does not include sand or fly ash, which is a common misconception. Sodium chloride, calcium chloride or an appropriate mixture of the two are usually added to abrasives in amounts dependent upon existing weather conditions. Stockpiles of abrasives are usually treated with chloride at the start of the season to prevent subsequent freezing."*

3.6.2. Ohio Turnpike and Infrastructure Commission

The following information was taken from the Ohio Turnpike Maintenance Snow & Ice Training:[22]

"Mission Statement

*Maintain a traversable pavement at all times consistent with storm conditions, and to strive to have a pavement in a "wet" condition within one-*hour *of storm cessation.*

Level of Service (LOS)

Categorizing of traffic flow with corresponding safe driving conditions ranges from LOS A to LOS F:

- *LOS A – Drive at posted speeds, mobility between lanes*
- *LOS C – Drive at or near posted speeds, reduced mobility between lanes*
- *LOS E – Cannot maintain posted speed, severely reduced mobility*
- *LOS F – Stop and go, speeds less than 25 mph, no mobility*

[22] Ohio Turnpike Maintenance Snow & Ice Training, Ohio Turnpike & Infrastructure Commission, October 2018.

Treatment Recommendations

Material Application Guidelines for Various Storm Conditions					
Conditions			***Light to Medium Snowfall***	***Medium to Heavy Snowfall***	***Freezing Rain***
Pavement Temp and Drift	***Pavement Surface Condition****	***Recommended Control Application***	***Pre-wet Salt (#'s/lane mile)***	***Pre-wet Salt (#'s/lane mile)***	***Pre-wet Salt (#'s/lane mile)***
>32°F Not expected to fall below 32°F	*Dry*	*None*			
	Wet	*None/Apply Salt*			*200*
	Slush	*Plow and Apply Salt*	*100*	*100*	*200-400*
>32°F Expected to fall below 32°F	*Dry*	*Anti-Ice per Field Directive prior to frosting or storm event*			
	Wet	*Apply Salt***	*100*	*100*	*200-400*
	Slush	*Plow and Apply Salt*	*200*	*200*	*200-400*
24°F to 32°F	*Dry*	*Anti-Ice per Field Directive prior to frosting or storm event*			
	Wet	*Apply Salt***	*100*	*100*	*200-400*
	Slush	*Plow and Apply Salt*	*200*	*200*	*200-400*
15°F to 24°F	*Dry*	*Anti-Ice per Field Directive prior to frosting or storm event*			
	Wet	*Apply Salt***	*100-200*	*300-400*	
	Slush	*Plow and Apply Salt*	*200*	*400*	
Less than 15°F	*Dry*	*Anti-Ice per Field Directive prior to frosting or storm event*			
	Wet	*Apply Salt***	*100-200*	*300-400*	
	Slush	*Plow and Apply Salt*	*200*	*400*	

Notes:
** When storm ceases, maintain patrol until assured that pavement is clear and wet.*
*** As necessary to prevent refreezing."*

3.6.3. New York State Thruway Authority

The following information was taken from the New York State Thruway Authority Winter Maintenance Manual:[23]

"I. Priorities and General Guidelines

The Authority will conduct snow and ice control activities to provide customers a roadway which is safely drivable at a reasonable speed under the weather conditions presented, with the ultimate goal of returning to bare pavement as quickly as possible.

[23]Winter Maintenance Manual, New York State Thruway Authority, Revised October 2019.

C. Ice/Snow Control Chemicals and Abrasives

5. Materials

a. Sodium Chloride – "Rock Salt"

- *Sodium Chloride, also known as rock salt, is used as the principal deicer because it is extremely effective and readily available. The melting action of salt begins with only minor delay at 32°F. However, the melting action at 25°F is delayed approximately 10 minutes, and while it stops melting at -6°F, its effectiveness below 20°F is limited and quite slow. Rock salt requires an outside source of moisture to form a de-icing solution and it takes on heat as it dissolves (endothermic). Using a liquid (brine, MgCl, water, etc.) to pre-wet the salt when spreading will help kick start the time it takes to begin its melting action.*
- *Rock salt is mined, crushed and graded at the mine, treated with anti-caking additives and stockpiled for loading and delivery. Solar salt is produced from evaporation of seawater or brine then processed into a gradation similar to rock salt.*
- *Mixtures of sodium chloride and calcium chloride are used for specific applications as noted in Section IV. If mixed prior to a storm, the materials must be mixed dry and covered with a four inch blanket of dry sand or other moisture proof cover to prevent moisture and air circulation. To prevent caking, spreaders will not be kept loaded with this mixture, especially in a warm garage.*

b. Salt Brine

- *Salt brine is produced through on-site batch units located at some Section Maintenance facilities. These batch units produce salt brine for pre-wetting of salt for de-icing or anti- icing treatments. Once produced and the concentration known (using a hydrometer), the batch can be adjusted to the optimal concentration by adding more water to decrease or dilute the mix or add more salt to increase concentration.*

c. Calcium Chloride

- *Two methods are used to manufacture commercial calcium chloride: 1) extraction from natural brines obtained from deep wells, and 2) by a chemical process (Solvay process) in which sodium chloride is reacted with calcium carbonate to produce sodium carbonate (soda ash) and calcium chloride.*
- *Calcium chloride attracts moisture to obtain the necessary solution to produce melting action. This property means that care should be used when choosing this chemical to anti-ice with. Putting this down on an even moderately humid day (or*

night) when the pavement is cold and dry may produce a wet road where there wasn't one before. Calcium chloride gives off heat as it dissolves (exothermic).
- *Personnel working with calcium chloride must be made aware of its drying effect on leather shoes and gloves as well as skin. Rubber gloves, boots or galoshes, and goggles should be worn at all times when handling this chemical.*

d. *Magnesium Chloride*
- *Brine from the Great Salt Lake is the principal source for this chemical and is used in liquid form for snow and ice control.*
- *Its eutectic temperature is about -28°F at a 21.6% concentration. Its ice melting capacity is about 40% greater than calcium chloride.*

e. *Magnesium Chloride Blends*
- *The chemical makeup of these blends is 50% magnesium chloride (at least 25 to 35% concentration) and 50% agricultural processing residue. The purposes of these blends are: the magnesium chloride brings the temperature at which snow/ice is effectively melted substantially below that of sodium chloride, and the agricultural processing residue provides a corrosion inhibitor.*
- *These blends can be used straight as a direct application for anti-icing or as a pre-wetting treatment for rock salt. The blends can also be used to treat salt stockpiles.*
- *These blends exhibit a corrosion rate at least 70% lower than that of rock salt tested under the same conditions. They must meet or exceed this corrosion rate requirement as established by the National Association of Corrosion Engineers (NACE) Standard TM-01-69 as modified by the Pacific Northwest States Coalition (PNS).*

f. *Calcium Magnesium Acetate (CMA)*
- *There is one currently commercial source for CMA, using the reaction of acetic acid with dolomitic limestone for production. The compound is available in pellets and although not as soluble as calcium or sodium chloride, solutions can be made at point of use for pre-wetting or straight use. Its benefit is that snow is made mealy and will not compact. Its eutectic temperature is about -18°F at a 32.5% concentration.*

g. *CG-90*
- *While very expensive, this product provides improved deicing performance with good protection against corrosion and scaling along the road surface. This product is made of rock salt mixed*

with flake magnesium chloride and monosodium phosphate. This is a dry product and put on the road surface dry.

6. *Abrasives*

Abrasives for snow and ice control shall consist of any of the following materials: sand, gravel or blast furnace tailings (slag sand). The sources must be thoroughly stripped and free of all sod, topsoil, overburden or any other objectionable material or coatings. Sand, gravel or blast furnace tailings shall be from an approved source as described in the most current Internet version of the New York State DOT Materials Bureau's Approved List Sources of Fine & Coarse Aggregates.

The main criteria of the specification is to provide a hard, angular, durable material of a size that will minimize accidental damage to windshields and provide traction, yet not blow off the road. This implies that all particles should pass through the 3/8" sieve size, but particles smaller than the #50 sieve are not effective as they contribute to bridging in the spreader and result in dirtier windshields.

During the winter maintenance season, abrasive stockpiles should be mixed with enough sodium chloride to keep the material from freezing solid. Minimum mixture should be 10:1 by volume for storage.

Abrasives are used as required to improve traction at low temperatures and to assist with break-up of hard pack ice and snow on pavement.

Appendix F – Charts for Spreading

Recommended Application Rates for Solid and Liquid Sodium Chloride (Road Salt)						
Probable Pavement Temperature at Treatment and Before Next Treatment	***Ice Control Chemical Dilution Potential***	***Ice Pavement Bond Characteristics Before Treatment***	***Application Rate***			
			Solid[24]		***Liquid[25]***	
			Pounds Per Lane Mile	***Kilograms Per Lane Kilometer***	***Gallons Per Lane Mile***	***Liters Per Lane Kilometer***
Greater than 32°F (0°C)	*Low*	*Bonded/Packed*	*50-100*	*14-28*	*NR*	*NR*
		Unbonded[26]	*See footnote 20*	*See footnote 20*	*See footnote 20*	*See footnote 20*
	Medium	*Bonded/Packed*	*100-200*	*28-55*	*NR*	*NR*
		Unbonded[27]	*See footnote 21*	*See footnote 21*	*See footnote 21*	*See footnote 21*
	High	*Bonded/Packed*	*200-300*	*55-83*	*NR*	*NR*
		Unbonded	*50-100*	*14-28*	*22-44*	*52-104*
23°F to 32°F (-5°C to 0°C)	*Low*	*Bonded/Packed*	*100-200*	*28-55*	*NR*	*NR*
		Unbonded	*50-150*	*14-42*	*22-66*	*52-155*
	Medium	*Bonded/Packed*	*200-300*	*55-83*	*NR*	*NR*
		Unbonded	*150-200*	*42-55*	*66-88*	*155-207*
	High	*Bonded/Packed*	*300-400*	*83-110*	*NR*	*NR*
		Unbonded	*200-300*	*55-83*	*88-134*	*207-319*
12°F to 22°F (-11°C to -5.5°C)	*Low*	*Bonded/Packed*	*250-400*	*70-110*	*NR*	*NR*
		Unbonded	*100-250*	*28-70*	*NR*	*NR*
	Medium	*Bonded/Packed*	*350-450*	*98-125*	*NR*	*NR*
		Unbonded	*250-400*	*70-110*	*NR*	*NR*
	High	*Bonded/Packed*	*400-500*	*110-140*	*NR*	*NR*
		Unbonded	*350-450*	*98-125*	*NR*	*NR*
Below 12°F (-11°C)	*A. If unbonded, try mechanical removal without chemical. B. If bonded, apply chemical @ 450 to 500 pounds per lane mile. Plow when slushy and retreat when necessary. C. Apply abrasives when necessary.*				*NR*	*NR*
Special Note: Depending on conditions – vehicle spreading speeds should be in the ***30 to 35 mph*** *range.*						

These are starting points. Local experience should refine these recommendations. Pre-wetting chemicals generally allows application rates to be reduced by 15-20%. Application rates for chemicals other than sodium chloride will have to be adjusted. Before applying any ice control chemical, the surface should be cleared of as much snow and ice as possible.
NR = Not Recommended.

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[24] Values include the equivalent dry chemical weight in the pre-wetting solutions.

[25] Values are shown for 23% concentration solution.

[26] If unbonded, try mechanical removal without applying chemicals. If pretreating, use 25-75 lbs/lm of or pre-wet solid chemical or 11-33 gallons/lm of liquid chemical.

[27] If unbonded, try mechanical removal without applying chemicals. If pretreating, use 38-88 lbs/lm of or pre-wet solid chemical or 17-39 gallons/lm of liquid chemical.

3.6.4. New Jersey Turnpike Authority

The following information was taken from the New Jersey Turnpike Authority Winter Operations – Snow and Ice Control Manual:[28]

"Introduction

It is the basic policy to maintain a "BARE PAVEMENT" at all times consistent with storm conditions.

5.3 Materials

A. De-Icing Materials

The choice of material is dependent upon weather and road conditions. Materials available include the following:

1. *Sodium Chloride – Sodium Chloride (salt) is most effective for melting purposes at temperatures above 26 degrees F., becoming slower acting as the temperature drops.*
2. *Magnesium Chloride w/OBFE or Type I – A chemical, which when added to Sodium Chloride (salt), increases de-icing effectiveness at lower temperatures.*
3. *Magnesium Chloride Type II – Magic-O is used as an anti-icing device which is applied to the roadway with a calibrated spray bar prior to a storm. Manufacturer suggested rates and application are to be followed.*
4. *Chemically Treated Salt – All salting material is delivered already pre-treated with magnesium chloride blended chemicals.*
5. *Miscellaneous Materials – As the state of the art changes relative to new de-icing materials becoming available for highway use, the Authority will utilize these materials under stringent controlled conditions.*

[28] Winter Operations – Snow and Ice Control Manual, Chapter 1 General Program, New Jersey Turnpike Authority, December 16, 2015.

5.4 Spreading Practices

Condition	*Temperature (F)*	*Chemical Treatment*	*Plowing Treatment*
Sleet, Freezing Rain	*30 - 32°*	*1st Pass – 250 lbs per lane mile – Chemically Treated Salt*	*None Required*
Snow, Less than 2 inches	*30 - 32°*	*Same as above*	*Possibly none required except to push back slush/snow on shoulders*
Snow, More than 2 inches	*26 - 32°*	*1st Pass – 500 lbs per lane mile – Chemically Treated Salt* *2nd Pass – 500 lbs per lane mile – Chemically Treated Salt*	*See Note #1*
Snow Covered Roadway	*Below 25°*	*Generally to be treated as a routine spreading operation See Note #2*	*Routine Plowing See Note #2*
Snow – Roadway Clear	*Below 25° Wind Blowing*	*Treat icy spots as they develop. See Note #2*	*See Note #1*

Note #1: If forecast indicates snow, plows should be mounted in anticipation of the storm beginning.
Note #2: For those weather conditions when the temperature is below 25 degrees, field consideration must be given to the next 24 hour forecast including anticipated temperature ranges, precipitation, wind conditions and the terrain."

3.6.5. Maryland Transportation Authority

The following information was taken from the Maryland Transportation Authority Snow Training Guidelines.[29] The Maryland Transportation Authority follows the Salt Institute *The Snowfighter's Handbook – A Practical Guide for Snow and Ice Control.*[30]

"Foreword

Maryland Transportation Authority policy is to practice *the Sensible Salting Approach to snow and ice control which emphasizes getting the most from every application of deicing salt while maintaining the safest roads possible in the most economical way and protecting the environment.*

[29] Snow Training Guidelines, Maryland Transportation Authority, 2014.

[30] Salt Institute, 700 North Fairfax Street, Suite 600, Alexandria, Virginia, copyright 1967, 1977, 1991, 1999, 2007.

Stormfighting Guidelines	
The following chart is a guideline to combat various types of storms. Local conditions and policies will be the final determining factor.	
Condition 1 *Temperature near 30°F* *Precipitation snow, sleet or freezing rain* *Road surface wet*	*If snow or sleet, apply salt at 500 lb per two-lane mile. If snow or sleet continues and accumulates, plow and salt simultaneously. If freezing rain, apply salt at 200 lb per two-lane mile. If rain continues to freeze, re-apply salt at 200 lb per two-lane mile. Consider anti-icing procedures.*
Condition 2 *Temperature below 30°F or falling* *Precipitation snow, sleet or freezing rain* *Road surface wet or sticky*	*Apply salt at 300 – 800 lb per two-lane mile, depending on accumulation rate. As snowfall continues and accumulates, plow and repeat salt application. If freezing rain, apply salt at 200 – 400 lb per two-lane mile. Consider anti-icing and deicing procedures as warranted.*
Condition 3 *Temperature below 20°F and falling* *Precipitation dry snow* *Road surface dry*	*Plow as soon as possible. Do not apply salt. Continue to plow and patrol to check for wet, packed or icy spots; treat them with heavy salt applications.*
Condition 4 *Temperature below 20°F* *Precipitation snow, sleet or freezing rain* *Road surface wet*	*Apply salt at 600 – 800 lb per two-lane mile, as required. If snow or sleet continues and accumulates, plow and salt simultaneously. If temperature starts to rise, apply salt at 500 – 600 lb per two-lane mile, wait for salt to react before plowing. Continue until safe pavement is obtained.*
Condition 5 *Temperature below 10°F* *Precipitation snow or freezing rain* *Road surface accumulation of packed snow or ice*	*Apply salt at rate of 800 lb per two-lane mile or salt-treated abrasives at rate of 1500 to 2000 lb per two-lane mile. When snow or ice becomes mealy or slushy, plow. Repeat application and plowing as necessary.*

Note: The light, 200 lb application called for in Condition 1 and 2 must be repeated often for the duration of the condition.

9 Anti-icing

Anti-icing has many advantages.

- *Anti-icing returns road surfaces to normal faster, resulting in fewer accidents and delays.*

Products available for use in an anti-icing program are sodium chloride, calcium chloride, magnesium chloride, potassium acetate, and calcium magnesium acetate.

Salt Brine Manufacture

Salt brine is made by mixing rock salt or solar salt with water. The process is simple: the resulting brine should be approximately 23% NaCl.

The proportion of salt to water is critical to the effectiveness of the brine. Too much or too little salt affects the freeze point depressing qualities of the brine. The proper brine mixture is 23.3% salt content by weight. This is the concentration at which salt brine has the lowest freezing point, -6°F."

4. Tests Conducted after the Crash

4.1. Highway Marking Reflectivity Tests

The highway markings in the westbound travel lanes in the vicinity of the crash were installed in September 2019 as part of a recent resurfacing project. At the request of the NTSB, the PTC contracted with Beck & Co. Engineering, Inc. to perform highway marking reflectivity tests after the crash on Thursday, January 23, 2020, in the westbound travel lanes. **Table 14** summarizes the highway marking dry retro-reflectivity tests performed in the westbound travel lanes after the crash. The PTC's standards for the replacement of highway markings includes the following:

Dry retro-reflectivity levels (test based on ASTM E-1710)[31]

- 0 – 150 $\frac{mcd}{} \frac{m^2}{lx}$ – Fair Condition
- 151 – 200 $\frac{mcd}{} \frac{m^2}{lx}$ – Good Condition
- Greater than 200 $\frac{mcd}{} \frac{m^2}{lx}$ – Excellent Condition

Where $\frac{mcd}{} \frac{m^2}{lx}$ is the measure of retro-reflectivity:

- mcd = millicandela (candela is the luminous intensity)
- m^2 = square meters
- lx or Lux = standardized unit of measurement of the light intensity

As shown in **Table 14**, the highway marking dry retro-reflectivity tests performed in the westbound travel lanes after the crash revealed the highway markings were in "Excellent Condition".

[31] ASTM E-1710 - Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer.

Table 14 – Highway marking dry retro-reflectivity tests performed in the westbound travel lanes after the crash.

Milepost Location	Solid Yellow Line (separating the paved shoulder from the leftmost travel lane) $\frac{mcd}{}\frac{m^2}{lx}$	Broken White Line (separating the 2 westbound travel lanes) $\frac{mcd}{}\frac{m^2}{lx}$	Solid White Line (separating the paved shoulder from the rightmost travel lane) $\frac{mcd}{}\frac{m^2}{lx}$
87.9	840	396	465
87.8	800	370	472
87.7	579	345	303
87.6	437	246	302
87.5	539	267	329
87.4	572	337	378
87.3	560	292	380
87.2	555	273	376
87.1	708	329	370
87.0	488	333	395
86.9	552	386	442
86.8	697	424	346
86.7	634	403	304
86.6	620	421	412
86.5	823	440	449
86.4	667	415	333
86.3	875	386	401
86.2	1,031	393	379
86.1	958	348	399
86.0	991	403	465

5. PTC Curve Warning System Study before the January 5, 2020 Crash

In 2014, the PTC had a Curve Warning System Study performed to examine the Intelligent Transportation System (ITS) options and potential mitigation strategies at horizontal curve locations with a high crash rate history. Based on crash data from 2008-2013, the study determined that there were eleven (11) horizontal curves along the Turnpike that met the criteria based on a radius of curvature less than or equal to 1,432-feet (or 4 degrees) and an average of four (4) or more crashes per year along the curve. The 1,296-foot radius left-hand curve prior to the January 5, 2020, crash site was not identified as a high crash rate location in the 2014 study because it did not meet the criteria of having an average of four (4) or more crashes per year along the curve. In fact, the 1,296-foot radius left-hand curve averaged less than one (1) crash per year for the last 5 years.

Based on the most recent crash rate data from 2017 – 2019, a majority of the eleven (11) horizontal curves have experienced a reduction in crash rates where mitigation efforts were implemented.

5.1. PTC Curve Warning Emerging Technologies

The PTC is researching new means to communicate with motorists through curve speed warning applications. An FM radio over-broadcast system as well as connected vehicle applications are currently being explored.

For the FM radio over-broadcast application, the PTC has been granted an experimental authority by the Federal Communications Commission (FCC) for an evaluation period of Emergency Warning System's Radiolert product. The existing curve speed warning system at the Breezewood Interchange eastbound exit ramp uses TrafiRadar video and radar vehicle presence sensors to activate flashing beacons and digital message sign displays. The Radiolert evaluation will utilize CONNECT:ITS technology to integrate with the existing curve speed warning system controllers. When the warning system activates, a control signal output will be processed by the CONNECT:ITS device and initiate communication with the Radiolert FM80 initiating an FM radio transmission. The PTC has been granted consent by WSKE and WBVE radio stations for the Radiolert to over-broadcast a short duration "Slow Down Curve Ahead" warning message on their frequency while the warning system is activated. The warning message will be repeated 5 times before ceasing FM transmission upon each activation. The message duration will provide adequate time for a vehicle traveling the exit ramp which is tuned to WSKE or WBVE to receive the message. Specific FM antenna installation methods are being used in order to control the radio signal propagation, containing it to the exit ramp to the greatest degree possible. The CONNECT:ITS and Radiolert technology will provide statistical information regarding the frequency of the warning system's activation.

Additionally, the PTC is closely monitoring developments in the emerging connected and automated vehicle (CAV) technology space. The PTC has acquired an FCC license for the Dedicated Short-Range Communications frequency band, which provides a standard for high-speed communications between vehicles and infrastructure. The PTC is actively establishing a test laboratory environment where proof-of-concept applications of CAV technologies can be evaluated, and preparations can be made for infrastructure support and integration into the PTC's Transportation Operations Center management and notification systems. The PTC intends for the curve speed warning system CAV application to be the initial evaluation in the test laboratory.

6. PTC Actions Taken after the Crash

Although the 1,296-foot radius left-hand curve prior to the January 5, 2020, crash site was not a high crash rate location, the PTC will proactively be installing curves ahead advisory speed signs at the following locations:

- MP 88.9 Westbound
- MP 99.7 Westbound
- MP 121.8 Eastbound

Figure 6 illustrates an example of the curves ahead advisory speed sign to be installed by the PTC. The curves ahead advisory speed sign will contain flashing beacons on either side of the sign to alert motorists to reduce speeds, particularly at night, in the vicinity of horizontal curves. The dimensions of the sign will be 14-feet by 15-feet (width by height). The source of power for the flashing beacons will be provided by a combination of either underground electric conduit from adjacent maintenance facilities or solar power panels.

The curves ahead advisory speed signs with flashing beacons were installed by the PTC in May of 2021.

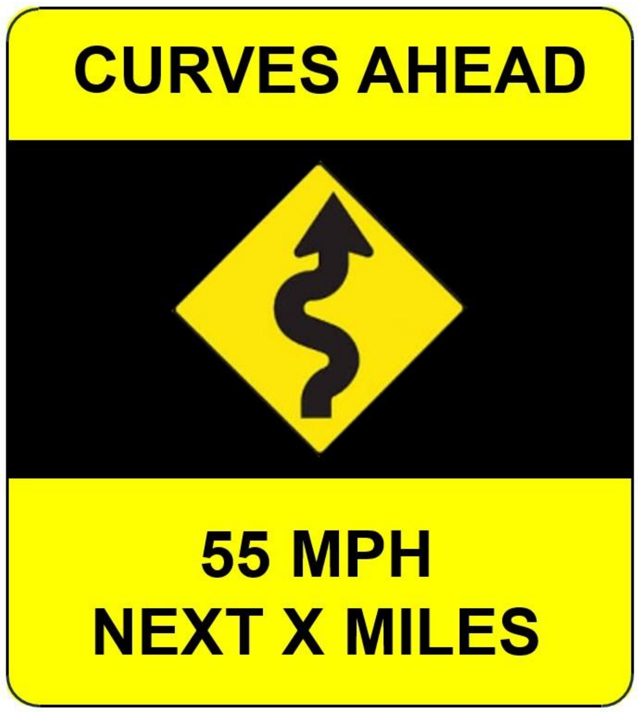


Figure 6 – Example of curves ahead advisory speed sign to be installed by the Pennsylvania Turnpike Commission.

7. Pennsylvania's 2017 Strategic Highway Safety Plan

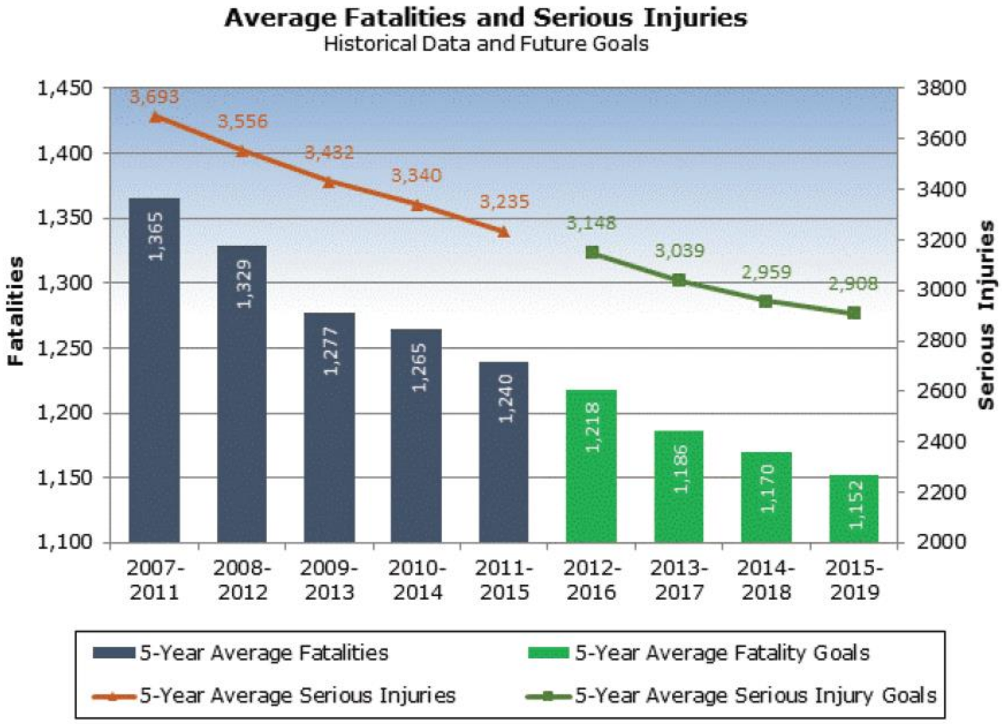
Pennsylvania's 2017 Strategic Highway Safety Plan (SHSP) had been developed as a multi-agency effort to substantially reduce traffic related fatalities and serious injuries.[32] The SHSP is a comprehensive, data-driven strategic plan. The goals and strategies included in this plan were established in collaboration with the SHSP Steering Committee in which the PTC was a key safety stakeholder and partner.

Pennsylvania's 2017 SHSP indicated the following:

"In October 2016, the National Highway Traffic Safety Administration (NHTSA) committed to eliminate traffic deaths within 30 years. Pennsylvania has adopted a goal to support this national effort. This ambitious timeline will rely heavily on the

[32]Pennsylvania Strategic Highway Safety Plan (SHSP), 2017, Pennsylvania Department of Transportation.

implementation of autonomous vehicle technology, which is anticipated to be implemented in the mid to late 2020's. Accordingly, the reduction in fatalities over the next 30 years will not be linear. Pennsylvania's goal is to reduce the current number of fatalities and serious injuries by 120 and 305 respectively over the next five years. As autonomous vehicle technologies are implemented, the fatality reduction goals will increase. The historical five year average fatalities and short-term goals are shown in the below chart."



7.1. Install High Friction Surface Treatment (HFST)

The United States Department of Transportation Federal Highway Administration's (FHWA's) High Friction Surface Treatment (HFST) website indicated the following:[33]

"HFST involves the application of very high-quality aggregate to the pavement using a polymer binder to restore and/or maintain pavement friction at existing or potentially high crash areas. The higher pavement friction helps motorists maintain better control in both dry and wet driving conditions.

While not an answer for corridor paving, HFST is an approach that has been demonstrated nationally and internationally and has provided significant increases in friction for spot applications. State-of-the-art friction measurement equipment has been used to verify the improved friction after installation.

[33] FHWA's High Friction Surface Treatment (HFST) website accessed on December 11, 2020 https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/high_friction/.

The concept of applying skid resistant surface treatments was first evaluated in the United Kingdom in 1967 for the greater London Council. The city undertook a program to improve intersections by applying a highly skid-resistant overlay at more than 800 intersections and other potential problem locations. A study of the project, entitled "The Location and Treatment of Urban Skidding Hazard Sites" (TRB Research Record 623, 1976) indicated a 31 percent reduction in crashes. The technology arrived in the United States a few decades later, but was used mainly for sealing bridge decks. It wasn't until the early 2000s that various HFST suppliers began to market the treatment as a safety countermeasure to State and local agency transportation departments."

7.1.1. Examples of High Friction Surface Treatment (HFST) on the Pennsylvania Turnpike System

Examples in which High Friction Surface Treatment (HFST) have been used on the Pennsylvania Turnpike include MP 13.21 in Beaver County and MP 49.03 in Allegheny County to improve friction/skid resistance.

7.2. ITS Road Weather Connected Vehicle Applications

FHWA's Intelligent Transportation Systems (ITS) Road Weather Connected Vehicle Applications website indicated the following:[34]

"Road Weather connected vehicle applications are the next generation of applications and services that assess, forecast, and address the impacts that weather has on roads, vehicles, and travelers. The applications and services are intended to capitalize on the previous Clarus Initiative research that has delivered a network of road weather information by integrating existing data sources. Through additional research, technology development, and community outreach, connected vehicle Road Weather Applications research will develop greater specificity regarding the impact that weather has on roadways and promote strategies and tools that mitigate those impacts. Such strategies will build upon decision support tools currently undergoing development, testing, and deployment (such as those developed under the Road Weather Management Program, e.g., the Clarus Regional Demonstrations and the Maintenance Decision Support System (MDSS)).

In close coordination with and cutting across the efforts under the other connected vehicle research programs, the vision for the Road Weather applications research is to broaden the foundation of road weather data to include mobile sources and to focus the analysis on improving the ability to detect and forecast road weather and pavement conditions by specific roadway links."

[34] FHWA's ITS Road Weather Connected Vehicle Applications website accessed on December 11, 2020 https://www.its.dot.gov/research_archives/road_weather/index.htm.

7.2.1. Examples of ITS Road Weather Connected Vehicle Applications on the Pennsylvania Turnpike System

Examples in which ITS Road Weather Connected Vehicle Applications have been used on the Pennsylvania Turnpike include the Harrisburg Connected Corridor.

Harrisburg Connected Corridor – the Harrisburg Connected Corridor (HCC) focuses on improving safety and mobility for Pennsylvania residents and turnpike customers. The Pennsylvania Turnpike Commission strategy and vision for the HCC is to understand how the use of connected infrastructure talks with vehicles now and in the future, to understand the data, security, applications, devices, messages and how these components will interface with the Commission's network. The initial HCC project will focus on safety, weather, incident management and work zone Traveler Information Message (TIM) applications.

The HCC deployment goals are the following:

Improving Safety and Mobility

- Reducing fatalities, crashes, and injuries – working toward achieving Vision Zero.
- Deploying safety, weather, work zone, reduced curve speed, and incident management applications.

Preparing for Future Technology

- Working to test and implement secure data and devices to improve the Turnpike and customer's trips.
- Preparing for new advances in communication devices and data.

Building a Better Pennsylvania

- Providing an environment for workforce development and training.
- Preparing Road to Zero.
- Helping to implement a sustainable transportation system with zero fatalities.

7.3. Variable Speed Limit Signage

FHWA's Synthesis of Variable Speed Limit Signs indicated the following:[35]

"Variable speed limit (VSL) systems utilize information on traffic speed, occupancy, volume detection, weather, and road surface conditions to determine the appropriate speeds at which drivers should be traveling, given current roadway and traffic conditions. The use of VSL during less than ideal conditions, such as heavy traffic and adverse weather conditions, 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 among vehicles. In addition, VSL can

[35] *Synthesis of Variable Speed Limit Signs*, FHWA, May 2017, page 1.

be used to dynamically manage speeds during planned (rush hour congestion) and unplanned (incidents) events. Used in conjunction with managed lanes and other active traffic management (ATM) strategies, VSL can respond to downstream congestion to eliminate or delay bottlenecks and mitigate the possibility of crashes.

VSL has been successfully implemented in Europe since the 1960s, with deployments in countries such as the Netherlands and Germany generating significant benefits. While the United States has deployed VSL systems for safety purposes over a few decades, during the past 15 years there has been a renewed interest in expanding VSL use among the States in order to achieve operational benefits."

7.4. Develop a curve inventory to allow for data-driven decisions

In addition to the 2014 PTC Curve Warning System Study that was discussed earlier in the factual report, the PTC provided the following information:

Blinker (Sequential) Chevron Signs – the Pennsylvania Turnpike Commission have installed blinker (sequential) chevron signs at MP 123.4 eastbound in Somerset County and will be installing blinker (sequential) chevron signs at MP 75.9 westbound in Westmoreland County in 2021. The blinker (sequential) chevron signs function dynamically to warn and guide motorists through horizontal curves. The chevron signs flash sequentially delivering a "pull-through" effect for motorists traveling along the horizontal curve.

7.5. Implement real time speed feedback warning systems

In addition to the PTC Curve Warning emerging connected and automated vehicle (CAV) technology space that was discussed earlier in the factual report, the PTC provided the following information:

Automated Truck Rollover Warning System (ATRWS) – through a crash analysis it was found the eastbound exit ramp at Breezewood interchange was prone to truck rollover crashes. One countermeasure that has reduced the frequency of truck rollovers on exit ramps is the Automated Truck Rollover Warning System (ATRWS). Three different system configurations were evaluated with a focus on measurable characteristics, cost effectiveness, and maintenance: full system, partial system, and speed-based system. Through this evaluation, a partial system was determined to best fit the project needs.

The selected partial system is composed of a series of radar detection, static signs, flashing lights and blankout signs. The basic configuration consists of two detection zones. Zone 1, located within the end of the tangent, identifies the vehicle class. If a truck is detected, overhead flashing lights are displayed in conjunction with static rollover signs. Zone 2, located prior to the curve, assesses the vehicle class and speed. If a truck is detected in Zone 2 and is exceeding the advisory speed of 35 mph, the blankout sign is activated, reading "ROLLOVER WARNING, REDUCE SPEED".

The system was installed in 2003 followed by an independent evaluation of the project in 2006. Prior to the system there were an average of 3 to 6 rollover crashes annually. After installation there was only one rollover crash between 2003 and 2005. **Figure 7** illustrates the Automated Truck Rollover Warning System (ATRWS) at the Breezewood eastbound exit ramp.

Figure 7 – Automated Truck Rollover Warning System (ATRWS) at the Breezewood eastbound exit ramp.

<u>Pennsylvania Turnpike Commission (PTC) Data Sharing</u> – the Pennsylvania Turnpike Commission (PTC) has been working with third parties for data sharing since 2014. PTC is a connected partner with Waze which is a popular navigation application used by about 20% of the traveling public. PTC is also working with Google Maps which is used by about 60% of the traveling public. Currently, PTC has agreements or are working on agreements with the following companies, which also include freight partners:

Waze – In April 2015 PTC entered into an agreement to share data. PTC became a Connected partner with Waze and shares information on a bilateral basis. PTC was the 11th Waze Connected partner. Waze receives the incident feed for accidents and work zones. PTC can also enter work zones, road closures and accidents directly into Waze. PTC uses Waze for Traffic Operations daily and maintains a good business relationship.

Drivewyze – In November 2016 PTC entered into an agreement to share data. Drivewyse receives PTC's incident feed for accidents and work zones.

TruckBlox – In April 2017 PTC entered into an agreement to share data. Truckblox receives PTC's incident feed for accidents and work zones. Truckblox application is for commercial vehicles to send audio alerts.

HERE- In November 2019 PTC entered into an agreement to share data. HERE receives PTC's incident feed for accidents and work zones.

Freightwaves – In August 2020 PTC entered into an agreement to share data. Freightwaves is developing a way to import PTC's incident feed into their Sonar application.

Google – In October 2020 PTC entered into an agreement to share data. Google is in the testing phase on how to integrate the data. Due to workload they are not planning on pushing it to production until 2021. PTC will continue to keep tabs on the progress of Google's effort. PTC has also asked Google to consider putting PTC's digital alerts on their map.

Apple maps – PTC is in discussions with Apple to share data. Apple is not currently ready to consume the map in geo reference format. Apple is hoping to work on the file format in 2021.

Trimble maps – PTC is in discussions with Trimble to share data. Trimble wants to integrate the data into several of their applications.

8. Speed Studies performed by the Pennsylvania Turnpike Commission

The Pennsylvania Turnpike was built in 1939-1940. One of the first tollways built in the United States, the Pennsylvania Turnpike served as precedent for additional limited-access toll roads and the Interstate Highway System.

The Pennsylvania Turnpike has numerous horizontal curves along the mainline that have posted advisory speeds of 55-mph, 60-mph, and 65-mph.[36] **Table 15** summarizes the types of horizontal curve advisory speed zones and miles of straight tangent sections versus horizontal curve locations along the Pennsylvania Turnpike.[37]

Table 15 – Types of horizontal curve advisory speed zones and miles of straight tangent sections versus horizontal curve locations along the Pennsylvania Turnpike.

Number of 55-mph horizontal curve advisory speed zones	Number of 60-mph horizontal curve advisory speed zones	Number of 65-mph horizontal curve advisory speed zones	Miles of straight tangent sections of posted regulatory speed of 70-mph	Miles of horizontal curves (55-mph advisory speed, 60-mph advisory speed, and 65-mph advisory speed)
22	124	4	1,054 miles	51 miles

[36] Advisory speed is a recommended speed for all vehicles operating on a section of highway and based on the highway design, operating characteristics, and conditions.

[37] These are directional miles for the Pennsylvania Turnpike mainline, northeast, and all the extensions.

The posted regulatory speed along the Pennsylvania Turnpike has fluctuated over the years. The posted regulatory speed limit is currently set at 70-mph and took effect in May of 2016.[38] **Table 16** summarizes the chronology of speed limits on the Pennsylvania Turnpike.

Table 16 – Chronology of speed limits on the Pennsylvania Turnpike.

Date	Speed Limit
October 1, 1940	No speed limit established by law
April 15, 1941	70-mph; various lower commercial speeds depending on vehicle weight
December 1941	Wartime restriction of 35-mph for all traffic
August 1945	Wartime restriction lifted. Speed limits revert to those of April 15, 1941
July 9, 1951	70-mph for cars, buses, motorcycles 50-mph for all other traffic
January 15, 1953	*Gateway to Breezewood* 60-mph for cars, buses 45-mph for trucks
May 7, 1956	*Breezewood to Valley Forge* 70-mph for cars, buses 50-mph for trucks *Bridges* 45-mph for all traffic
July 24, 1966	65-mph for cars, buses, motorcycles 55-mph for commercial vehicles
November 1973	55-mph restriction nationwide, enforced on Turnpike beginning December 2, 1973
July 13, 1995	65-mph for cars, buses, motorcycles, and commercial vehicles, except in urban areas where speed limit is 55-mph
April 3, 2001	55-mph from milepost 75 to milepost 130 for all vehicles
April 11, 2005	65-mph for all vehicles, except tunnels, MP 122-130, and approaches to mainline toll plazas will remain at 55-mph
July 2014	70-mph for all vehicles between MP 201-298
May 2016	70-mph for all vehicles in all areas that were previously 65-mph

The PTC conducted an assessment of the safety of the horizontal curves along the Pennsylvania Turnpike before raising the speed limit from 65-mph to 70-mph in May of 2016. All horizontal curves along the Pennsylvania Turnpike were evaluated to determine if the design speed of the horizontal curve was less than the proposed 70-mph speed limit.[39] The results of the study can be found in a *Preliminary Report 70 MPH Speed Limit Study* dated March 4, 2014.[40] The design speed of the horizontal curves was determined from the following information:

- Location

[38] Speed limit is the maximum (or minimum) speed applicable to a section of highway as established by law or regulation.

[39] Design speed is a selected speed used to determine the various geometric design features of a roadway. It is generally understood as the maximum speed that vehicles can travel based on driver comfort given the centrifugal forces imparted on the vehicle.

[40] *Preliminary Report 70 MPH Speed Limit Study*, prepared by URS, prepared for PTC, dated March 4, 2014.

- Radius (or degree) of curve
- Super-elevation rate

The design speed for the horizontal curve prior to the crash location at MP 86.1 can be computed from the following formula:

$$R_{min} = \frac{V^2}{15(0.01e_{max} + f_{max})}$$

Where: R_{min} = radius of horizontal curve (1,296 feet)
e_{max} = super-elevation rate (8%)
f_{max} = side friction demand factor (0.12)
V = design speed (mph)

Solving for V: $$1{,}296 = \frac{V^2}{15(0.01(8) + 0.12)}$$

Design speed (V) = 62.35-mph or 62-mph

The methodology for determining the advisory speed for the horizontal curve prior to the crash location at MP 86.1 can be found in the *Preliminary Report 70 MPH Speed Limit Study*:[41]

> *"The advisory speed was computed by subtracting 5 mph from* V_{max} *and rounding the remainder down to the nearest 5 mph increment."*

Hence, the advisory speed was computed as follows:

Advisory speed = 62 mph – 5 mph = 57 mph (rounding down to nearest 5 mph increment)

Advisory speed = 55 mph

[41] ibid, page 9.

The *Preliminary Report 70 MPH Speed Limit Study* discussed the appropriate warning signage and spacing of chevron signs for each horizontal curve along the Pennsylvania Turnpike. The warning signage was determined from **Table 2C-5** and the spacing of chevron signs was determined from **Table 2C-6**.[42]

Table 2C-5 – Horizontal Alignment Sign Selection.

Type of Horizontal Alignment Sign	**Difference Between Speed Limit and Advisory Speed**				
	5-mph	**10-mph**	**15-mph**	**20-mph**	**25-mph or more**
Turn, Curve, Reverse Turn, Reverse Curve, Winding Road, and Combination Horizontal Alignment / Intersection (see Section 2C.07 to determine which sign to use)	Recommended	Required	Required	Required	Required
Advisory Speed Plaque	Recommended	Required	Required	Required	Required
Chevrons and/or One Direction Large Arrow	Optional	Recommended	Required	Required	Required
Exit Speed and Ramp Speed on exit ramp	Optional	Optional	Recommended	Required	Required

Note: Required means that the sign and/or plaque shall be used, recommended means that the sign and/or plaque should be used, and optional means that the sign and/or plaque may be used.
See Section 2C.06 for roadways with less than 1,000 ADT.

Table 2C-6 – Typical Spacing of Chevron Alignment Signs on Horizontal Curves.

Advisory Speed	**Curve Radius**	**Sign Spacing**
15 mph or less	Less than 200 feet	40 feet
20 to 30 mph	200 to 400 feet	80 feet
35 to 45 mph	401 to 700 feet	120 feet
50 to 60 mph	701 to 1,250 feet	160 feet
More than 60 mph	More than 1,250 feet	200 feet

Note: The relationship between the curve radius and the advisory speed shown in this table should not be used to determine the advisory speed.

[42] *Manual on Uniform Traffic Control Devices*, Federal Highway Administration, 2009 Edition, pages 110 and 113.

NTSB investigators requested the Pennsylvania Turnpike Commission perform speed studies at the horizontal curve prior to the crash location at MP 86.1 westbound (WB) and at 2 other locations with similar characteristics. **Table 17** summarizes the similar characteristics of all 3 horizontal curves in which the PTC performed speed studies.

Table 17 - Similar characteristics of all 3 horizontal curves in which the PTC performed speed studies.

	Horizontal curve prior to crash location	Similar horizontal curve #1	Similar horizontal curve #2
Location	MP 86.1	MP 82.9	MP 95.7
Direction	Westbound	Westbound	Westbound
Type of horizontal curve	Left-hand horizontal curve	Left-hand horizontal curve	Left-hand horizontal curve
Radius	1,296 feet	1,429 feet	1,432 feet
Super-elevation	8%	8%	8%
Number of shoulder chevron signs	14	13	17
Design speed	62-mph	65-mph	65-mph

The PTC performed the speed studies using two data sets. One data set was performed advising the travelling public that an active speed study was being conducted. A portable changeable message sign was located approximately one mile prior to each horizontal curve that indicated “ADVISORY SPEED 55 MPH / ACTIVE SPEED STUDY.” A Pennsylvania State Police squad car was positioned with lights deactivated approximately one to five miles prior to each horizontal curve. A second data set was performed with no portable changeable message sign advising the travelling public that an active speed study was being conducted and with no law enforcement present. **Table 18** summarizes the two data sets for the speed studies performed by the PTC and **Table 19** summarizes how much vehicles were travelling over the advisory speed and design speed.

Table 18 – Summary of two data sets for the speed studies performed by the Pennsylvania Turnpike Commission.

Data Set #1 – Advising the travelling public that an active speed study was being conducted			
Horizontal curve location	**MP 86.1**	**MP 82.9**	**MP 95.7**
Date speed study conducted	April 8, 2021	April 21, 2021	April 20, 2021
Time of speed study	8 a.m. to 2 p.m.	8 a.m. to 2 p.m.	8 a.m. to 2 p.m.
85th percentile speed bin[43] – All vehicles	70 to 75-mph	65 to 70-mph	70 to 75-mph
85th percentile speed bin – Passenger cars	70 to 75-mph	65 to 70-mph	70 to 75-mph
85th percentile speed bin – Buses	65 to 70-mph	70 to 75-mph	N/A[44]
85th percentile speed bin – Single unit trucks	70 to 75-mph	65 to 70-mph	65 to 70-mph
85th percentile speed bin – Single trailer trucks	65 to 70-mph	65 to 70-mph	65 to 70-mph
85th percentile speed bin – Multi trailer trucks	65 to 70-mph	65 to 70-mph	65 to 70-mph
Data Set #2 – Not advising the travelling public that an active speed study was being conducted			
Horizontal curve location	**MP 86.1**	**MP 82.9**	**MP 95.7**
Date speed study conducted	May 12, 2021	May 13, 2021	May 11, 2021
Time of speed study	8 a.m. to 2 p.m.	8 a.m. to 2 p.m.	8 a.m. to 2 p.m.
85th percentile speed bin – All vehicles	70 to 75-mph	70 to 75-mph	70 to 75-mph
85th percentile speed bin – Passenger cars	75 to 80-mph	75 to 80-mph	75 to 80-mph
85th percentile speed bin – Buses	65 to 70-mph	70 to 75-mph	65 to 70-mph
85th percentile speed bin – Single unit trucks	70 to 75-mph	70 to 75-mph	70 to 75-mph
85th percentile speed bin – Single trailer trucks	70 to 75-mph	70 to 75-mph	70 to 75-mph
85th percentile speed bin – Multi trailer trucks	70 to 75-mph	70 to 75-mph	65 to 70-mph

[43] Speed bins are reported to correlate with the raw data performed by the Pennsylvania Turnpike Commission. Additional information regarding setting speed limits can be found on FHWA's website [Engineering Speed Limits - Safety | Federal Highway Administration (dot.gov)].

[44] Only 1 bus was counted in the speed study and it was travelling in the 65 to 70-mph speed bin.

Table 19 - How much vehicles were travelling over the advisory speed and design speed for the 3 speed studies performed by the Pennsylvania Turnpike Commission.

Data Set #1 – Advising the travelling public that an active speed study was being conducted			
Horizontal curve location	**MP 86.1**	**MP 82.9**	**MP 95.7**
Advisory speed	55-mph	55-mph	55-mph
Design speed	62-mph	65-mph	65-mph
85th percentile speed bin – All vehicles	15 to 20-mph over the advisory speed and 8 to 13-mph over the design speed	10 to 15-mph over the advisory speed and 0 to 5-mph over the design speed	15 to 20-mph over the advisory speed and 5 to 10-mph over the design speed
85th percentile speed bin – Passenger cars	15 to 20-mph over the advisory speed and 8 to 13-mph over the design speed	10 to 15-mph over the advisory speed and 0 to 5-mph over the design speed	15 to 20-mph over the advisory speed and 5 to 10-mph over the design speed
85th percentile speed bin – Buses	10 to 15-mph over the advisory speed and 3 to 8-mph over the design speed	15 to 20-mph over the advisory speed and 5 to 10-mph over the design speed	N/A[45]
85th percentile speed bin – Single unit trucks	15 to 20-mph over the advisory speed and 8 to 13-mph over the design speed	10 to 15-mph over the advisory speed and 0 to 5-mph over the design speed	10 to 15-mph over the advisory speed and 0 to 5-mph over the design speed
85th percentile speed bin – Single trailer trucks	10 to 15-mph over the advisory speed and 3 to 8-mph over the design speed	10 to 15-mph over the advisory speed and 0 to 5-mph over the design speed	10 to 15-mph over the advisory speed and 0 to 5-mph over the design speed
85th percentile speed bin – Multi trailer trucks	10 to 15-mph over the advisory speed and 3 to 8-mph over the design speed	10 to 15-mph over the advisory speed and 0 to 5-mph over the design speed	10 to 15-mph over the advisory speed and 0 to 5-mph over the design speed

[45] ibid.

Data Set #2 – Not advising the travelling public that an active speed study was being conducted			
Horizontal curve location	**MP 86.1**	**MP 82.9**	**MP 95.7**
Advisory speed	55-mph	55-mph	55-mph
Design speed	62-mph	65-mph	65-mph
85th percentile speed bin – All vehicles	15 to 20-mph over the advisory speed and 8 to 13-mph over the design speed	15 to 20-mph over the advisory speed and 5 to 10-mph over the design speed	15 to 20-mph over the advisory speed and 5 to 10-mph over the design speed
85th percentile speed bin – Passenger cars	20 to 25-mph over the advisory speed and 13 to 18-mph over the design speed	20 to 25-mph over the advisory speed and 10 to 15-mph over the design speed	20 to 25-mph over the advisory speed and 10 to 15-mph over the design speed
85th percentile speed bin – Buses	10 to 15-mph over the advisory speed and 3 to 8-mph over the design speed	15 to 20-mph over the advisory speed and 5 to 10-mph over the design speed	10 to 15-mph over the advisory speed and 0 to 5-mph over the design speed
85th percentile speed bin – Single unit trucks	15 to 20-mph over the advisory speed and 8 to 13-mph over the design speed	15 to 20-mph over the advisory speed and 5 to 10-mph over the design speed	15 to 20-mph over the advisory speed and 5 to 10-mph over the design speed
85th percentile speed bin – Single trailer trucks	15 to 20-mph over the advisory speed and 8 to 13-mph over the design speed	15 to 20-mph over the advisory speed and 5 to 10-mph over the design speed	15 to 20-mph over the advisory speed and 5 to 10-mph over the design speed
85th percentile speed bin – Multi trailer trucks	15 to 20-mph over the advisory speed and 8 to 13-mph over the design speed	15 to 20-mph over the advisory speed and 5 to 10-mph over the design speed	10 to 15-mph over the advisory speed and 0 to 5-mph over the design speed

NTSB investigators requested a crash study be performed on the Pennsylvania Turnpike for 5 consecutive years before and 5 consecutive years after the 70-mph regulatory speed limit took effect in May of 2016. The purpose of the crash study was to determine if crashes have increased or decreased as a result of increasing the speed limit from 65 mph to 70 mph. **Table 20** summarizes the crash study on the Pennsylvania Turnpike for 5 consecutive years before and 5 consecutive years after the 70-mph regulatory speed limit took effect in May of 2016.[46]

Table 20 - Crash study on the Pennsylvania Turnpike for 5 consecutive years before and 5 consecutive years after the 70-mph regulatory speed limit took effect in May of 2016.

Date start	Date end	Number of crashes	Average daily traffic (ADT)	Crash rate (100 million vehicle miles traveled)	Average 5-year crash rate
5/3/2009	5/2/2010	2,412	1,464,570	0.97	1.28
5/3/2010	5/2/2011	2,431	1,516,593	0.94	
5/3/2011	5/2/2012	2,419	1,500,465	0.94	
5/3/2012	5/2/2013	4,348	1,512,191	1.69	
5/3/2013	5/2/2014	4,925	1,555,470	1.86	
5/3/2016	5/2/2017	4,888	1,641,055	1.75	1.64
5/3/2017	5/2/2018	4,791	1,658,957	1.69	
5/3/2018	5/2/2019	5,030	1,671,915	1.76	
5/3/2019	5/2/2020	4,104	1,553,743	1.54	
5/3/2020	4/15/2021	3,427	1,461,037	1.44	

[46] Email received from the Pennsylvania Turnpike Commission dated April 29, 2021.

9. Speed Study Raw Data

Tables 21 through 23 summarize the raw data from the speed studies performed by the PTC.

Table 21 - Raw data from the speed studies performed by the PTC for horizontal curve location MP 86.1.

Horizontal curve location MP 86.1 Data Set #1 – Advising the travelling public that an active speed study was being conducted			
FHWA vehicle class	**Description**	**Total vehicles counted**	**Raw data for speed bins**
1	Motorcycles	7	See Highway Factors Attachment – Horizontal curve location MP 86.1, Data Set #1 Raw data for speed bins.
2	Passenger cars	2,234	
3	Four tire single unit trucks	570	
4	Buses	9	
5,6,7	Single unit trucks	274	
8,9,10	Single trailer trucks	1,766	
11,12,13	Multi trailer trucks	184	
Unclassified		3	
Totals		**5,047**	
Data Set #2 – Not advising the travelling public that an active speed study was being conducted			
FHWA vehicle class	**Description**	**Total vehicles counted**	**Raw data for speed bins**
1	Motorcycles	6	See Highway Factors Attachment – Horizontal curve location MP 86.1, Data Set #2 Raw data for speed bins.
2	Passenger cars	2,154	
3	Four tire single unit trucks	650	
4	Buses	4	
5,6,7	Single unit trucks	302	
8,9,10	Single trailer trucks	1,731	
11,12,13	Multi trailer trucks	174	
Unclassified		0	
Totals		**5,021**	

Table 22 - Raw data from the speed studies performed by the Pennsylvania Turnpike Commission for horizontal curve location MP 82.9.

Horizontal curve location MP 82.9 Data Set #1 – Advising the travelling public that an active speed study was being conducted			
FHWA vehicle class	**Description**	**Total vehicles counted**	**Raw data for speed bins**
1	Motorcycles	1	See Highway Factors Attachment – Horizontal curve location MP 82.9, Data Set #1 Raw data for speed bins.
2	Passenger cars	1,713	
3	Four tire single unit trucks	579	
4	Buses	6	
5,6,7	Single unit trucks	240	
8,9,10	Single trailer trucks	1,831	
11,12,13	Multi trailer trucks	188	
Unclassified		0	
Totals		**4,558**	
Data Set #2 – Not advising the travelling public that an active speed study was being conducted			
FHWA vehicle class	**Description**	**Total vehicles counted**	**Raw data for speed bins**
1	Motorcycles	11	See Highway Factors Attachment – Horizontal curve location MP 82.9, Data Set #2 Raw data for speed bins.
2	Passenger cars	2,908	
3	Four tire single unit trucks	619	
4	Buses	4	
5,6,7	Single unit trucks	331	
8,9,10	Single trailer trucks	1,725	
11,12,13	Multi trailer trucks	176	
Unclassified		0	
Totals		**5,774**	

Table 23 - Raw data from the speed studies performed by the PTC for horizontal curve location MP 95.7.

Horizontal curve location MP 95.7 Data Set #1 – Advising the travelling public that an active speed study was being conducted			
FHWA vehicle class	**Description**	**Total vehicles counted**	**Raw data for speed bins**
1	Motorcycles	0	See Highway Factors Attachment – Horizontal curve location MP 95.7, Data Set #1 Raw data for speed bins.
2	Passenger cars	1,495	
3	Four tire single unit trucks	441	
4	Buses	1	
5,6,7	Single unit trucks	252	
8,9,10	Single trailer trucks	1,886	
11,12,13	Multi trailer trucks	189	
Unclassified		0	
Totals		**4,264**	
Data Set #2 – Not advising the travelling public that an active speed study was being conducted			
FHWA vehicle class	**Description**	**Total vehicles counted**	**Raw data for speed bins**
1	Motorcycles	6	See Highway Factors Attachment – Horizontal curve location MP 95.7, Data Set #2 Raw data for speed bins.
2	Passenger cars	1,943	
3	Four tire single unit trucks	476	
4	Buses	2	
5,6,7	Single unit trucks	340	
8,9,10	Single trailer trucks	1,869	
11,12,13	Multi trailer trucks	201	
Unclassified		0	
Totals		**4,837**	

The following were the setup procedures used by the consultant performing the speed studies for the PTC at MP 86.1, MP 82.9, and MP 95.7. Two cameras were used by the consultant that consisted of a Miovision Camera and Black Cat Radar Unit.

<u>Miovision Camera</u>

- Where it was setup – Pennsylvania Turnpike, Westbound Direction, MP 86.1, MP 82.9, MP 95.7
- What equipment was used - Miovision Scout Camera
- How high was the camera from the ground – 14 to 15-feet above the lane (the tops of trailer trucks were visible)
- Camera mounted to what type of pole - 6”x6” wood post
- Offset of pole from edge of pavement – 16 feet
- Camera orientation to capture vehicles traveling in westbound direction of travel – perpendicular to traffic

<u>Black Cat Radar Unit</u>

- Where it was setup – Pennsylvania Turnpike, Westbound Direction, MP 86.1, MP 82.9, MP 95.7
- What equipment was used – JAMAR Blackcat II
- How high was the camera from the ground – 7 foot 10 inches above the lane
- Camera mounted to what type of pole - 6”x6” wood post
- Offset of pole from edge of pavement – 16 feet
- Camera orientation to capture vehicles traveling in westbound direction of travel – 45 degrees

10. Pavement Friction Testing

The NTSB contracted with Applied Research Associates (ARA) to provide pavement friction testing near milepost 86.1 westbound on the Pennsylvania Turnpike. The testing was performed on July 26, 2021. Testing was conducted using both an ASTM E-501 ribbed testing tire in the left wheel path and an ASTM E-524 smooth testing tire in the right wheel path in both westbound lanes. Testing was conducted at 40, 50, 55, 60, and 70 mph. ARA’s locked-wheel skid friction tester was manufactured by International Cybernetics Corporation in 2012. The locked-wheel skid friction tester was in full compliance with ASTM E-274 and has been maintained to all manufacturer recommendations since that time. The equipment was most recently calibrated by ARA on June 18, 2021. Lane 1 was considered the left lane and Lane 2 was considered the right lane for motorists travelling in the westbound direction.[47]

[47] The pavement friction tests can be found in Highway Factors Attachment – *ARA Pavement Friction Tests conducted on July 26, 2021, in the westbound left lane (Lane 1) near milepost 86.1 on the Pennsylvania Turnpike and Highway Factors Attachment – ARA Pavement Friction Tests conducted on July 26, 2021, in the westbound right lane (Lane 2) near milepost 86.1 on the Pennsylvania Turnpike.*

E. DOCKET MATERIAL

The following attachments and photographs are included in the docket for this investigation:

LIST OF ATTACHMENTS

Highway Factors Attachment – Commonwealth of Pennsylvania Police Crash Reports on the horizontal curve to the left just prior to the crash location in the westbound direction for the last 5 years.

Highway Factors Attachment – Dynamic message sign (DMS) locations and messages that had been displayed in the westbound direction of the Pennsylvania Turnpike prior to the crash.

Highway Factors Attachment – Roadway and Bridge Reconstruction Plans for the Pennsylvania Turnpike in the vicinity of the crash location.

Highway Factors Attachment – Pennsylvania Turnpike Commission specifications for single axle dump truck.

Highway Factors Attachment – Pennsylvania Turnpike Commission weather event management playbook.

Highway Factors Attachment – Pennsylvania Turnpike Commission maintenance manual.

Highway Factors Attachment – Pennsylvania Department of Transportation Maintenance Manual, Chapter 4: Winter Services.

Highway Factors Attachment – Ohio Turnpike Maintenance Snow & Ice Training.

Highway Factors Attachment – New York State Thruway Authority Winter Maintenance Manual.

Highway Factors Attachment – New Jersey Turnpike Authority Winter Operations – Snow and Ice Control Manual.

Highway Factors Attachment – Maryland Transportation Authority Snow Training Guidelines.

Highway Factors Attachment – Electrical plan for curves ahead advisory speed sign with flashing beacons to be installed by the Pennsylvania Turnpike Commission.

Highway Factors Attachment – Horizontal curve location MP 86.1, Data Set #1 Raw data for speed bins.

Highway Factors Attachment – Horizontal curve location MP 86.1, Data Set #2 Raw data for speed bins.

Highway Factors Attachment – Horizontal curve location MP 82.9, Data Set #1 Raw data for speed bins.

Highway Factors Attachment – Horizontal curve location MP 82.9, Data Set #2 Raw data for speed bins.

Highway Factors Attachment – Horizontal curve location MP 95.7, Data Set #1 Raw data for speed bins.

Highway Factors Attachment – Horizontal curve location MP 95.7, Data Set #2 Raw data for speed bins.

Highway Factors Attachment – Pennsylvania Department of Transportation District Highway Safety Guidance Manual on Wet Pavement Crashes dated May 2019.

Highway Factors Attachment – Preliminary Report 70 MPH Speed Limit Study dated March 4, 2014.

Highway Factors Attachment – Harrisburg Connected Corridor (HCC) Project Brochure.

Highway Factors Attachment – ARA Pavement Friction Tests conducted on July 26, 2021 in the westbound left lane (Lane 1) near milepost 86.1 on the Pennsylvania Turnpike.

Highway Factors Attachment – ARA Pavement Friction Tests conducted on July 26, 2021 in the westbound right lane (Lane 2) near milepost 86.1 on the Pennsylvania Turnpike.

Highway Factors Attachment – Email received from the Pennsylvania Turnpike Commission dated April 29, 2021.

LIST OF PHOTOGRAPHS

Highway Factors Photo 1 – Advisory speed sign of 55 mph posted approximately 2,112 feet from the crash in the westbound direction of the Pennsylvania Turnpike.

Highway Factors Photo 2 – View of front and side of Pennsylvania Turnpike Commission single axle truck number 75-728, the truck used in applying salt in the westbound direction of the Pennsylvania Turnpike in the vicinity of the crash.

Highway Factors Photo 3 - View of back and side of Pennsylvania Turnpike Commission single axle truck number 75-728, the truck used in applying salt in the westbound direction of the Pennsylvania Turnpike in the vicinity of the crash.

Highway Factors Photo 4 – View of spinner in the back of Pennsylvania Turnpike Commission single axle truck number 75-728, the truck used in applying salt in the westbound direction of the Pennsylvania Turnpike in the vicinity of the crash.

Highway Factors Photo 5 – View looking to the east in the vicinity of the crash standing near 52-inch-tall concrete barrier in the median that separated the westbound travel lanes and the eastbound travel lanes of the Pennsylvania Turnpike.

Highway Factors Photo 6 – View looking to the west in the vicinity of the crash standing near 52-inch-tall concrete barrier in the median that separated the westbound travel lanes and the eastbound travel lanes of the Pennsylvania Turnpike.

Highway Factors Photo 7 – View looking to the west toward the crash site standing in the middle of the westbound travel lanes of the Pennsylvania Turnpike.

Highway Factors Photo 8 – View looking to the west toward the crash site standing in the shoulder adjacent to the westbound travel lanes of the Pennsylvania Turnpike.

Highway Factors Photo 9 - View looking to the west at the crash site location standing on the edge of the shoulder adjacent to the westbound travel lanes of the Pennsylvania Turnpike.

Highway Factors Photo 10 – View looking to the east at the crash site location illustrating the steep embankment standing on the highway marking separating the shoulder from the westbound travel lanes of the Pennsylvania Turnpike.

Highway Factors Photo 11 – View of sections of 52-inch-tall concrete barrier removed from the median in the vicinity of the crash site and stored at a Donegal Maintenance Yard.

Highway Factors Photo 12 – View of curves ahead advisory speed sign with flashing beacons at MP 88.9 in westbound direction.

END OF REPORT

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