Multiple Vehicle Collision on Interstate 95 Fairfield, Connecticut January 17, 2003

Highway Accident Report

NTSB/HAR-05/03

PB2005-916203
Notation 7734

National Transportation Safety Board
Washington, D.C.

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Adopted November 16, 2005

National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2006. *Multiple Vehicle Collision on Interstate 95, Fairfield, Connecticut, January 17, 2003.* Highway Accident Report NTSB/HAR-05/03. Washington, DC.

Abstract: On Interstate 95 (I-95) near Fairfield, Connecticut, two consecutive accidents occurred within 11 minutes in the early morning hours of January 17, 2003. At the time of the accidents, light snow was falling, the roads were wet and icy, and snow covered the roadway shoulders. About 4:50 a.m., a 1996 Freightliner tractor flatbed semitrailer was involved in a nonfatal multivehicle accident. The truck was traveling in a work zone on I-95 north, near milepost 26.6, at a driver-estimated speed of 50 mph, when it slid out of control. The vehicle entered the median, overturned and overrode the portable concrete barrier, and collided with a southbound 1997 Dodge Avenger sedan. A southbound 2001 Freightliner tractor/ refrigerated trailer combination unit struck the Dodge sedan and then struck the 1996 Freightliner tractor. The three vehicles came to rest blocking the southbound lanes of the highway. During the accident sequence, the flatbed semitrailer separated from the 1996 Freightliner tractor. The semitrailer came to rest perpendicular to the roadway, straddling the portable concrete barrier and partially obstructing the left lane of I-95 north. At 5:01 a.m., a 1999 Chevrolet Tahoe sport utility vehicle—occupied by nine college students and traveling north in the left lane—collided with and underrode the left side corner of the 1996 Freightliner semitrailer. Following the impact, the Chevrolet disengaged from the semitrailer and entered the median, skidded along the concrete barrier, and came to rest about 450 feet to the northeast. The driver and three passengers in the Chevrolet were fatally injured. The surviving occupants were seriously injured.

Major safety issues identified in this investigation include the adequacy of snow and ice treatment strategies, lack of specific guidance on the use of high-performance median barriers, placement of portable concrete median barriers, and need for primary seat belt laws for all seating positions. As a result of this accident investigation, the National Transportation Safety Board makes recommendations to the Federal Highway Administration, the Connecticut Department of Transportation, and the American Association of State Highway and Transportation Officials. The Safety Board reiterates a recommendation to the Governor and legislative leaders of Connecticut.

Contents

Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ABS	antilock braking system
ADT	average daily traffic
C	Celsius
CAMI	Civil Aeromedical Institute
CDL	commercial driver's license
CFR	*Code of Federal Regulations*
ConnDOT	Connecticut Department of Transportation
CSP	Connecticut State Police
DOT	U.S. Department of Transportation
ECM	electronic control module
EMS	emergency medical services
F	Fahrenheit
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMCSRs	*Federal Motor Carrier Safety Regulations*
I-95	Interstate 95
LOS	level of service
MP	milepost
MUTCD	*Manual on Uniform Traffic Control Devices*
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NWS	National Weather Service
NYSDOT	New York State Department of Transportation
PVL	Photometric and Visibility Laboratory
SAFER	Safety and Fitness Electronic Records
SDM	sensing diagnostic module
SUV	sport utility vehicle
TL	test level (NCHRP)
TTC	temporary traffic controls
VMS	variable message sign
VMT	vehicle miles traveled

Executive Summary

On Interstate 95 (I-95) near Fairfield, Connecticut, two consecutive accidents occurred within 11 minutes in the early morning hours of January 17, 2003. About 4:50 a.m., a 1996 Freightliner tractor flatbed semitrailer, loaded with five portable compressor units, was involved in a nonfatal multivehicle accident. The truck was traveling in a work zone on I-95 north, near milepost 26.6, at a driver-estimated speed of 50 mph, when it slid out of control approximately 1,150 feet south of the exit 24 southbound off-ramp. The vehicle entered the median, overturned and overrode the portable concrete barrier, and collided with a southbound 1997 Dodge Avenger sedan. A southbound 2001 Freightliner tractor/refrigerated trailer combination unit struck the Dodge sedan and then struck the 1996 Freightliner tractor. The three vehicles came to rest blocking the southbound lanes of the highway. During the accident sequence, the flatbed semitrailer separated from the 1996 Freightliner tractor. The semitrailer came to rest perpendicular to the roadway, straddling the portable concrete barrier and partially obstructing the left lane of I-95 north.

At 5:01 a.m., a 1999 Chevrolet Tahoe sport utility vehicle—occupied by nine students from Yale University and traveling north in the left lane—collided with and underrode the left side corner of the 1996 Freightliner tractor flatbed semitrailer. Following the impact, the Chevrolet disengaged from the semitrailer and entered the median, skidded along the concrete barrier, and came to rest about 450 feet northeast of the semitrailer. The driver and three passengers in the Chevrolet were fatally injured. The surviving occupants were seriously injured.

Witnesses reported that at the time of the accidents, light snow was falling, the roads were wet and icy, and snow covered the roadway shoulders.

The National Transportation Safety Board determines that the probable cause of the 4:50 a.m. accident was the 1996 Freightliner's loss of lateral stability, probably due to the operator driving too fast for conditions and to the presence of black ice on the roadway. Contributing to the accident were the inadequate roadway treatment provided by the Connecticut Department of Transportation in response to inclement weather and also its failure to provide a median barrier capable of preventing crossovers by heavy vehicles. The probable cause of the 5:01 a.m. accident was the failure of the Chevrolet driver to identify and avoid the flatbed semitrailer due to fatigue, in conjunction with the distraction from the median crossover accident in the southbound lanes.

The following safety issues were identified in this investigation:

- Adequacy of snow and ice treatment strategies,
- Lack of specific guidance on the use of high-performance median barriers,
- Placement of portable concrete median barriers, and
- Need for primary seat belt laws for all seating positions.

As a result of this accident investigation, the Safety Board makes recommendations to the Federal Highway Administration, the Connecticut Department of Transportation, and the American Association of State Highway and Transportation Officials. The Safety Board reiterates a recommendation to the Governor and legislative leaders of Connecticut.

Factual Information

Accident Narrative

Two consecutive accidents occurred within about 11 minutes in the early morning hours of January 17, 2003, on Interstate 95 (I-95) near Fairfield, Connecticut. (See figure 1.) Witnesses reported that at the time of the accidents, light snow was falling, the roads were wet and icy, and snow covered the roadway shoulders.

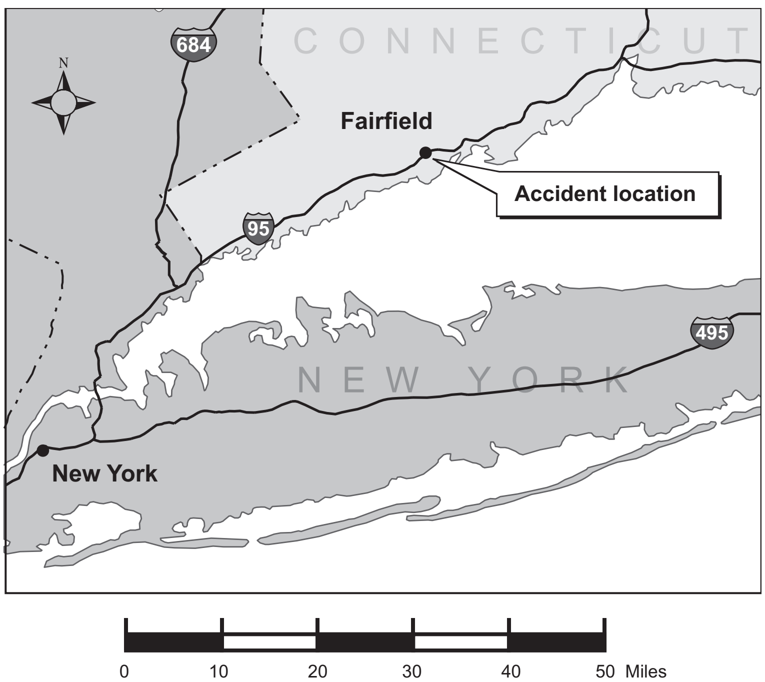


Figure 1. Map of accident location.

About 4:50 a.m.,[1] a 1996 Freightliner tractor flatbed semitrailer, loaded with five portable compressor units, was involved in a nonfatal multivehicle accident. The truck was traveling in a work zone on I-95 north, near milepost (MP) 26.6, at a driver-estimated speed of 50 mph, when it slid out of control approximately 1,150 feet south of the exit 24 southbound off-ramp. The vehicle entered the median, overturned and overrode the portable concrete median barrier (see figure 2a), and collided with a southbound 1997 Dodge Avenger sedan. The sedan was subsequently struck from behind by a southbound 2001 Freightliner tractor/refrigerated trailer combination unit, which then struck the 1996 Freightliner tractor. The three vehicles came to rest blocking the southbound lanes of the highway. The drivers of the two combination units and the Dodge sedan received minor or

[1] Unless otherwise indicated, all times in this report are eastern standard time.

no injuries. During the accident sequence, the flatbed semitrailer separated from the 1996 Freightliner tractor. The semitrailer came to rest perpendicular to the roadway, straddling the portable concrete barrier and partially obstructing the left lane of I-95 north. (See figure 2b.)

Approximately 11 minutes after the 4:50 a.m. accident, a 1999 Chevrolet Tahoe sport utility vehicle (SUV)—occupied by nine students from Yale University and traveling north in the left lane—collided with and underrode the left side corner of the 1996 Freightliner flatbed semitrailer. (See figure 2c.) Following the impact, the Chevrolet disengaged from the semitrailer, entered the median, skidded along the concrete barrier, and came to rest about 450 feet northeast of the semitrailer. (See figure 3.) The driver and three passengers were fatally injured; the other occupants were seriously injured. A witness reported that there were no signs that the Chevrolet driver tried to stop or swerve his vehicle to avoid the semitrailer.

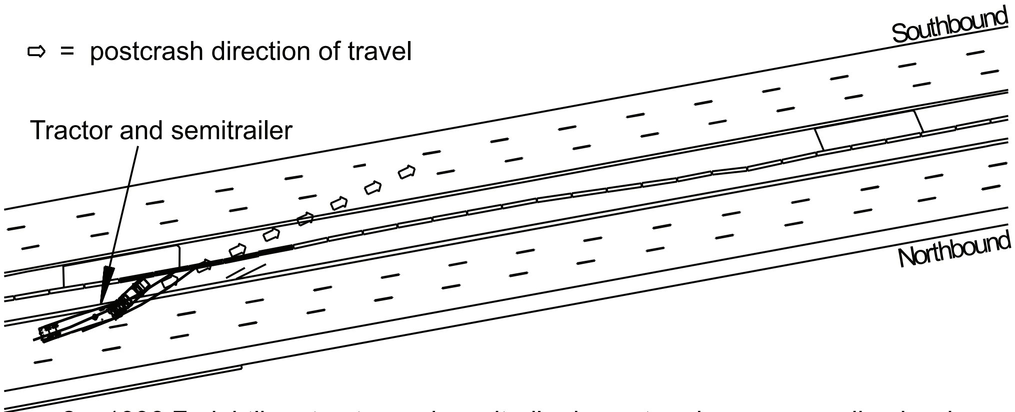
Figure 4 presents forensic evidence from both accidents; included are areas of impact for each vehicle and final rest locations for the 1996 Freightliner and the Chevrolet.

Preaccident Events

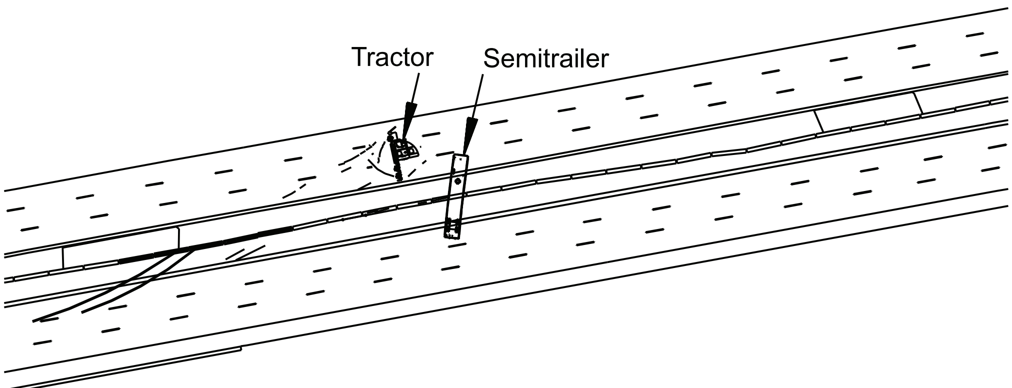
According to the 1996 Freightliner driver, he was traveling in the center lane of I-95 north at approximately 50 mph. As he negotiated a wide right curve in the vicinity of exit 25, his trailer began to skid to the left. He counter-steered to the left in an attempt to straighten the vehicle. The trailer then began to skid to the right; the driver counter-steered to the right, but both the truck and the trailer entered a right-hand skid and began rotating in a counter-clockwise direction. The vehicle entered the median and collided with a portable concrete barrier.

The driver stated that he had not experienced any skidding or loss of control earlier in his trip, though he had become aware of the forecast weather conditions when he stopped in New Jersey.

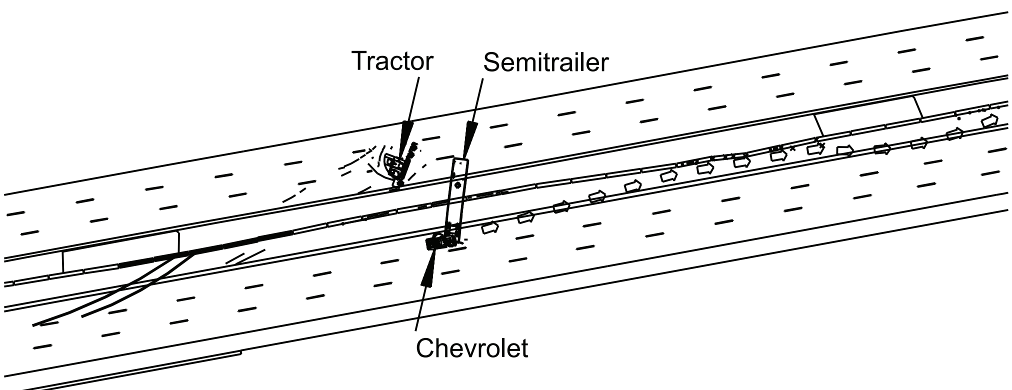
According to the driver of the 2001 Freightliner involved in the 4:50 a.m. accident, the 1996 Freightliner driver stated that he had seen three flares on the northbound roadway and "panicked," which led to the accident. The driver of the 2001 Freightliner stated that he had approached the median barrier and saw flares burning on I-95 north. He recalled that the flares were "almost out" because they had begun to change color. In a postaccident interview, a Connecticut State Police (CSP) officer stated that she had left two flares burning in the left lane of I-95 north after clearing a 3:56 a.m. single-vehicle accident. The flares were located about 500 feet northeast of the location where tire marks from the 1996 Freightliner first appeared.



2a. 1996 Freightliner tractor and semitrailer impact and overrun median barrier.



2b. Tractor and semitrailer separate, causing semitrailer to encroach into northbound traffic lanes.



2c. Chevrolet collides with semitrailer followed by secondary impacts with median barrier.

Figure 2. Representation of multivehicle accident sequence.

Figure 3. Chevrolet Tahoe at final rest in northbound roadway.

Injuries

Table 1 summarizes the injuries resulting from the two consecutive multivehicle accidents. It is based on the International Civil Aviation Organization injury criteria, which the Safety Board uses in accident reports for all transportation modes.

Table 1. Injuries.[2]

Injuries	1996 Freightliner	Dodge	2001 Freightliner	Chevrolet
Fatal	0	0	0	4
Serious	0	0	0	5
Minor	1	1	0	0
None	0	0	1	0
Total	1	1	1	9

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

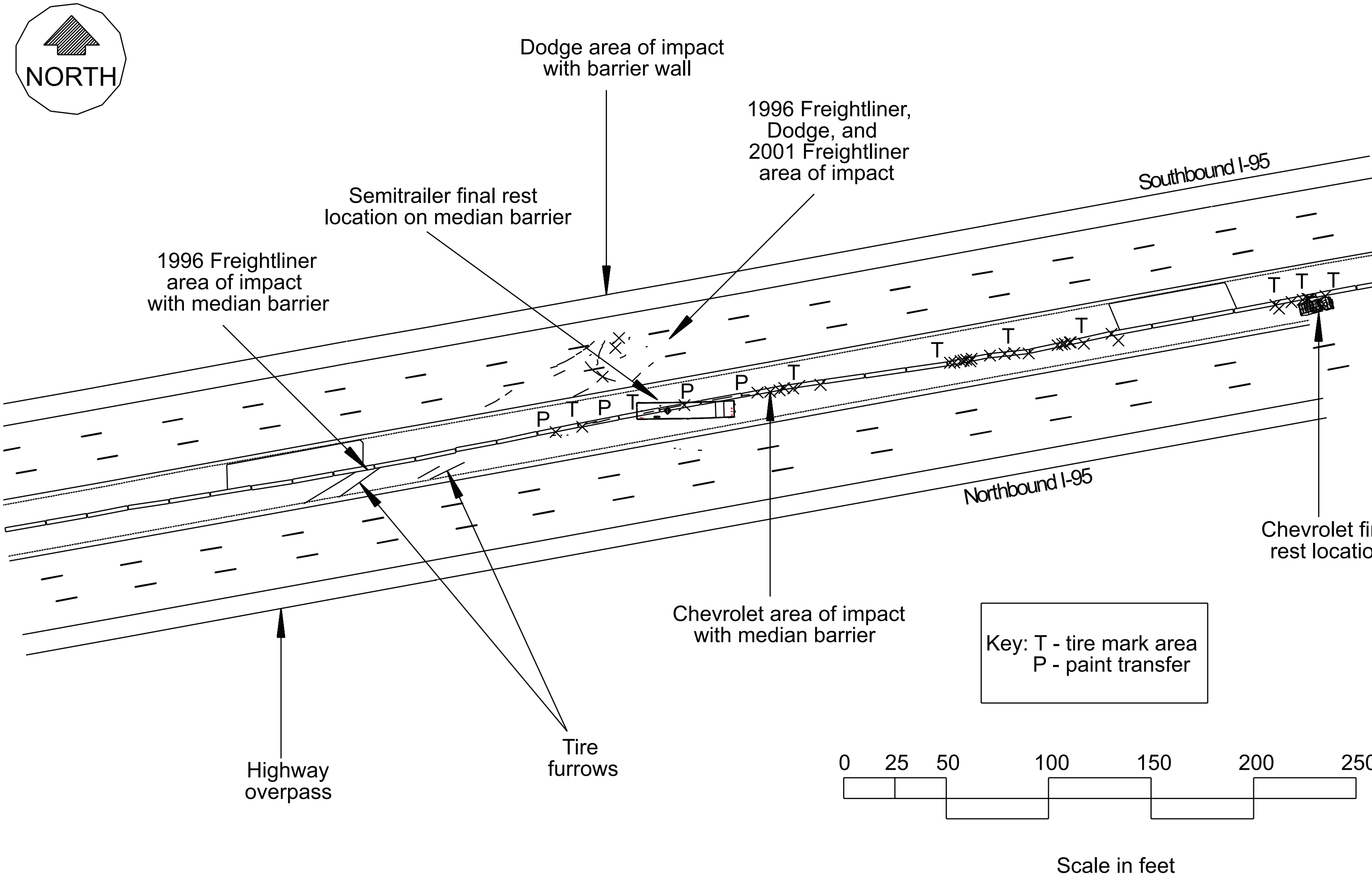


Figure 4. Highway forensic evidence from 4:50 a.m. and 5:01 a.m. accidents.

The 1996 Freightliner driver sustained minor lacerations and contusions on the left side of his face and left shoulder. The driver of the Dodge sustained minor lacerations on his left shoulder and left hip. The 2001 Freightliner driver was not injured. The Chevrolet driver and three occupants received fatal head injuries. (See figure 5 for a seating chart.) The front-seat passenger sustained serious chest and neck fractures. The passenger in the right rear seat suffered a fractured arm and jaw. For the three passengers seated in the cargo area, the injuries included head and neck fractures, cranial trauma, and a fractured left knee and contusions. The occupants of the four vehicles were transported to three area hospitals—Saint Vincent's Medical Center, Bridgeport Hospital, or Norwalk Hospital.

Medical and Pathological Information

Blood and urine specimens from the 1996 Freightliner driver were taken and examined at St. Vincent's Medical Center in Bridgeport, Connecticut, while the driver underwent treatment. The specimens were found to be negative for alcohol and illicit drugs. Portions of the hospital specimens were forwarded to the Federal Aviation Administration's Civil Aeromedical Institute (CAMI) in Oklahoma City, Oklahoma, for further examination; they were also found to be negative for alcohol and other drugs.[3]

The Fairfield Medical Examiner collected toxicological specimens from the Chevrolet driver during postmortem examination. The specimens were found to be negative for alcohol and illicit drugs. Portions of the specimens were also forwarded to CAMI for further examination and were found to be negative for alcohol and other drugs.

No toxicological specimens were collected from the 2001 Freightliner driver. Title 49 CFR 382.303 does not require the collection of toxicological specimens from a commercial driver unless: (1) an accident involves a fatality or (2) the driver received a citation in an accident involving either bodily injury with immediate medical treatment away from the scene or disabling damage to any motor vehicle requiring towaway. The southbound accident did not involve a fatality, and the 2001 Freightliner driver did not receive a citation.

Survival Aspects

Restraint Use and Survivable Space

The 1996 Freightliner driver, the 2001 Freightliner driver, and the 1997 Dodge driver stated that they were wearing seat belts at the time of the 4:50 a.m. accident. The Dodge was equipped with an airbag, which deployed during the accident sequence.

[3] CAMI tests samples for carbon monoxide, cyanide, ethanol, amphetamines, opiates, marijuana, cocaine, phencyclidine, benzodiazepines, barbiturates, antidepressants, antihistamines, meprobamate, methaqualone, and nicotine.

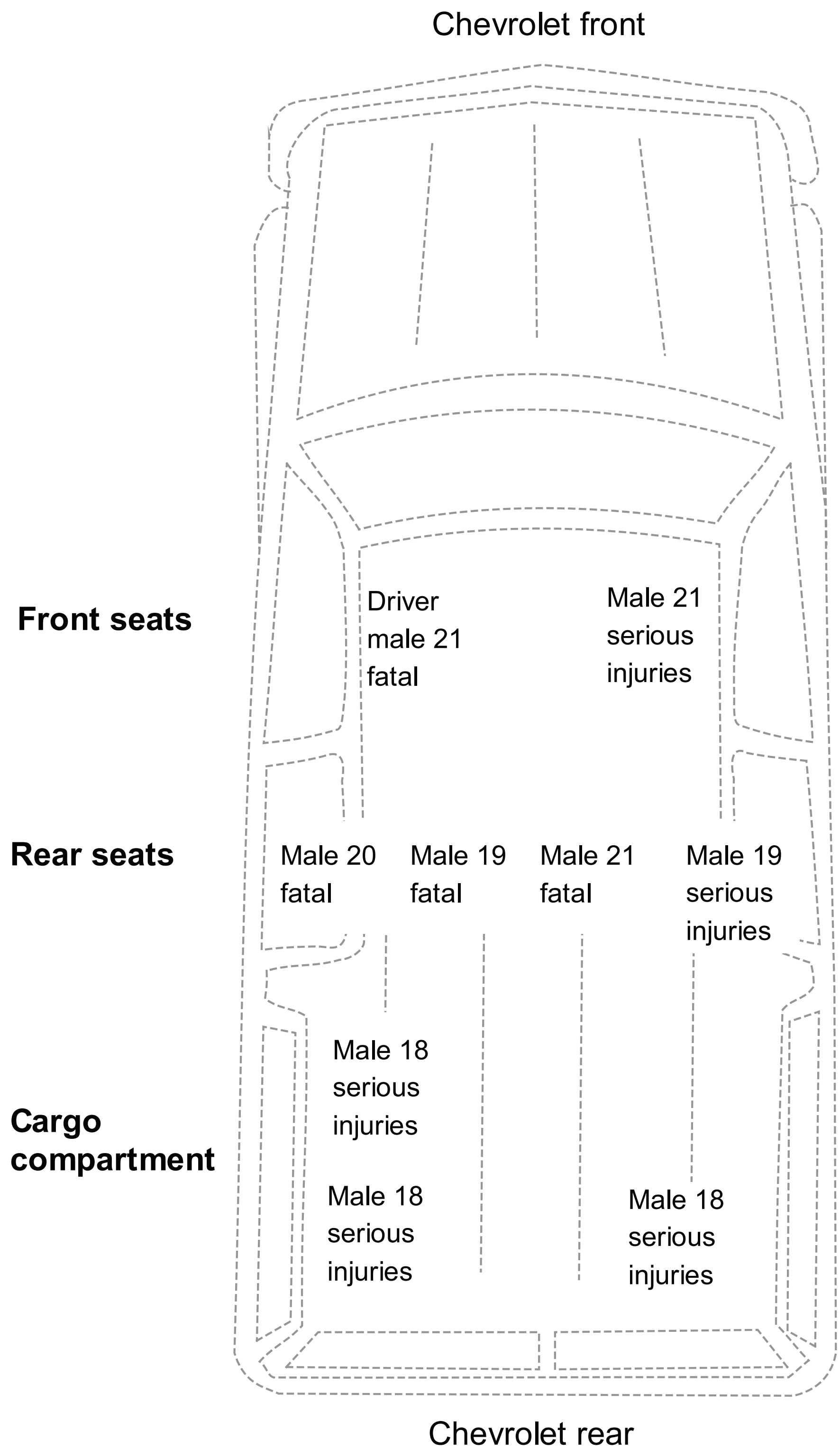


Figure 5. Chevrolet Tahoe seating chart.

The Chevrolet was designed to accommodate a maximum of five passengers. It included seat belts for the two front seats and the three rear seats. Figure 5 shows the seating arrangement at the time of the accident. According to survivor testimony, only the driver and front-seat passenger wore their seat belts. Four passengers sat in the rear seat; and three passengers sat in the rear cargo area, which had no restraints and was not configured for seating. Physical evidence was used to confirm restraint use within the vehicle.

All of the Chevrolet occupants, except for the left rear-seat passenger, were contained in the vehicle. According to an American Medical Response emergency medical technician, the left rear-seat passenger was found with his upper body protruding between the B-pillar and the rear left door. The Chevrolet was equipped with a driver's side airbag, which was found intact and not deployed.

Title 14, Chapter 246, Section 14-100a(C)(1), of the Connecticut General Statutes requires all individuals under the age of 16 to use safety belts in the front and back seats. There are no safety belt requirements for back seat passengers over 16 years of age. On April 15, 2005, an amendment to this statute, House Bill No. 5450, was proposed in the Connecticut House of Representatives to require safety belt usage in all seating positions regardless of passenger age. The bill was not passed into law.

Title 14, Chapter 248, Section 14-272a, of the Connecticut General Statutes requires passengers under the age of 16 to be belted when riding in the cargo area of any open-bed vehicle, such as a pickup truck, that is traveling on the highway. There are no requirements that passengers under 16 be belted when riding in the cargo area of a closed-bed vehicle, such as the Chevrolet; and there are no passenger safety restrictions for those over the age of 16 riding in the cargo area of either an open- or closed-bed vehicle.

During the accident sequence, the 1996 Freightliner flatbed semitrailer intruded into the survivable space of the Chevrolet passenger compartment. The driver's side of the Chevrolet was torn open up to the rear passenger door. Contact damage extended about 28 inches into the passenger compartment. The roof of the vehicle was displaced aft and downward to a point about midway between the front seats and the rear bench seat. The front and rear-seat portion of the passenger compartment was reduced by approximately 60 percent. The cargo area was intact, with the exception of intrusion by the rear bench seat about 8 inches aft.

Emergency Response

Table 2 provides the emergency response timeline for the 4:50 a.m. and 5:01 a.m. accidents. The data are based on witness cellular phone records and dispatch records from the CSP Bridgeport Operations Center. The times recorded by the operations center were generally a few minutes earlier than the times from 911 phone records, on which the accident times were based. This discrepancy accounts for the time gap between the 911 calls and dispatch of the CSP. The times listed in table 2 are the actual times recorded from cellular phone and dispatch records.

Table 2. Emergency response timeline for 4:50 a.m. and 5:01 a.m. accidents.

I-95 South		I-95 North	
Time	Event	Time	Event
4:50	Northbound 1996 Freightliner hits median barrier and partially crosses over to southbound side		
4:50	Bridgeport Operations Center receives 911 call but is not informed of blockage of northbound lane		
4:56	CSP dispatched to accident scene		
4:59	CSP requests Fairfield Police Department assistance in locating accident		
5:00	Fire Department dispatched to accident scene		
5:02	Emergency medical services (EMS) dispatched	5:01	Chevrolet Tahoe collides with 1996 Freightliner flatbed semitrailer
		5:01	Bridgeport Operations Center receives 911 call
5:04	Fire Department arrives at accident scene; informed of northbound accident	5:05	CSP informed of accident
		5:10	EMS dispatched
5:12	CSP arrives	5:12	CSP arrives
5:18	EMS arrives	5:18	EMS arrives
		6:10	Final passenger transported to hospital

The Bridgeport Operations Center fielded the emergency calls and dispatched first responders to the 4:50 a.m. accident scene on I-95 south. The 5:01 a.m. accident involving the Chevrolet occurred while first responders were enroute to the southbound accident. According to the CSP, both accident scenes were treated as one large event. The responding agencies were able to communicate with each other and allocate resources. The CSP added that response time was negatively affected by three factors:

- Two of the closest patrol officers were detained at the Bridgeport Hospital with the driver from the 3:56 a.m. accident, who happened to have an outstanding arrest warrant.
- Road and weather conditions were poor.
- The traffic queue that formed after the southbound accident caused additional highway congestion.

Driver Information

1996 Freightliner Driver

The 33-year-old 1996 Freightliner driver was an owner/operator who was driving his personal truck tractor and a flatbed semitrailer owned by Arrow Trucking Company of Tulsa, Oklahoma. He held a valid California Class A commercial driver's license (CDL) with hazardous materials and doubles/triples endorsements, issued July 6, 1999, and expiring May 13, 2004. The driver also held a valid medical certificate, issued May 30, 2001, and expiring May 31, 2003. He had attended a professional truck driving school from May 24 through June 24, 1999, and then worked as an employee driver for Arrow Trucking for 1 year. He subsequently purchased the 1996 Freightliner and worked for Arrow Trucking as an owner/operator. Table 3 lists his traffic violations prior to the Fairfield accidents. The 1996 Freightliner driver indicated to Safety Board investigators that he had prior experience driving commercial vehicles in winter weather conditions and snow.

Table 3. Prior moving violations for 1996 Freightliner driver.

Date	Violation
August 31, 2002	Speeding
March 26, 2002	Exceeding/violating weight limits of vehicle/truck
January 30, 2002	Failing to file document/report as required
July 18, 2001	Property damage accident

The 1996 Freightliner driver's 72-hour history was reconstructed using a combination of his daily logs and other records that were found in the tractor cab following the accident. (See table 4.)

Table 4. Timeline of 1996 Freightliner driver's activities leading up to accident.

Driver's logs		External evidence	
January 14, 2003		**January 14, 2003**	
12:45–3:00 p.m.	Off duty, Mocksville, NC		
3:00 p.m.–12:00 a.m.	Resting, sleeper berth		
January 15, 2003		**January 15, 2003**	
12:01–12:00 a.m .	Off duty, Mocksville, NC		
January 16, 2003		**January 16, 2003**	
12:01–3:45 a.m.	Resting, sleeper berth		
3:45–4:00 a.m.	On duty, pretrip inspection/loading		
4:00–8:45 a.m.	On duty, driving		
8:45– 9:00 a.m.	On duty, not driving, Fredericksburg, VA	*7:02– 9:25 a.m.*	*Loading, Mocksville, NC (shipper's log)*
9:00 a.m.–1:00 p.m.	Resting, sleeper berth, Fredericksburg, VA		
1:00–4:00 p.m.	Driving		
4:00–4:15 p.m.	Fueling, Paulsboro, NJ		
4:15–5:15 p.m.	Driving	*4:40 p.m.*	*Toll receipt, JFK Memorial Hwy, Perryville, MD*
5:15 p.m.–12:00 a.m.	Resting, sleeper berth, NJ Turnpike, exit 8 travel plaza	*6:54 p.m.*	*Fueling receipt, Paulsboro, NJ*
January 17, 2003		**January 17, 2003**	
12:01–1:15 a.m.	Resting, sleeper berth, NJ Turnpike, exit 8 travel plaza		
1:15–1:30 a.m.	On duty, pretrip inspection		
1:30 a.m.	Began driving		
		3:47 a.m.	*Toll receipt, NJ Turnpike, Allentown, NJ*
		4:00 a.m.	*Toll receipt, GW Memorial Bridge, Edgewater, NJ*
		4:50 a.m.	*Accident (CSP records)*

Chevrolet Tahoe Driver

At the time of the accident, the 20-year-old Chevrolet driver held a valid California noncommercial Class C driver's license, which was issued on June 19, 1998, and set to expire on April 13, 2006. The driver's California record indicated one violation on July 3, 2002, for "unsafe speed for road conditions." The driver did not own the Chevrolet, which belonged to another fraternity member.

Safety Board investigators reconstructed the activities of the Chevrolet driver during rush week and prior to the accident using information gathered during interviews with the driver's dormitory roommate; the chapter president of Delta Kappa Epsilon; and the driver's friend, also a Yale student. (See table 5.) The driver's sleep/wake pattern was also derived from this information. (See figure 6.)

Table 5. Timeline of Chevrolet driver's activities leading up to accident.

Time	Activity
January 12, 2003	
2:00–7:00 a.m.	Slept
9:00 a.m.–1:30 p.m.	Visited friend
Afternoon	Observed in dorm room
9:00 p.m.–2:00 a.m.	Participated in fraternity "rush" activities
January 13, 2003	
After 2:00 a.m.	Slept
Daytime	Attended classes and activities
9:30 p.m.–12:15 a.m.	Participated in fraternity "rush" activities
January 14, 2003	
12:15–3:00 a.m.	Visited friend
3:00–9:30 a.m.	Slept
Daytime	Attended classes and activities
Nighttime	Stayed up late at fraternity house
January 15, 2003	
6:00 a.m.	Returned to dorm room
10:00 a.m.	Went to classes
Afternoon	Took 2–3 hour nap
10:00 p.m.	Departed for fraternity "rush" activities
January 16, 2003	
12:30–2:45 a.m.	Visited friend
3:00–10:45 a.m.	Slept
10:45 a.m.–10 p.m.	Attended classes and activities
10:00 p.m.	Departed for fraternity "rush" activities
10:30 p.m.	Departed New Haven for New York City
January 17, 2003	
11:30 p.m.–12:00 a.m.	Arrived in New York City
1:30–3:30 a.m.	Attended party in bar(s)
3:45 a.m.	Departed New York City for New Haven
5:01 a.m.	Accident

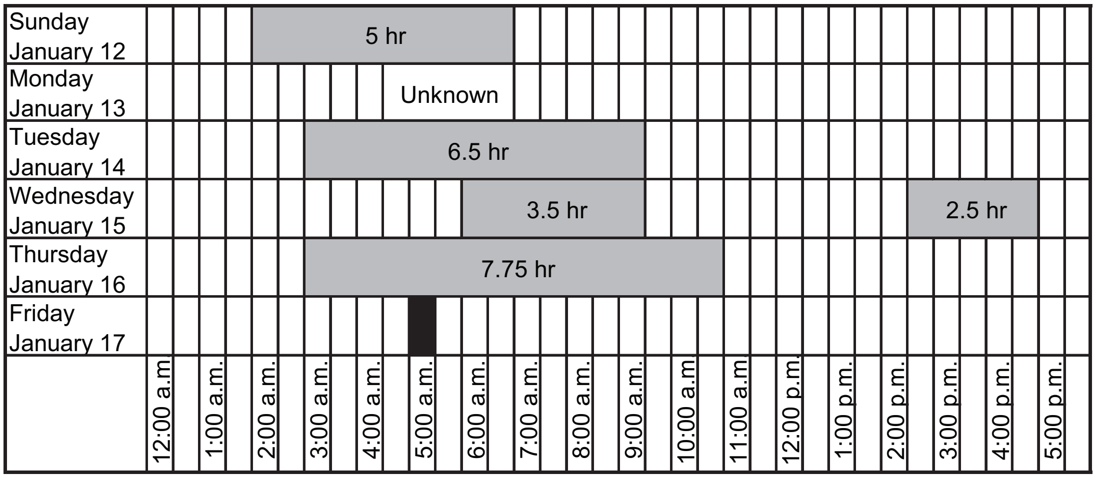


Figure 6. Chevrolet driver sleep pattern prior to accident.

According to the president of the fraternity chapter to which the Chevrolet driver belonged, the Fairfield accidents occurred during “rush week,” a period when pledges are considered for membership. The chapter president stated that the Chevrolet driver volunteered to serve as one of three designated nondrinking drivers for the Thursday night rush activity in New York City. The fraternity members arrived at an Irish pub in New York City between 11:30 p.m. and midnight. They were later joined by several pledges who had taken the train to the city. The chapter president stated that he had observed the Chevrolet driver drink one beer while at the pub.

The fraternity members and pledges departed New York City for New Haven about 3:45 a.m. The pledges who had arrived by train returned by car because the first train for New Haven did not leave until 5:00 a.m. The fraternity chapter president, who was also a designated nondrinking driver and who was the last to leave for New Haven, stated that he experienced slippery road conditions along I-95. He briefly skidded while traveling at 65 mph, then reduced his speed to 50 mph and experienced no further problems. He said that he also observed a tractor-trailer skidding on the roadway. He learned that the Chevrolet had been involved in a collision when he approached the accident site.

The CSP and the Safety Board interviewed four of the surviving five Chevrolet passengers. Two of the passengers, who had been seated in the cargo area, stated that they were asleep when the accident occurred. Another passenger, also seated in the cargo area, had sustained serious head injuries and had no recollection of events prior to the accident. The right rear-seat passenger stated that he had slept most of the way back from New York, except when a friend shared a sandwich with him after a fast food stop along I-95.

Vehicle and Wreckage

1996 Freightliner Tractor and Flatbed Semitrailer

The 1996 Freightliner tractor, model D120064ST, had a wheel base of 235 inches and an unladened weight of 17,000 pounds. The odometer indicated that it had been driven 655,420.3 miles. The tractor was powered by a 12.7-liter, 360-horsepower Detroit Diesel Corporation 60-Series engine, with a 10-speed Rockwell Automation, Inc., manual transmission. The 2000 Fontaine Trailer Company flatbed semitrailer was 48 feet long and had an unladened weight of 14,000 pounds. It carried five portable generators, each weighing 2,265 pounds (total weight, 11,325 pounds), for a total trailer weight of 25,325 pounds.

The tractor and semitrailer combination unit was equipped with an air braking system that consisted of 15-inch drum brakes on the steer axle and 16.5-inch drum brakes on the second, third, fourth, and fifth axles. The tractor did not have an antilock braking system (ABS); the semitrailer was equipped with ABS. The tractor had an engine retarder,[4] also called a "Jake" brake, which could be set to operate on two, four, or six cylinders. The retarder switch was in the "off" position when the Safety Board inspected the tractor. Manufacturers generally advise drivers not to use a retarder under wet or slippery roadway conditions. In fact, a Safety Board investigation of a motorcoach accident that occurred in Canon City, Colorado, in December 1999, revealed that an enabled retarder most likely triggered the loss of control and eventual crash of the motorcoach on a snow-covered and mountainous roadway.[5]

The truck tractor had scrape marks along the entire passenger side as a result of overturning during the 4:50 a.m. accident sequence. The steer axle and engine compartment received extensive contact damage. The engine was crushed downward. In addition, the fifth wheel[6] plate was torn off the tractor's frame. On the semitrailer, the area where the fifth wheel was connected was damaged, the landing gear was damaged,[7] the rear impact bar was separated,[8] and the surface of both the underside and flatbed area was damaged. The bars that had attached the rear impact bar to the semitrailer were bent rightward.

The tractor was equipped with a Detroit Diesel Electronic Control III Module (ECM).[9] The ECM's optional memory feature, which records operating information about the engine and the vehicle, was not activated. There was extensive damage to the brakes on the fourth axle and to the right chamber of the second axle. The brakes that could be

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[4] An engine retarder is a device that assists the brakes in slowing a vehicle. The most common type of retarder on over-the-road trucks manipulates the engine's valves to create drag.

[5] National Transportation Safety Board, *Motorcoach Run-Off-the-Road Near Canon City, Colorado, December 21, 1999*, Highway Accident Brief NTSB/HAB-02/19 (Washington, DC: NTSB, 2002).

[6] The fifth wheel is a coupling device attached to a tractor that supports the front of a semitrailer and locks it to the tractor.

[7] Retracting legs support the front of a semitrailer when it is not coupled to a tractor.

[8] The impact bar is a lower appendage to the rear bumper that helps prevent underride.

[9] The primary function of an ECM is to control fuel flow to the engine to provide maximum fuel economy and to meet Government emission standards.

inspected and measured were found to be properly adjusted. No preexisting defects were found in the lines, valves, couplings, or brake chambers. The tires on the tractor and semitrailer were found to be in good condition, with little sign of uneven wear; tread depths were within regulations.[10]

The fifth wheel slide[11] was in the "off" position, which meant that the flatbed semitrailer had been locked to the tractor prior to the accident. Cruise control was in the "off" position. The windshield wiper selection knob was in the "low speed" setting. The factory fog light switch was in the "off" position, and a second after-market add-on fog light switch was in the "on" position.

Retroreflective tape on the semitrailer was 3 inches wide and ran down both sides in 18-inch segments spaced 17 inches apart. (See figure 7.) It also ran fully along the rear of the semitrailer and rear impact bar. Each segment of the tape consisted of 7 inches of white material and 11 inches of red material. The left side of the semitrailer—the area impacted by the Chevrolet—also included two circular light covers. The smaller of the two covers was amber, about 2 inches in diameter, and cracked and damaged. The larger light cover was red, about 3 inches in diameter, and undamaged.

Figure 7. Retroreflective tape on rear of flatbed semitrailer.

[10] According to the 2002 *Federal Motor Carrier Safety Regulations* (FMCSRs), tread depth must be at least 4/32 inch for front tires and at least 2/32 inch for all other tires.

[11] A slide is a mechanism that allows the fifth wheel to be moved back and forth to adjust the distribution of weight on the tractor's axles.

Chevrolet Tahoe

The rear impact bar of the semitrailer was embedded in the Chevrolet's radiator and engine compartment, approximately at the center of the vehicle. The engine hood was detached from the vehicle and deformed. The top portion of the engine compartment was severely damaged, as were various components mounted above the engine—the air conditioning unit, brake booster, ECM, throttle, air filter, and air intake. The windshield was broken and detached from the vehicle. The engine compartment firewall was pushed rearward and down toward the passenger compartment. The left side A-pillar was deformed and pushed rearward. The front portion of the roof was peeled back. The driver's side door was detached. The left rear door was pushed rearward into the left rear quarter panel and was in contact with the left rear tire. (See figure 8.)

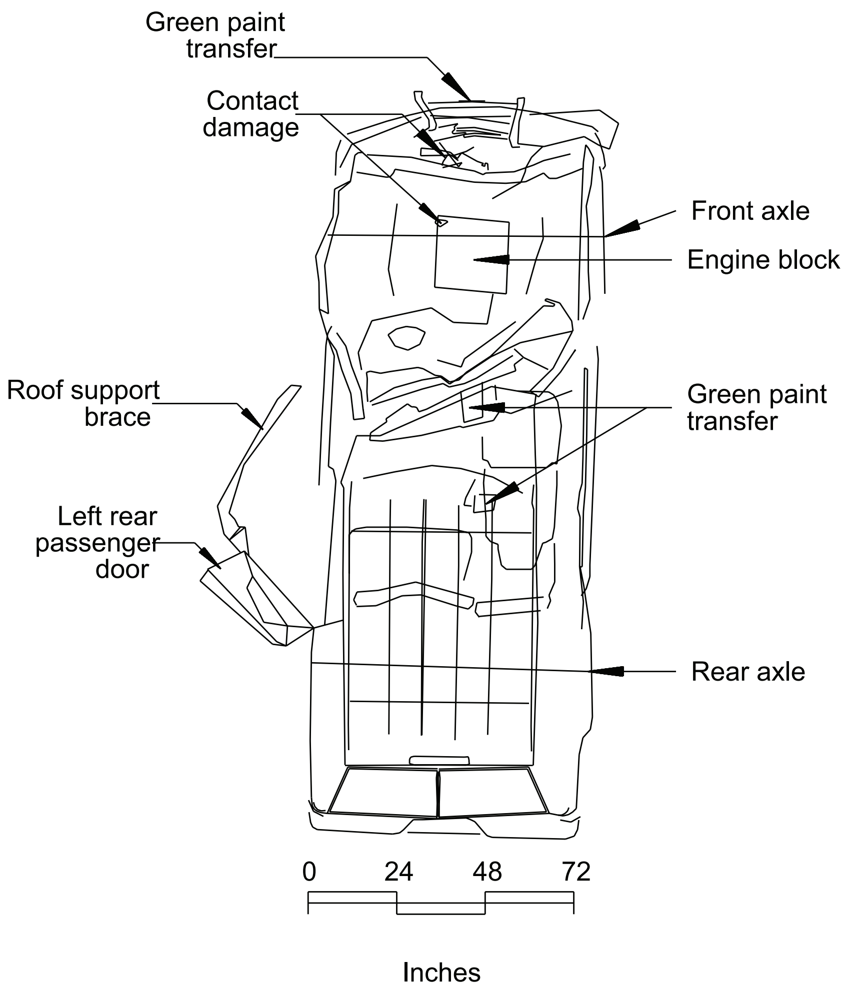

Figure 8. Diagram of Chevrolet Tahoe wreckage.

Safety Board investigators examined the Chevrolet's wheels, power train, steering mechanism, brakes, and sensors. No preexisting defects were found to be associated with these systems. Light bulbs extracted from the Chevrolet were taken to the Safety Board's

Materials Laboratory for testing. Inspection of the headlight bulbs revealed that the high beams were on at the time of the accident, as evidenced by hot stretching on the bulb filaments.[12] The Chevrolet was equipped with an after-market brush guard over the front exterior lighting area. (See figure 9.) The upper and lower metal bars on the guard were approximately 1 1/2 inches in diameter, separated by five smaller metal bars of approximately 3/8 inch diameter. One of the smaller diameter bars and a small portion of the thick upper bar were directly in front of the headlight lenses.

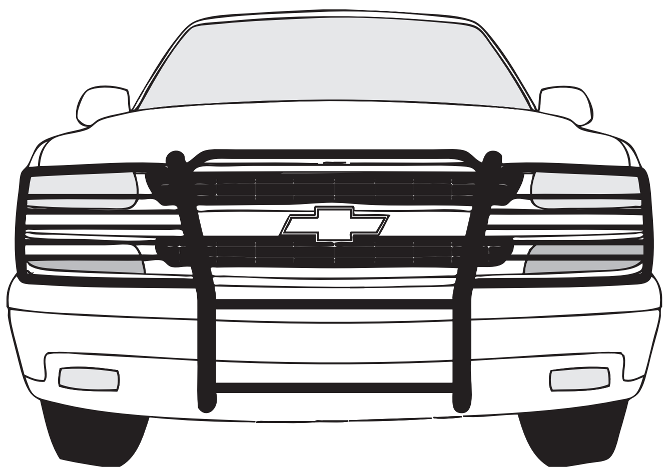

Figure 9. Chevrolet Tahoe with brush guard.

The Chevrolet was equipped with a sensing diagnostic module (SDM) located under the driver's seat. An SDM interprets a crash pulse (the time over which a crash occurs) and determines whether to deploy the airbags. The module can store one nondeployment event,[13] which is overwritten by subsequent nondeployment events. An SDM can also store one deployment event, as well as related information that occurs within 5 seconds of that event. In this case, one nondeployment event was stored because the airbags did not deploy. SDM data obtained by the CSP indicated that the Chevrolet reached a maximum change in velocity of 29 mph (5 g's) about 272.5 milliseconds after the algorithm was enabled, at which time power was lost and no additional data were recorded. The SDM can record up to 300 milliseconds of data once the algorithm is enabled.

Meteorological Information

The National Weather Service (NWS) reporting facility at Igor Sikorsky Memorial Airport, Bridgeport, Connecticut, is located approximately 7 miles east of the accident site. Between 11:17 p.m. on January 16 and 3:16 a.m. on January 17, 2003, the airport

[12] When a bulb is on, the metal filament inside is at an extremely high temperature and becomes malleable. The hot metal filament stretches with an impact of sufficient force.

[13] A nondeployment event is one that is severe enough to trigger the algorithm but not severe enough to deploy the airbag.

recorded light snow with only a trace of precipitation. The NWS recorded the following temperatures and visibilities in the hours preceding the accidents:

- 2:54 a.m.: Wind from 280º at 7 knots, visibility 3 miles in light snow and mist. Temperature -5º Celsius (C; 23º Fahrenheit [F]).
- 3:54 a.m.: Wind from 310º at 3 knots, visibility 9 miles. Temperature -6º C (21º F), with snow ending at 3:16 a.m.
- 4:54 a.m.: Wind from 340º at 5 knots, visibility 10 miles. Temperature -5º C (23º F).

Highway Information

In the vicinity of the accidents, I-95 is a six-lane concrete urban principal arterial roadway.[14] In January 2003, the width of the paved portion of the northbound roadway was 48 feet. The paved area consisted of a 10-foot-wide right shoulder, three 12-foot-wide main travel lanes, and a 2-foot-wide left shoulder. The paved portion of the southbound roadway was identical. A 26-foot-wide earthen median divided the roadway. A 32-inch-high portable concrete barrier system had been placed in the middle of the median as part of an ongoing work zone project. (See figure 10.)

According to the Connecticut Department of Transportation (ConnDOT), in 2002, the average daily traffic (ADT) on I-95 in the vicinity of the accidents was 125,300 vehicles, with 63,600 vehicles traveling south and 61,700 traveling north. Trucks accounted for 28 percent of the northbound traffic and 26 percent of the southbound traffic. The normally posted speed limit was 65 mph. Because of highway construction, the speed limit at and in the vicinity of the accident site had been reduced to 45 mph.

The accidents occurred within a work zone that began approximately 660 feet south of the exit 24 northbound off-ramp and ended about 340 feet north of the exit 24 on-ramp—a total distance of 3,983 feet. According to ConnDOT, the objectives of the highway construction were to eliminate the earthen median, provide full shoulders (emergency breakdown lanes), install concrete median barriers and improved drainage facilities, and rehabilitate the concrete pavement and bridge decks. Details of this project are provided in the discussion of work zone construction.

[14] Under the American Association of State Highway and Transportation Officials (AASHTO) functional classification of highway facilities and systems, the service characteristics of an urban principal arterial road provide for, among other things, service to the major centers of activity of urbanized areas, carrying most of the trips entering and leaving the urban area, and significant intra-area travel, such as between central business districts and outlying residential areas.

Figure 10. Overturned portable concrete barrier segments viewed from northbound lanes of I-95.

Forensic Evidence

Physical evidence of the initial accident involving the 1996 Freightliner consisted of furrow marks on the northbound side of the median, contact damage to the concrete median barrier, and pavement scrape marks in the southbound lanes. (See figure 4.) The furrow marks began in the median adjacent to the left lane, veered off toward the concrete median barrier at approximately a 23º angle, and then continued into the southbound traffic lanes. The pavement scrape marks traversed the three southbound lanes and extended a distance of approximately 63 feet. Additional contact damage to the top of the concrete median barrier consisted of green paint transfer that began about 80 feet beyond the furrow marks and continued for a distance of 101 feet.

The Chevrolet left pavement scrape marks on the left lane at the point of impact with the 1996 Freightliner flatbed semitrailer; additional forensic evidence included intermittent contact damage to the median barrier beyond the impact with the trailer. (See figure 4.) The pavement scrape marks were 10 feet long and were located approximately 150 feet north of the furrow marks. The contact damage to the median barrier—consisting of tire marks that extended about 500 feet—was located 215 feet north of the furrow marks.

Accident History

In the 28 miles of I-95 from the New York State line to the eastern boundary of Fairfield, Connecticut, which includes the accident location, ConnDOT accident records indicated 40 traffic fatalities from 1998 to 2002—a 5-year average of 0.63 fatalities per 100 million vehicle miles traveled (VMT). The rest of the Connecticut urban interstate system averaged 0.596 fatalities per 100 million VMT; the national urban interstate system averaged 0.640 fatalities per 100 million VMT.

From 1998 to 2002, a total of 5,743 fatal and nonfatal accidents were recorded within the 5 miles of I-95 north that encompass the accident site. Table 6 categorizes these accidents.

Table 6. Accidents occurring within 5 miles of I-95 north accident site, 1998–2002.[15]

Year	Total	Rear end	Sideswipe	Fixed object	Moving object	Other
1998	969	455	221	196	49	48
1999	1,059	512	237	196	65	49
2000	1,240	615	300	223	55	47
2001	1,248	542	345	224	58	79
2002	1,227	572	327	215	53	60
Total	**5,743**	2,696	1,430	1,054	280	283

Roadway Condition

The 1996 Freightliner driver stated to Safety Board investigators that the accident occurred because he had lost control of his vehicle immediately after crossing an overpass[16] and encountering black ice.[17] Several witnesses interviewed by the Safety Board reported experiencing sideslip or skidding while driving on I-95 north in the vicinity of the accident site. Witnesses also stated that there was no evidence of plowing or road treatment in the northbound or southbound lanes along the area of the Fairfield accidents.

According to the CSP, 18 other traffic accidents occurred on I-95 between midnight and 4:50 a.m. on January 17 "within several miles" of the Fairfield collisions, including one at 3:56 a.m. According to the police report for the 3:56 a.m. accident, a Ford

[15] A rear-end accident is a collision in which the front of one vehicle in transport impacts the back end of another vehicle in transport. A sideswipe accident is a collision in which two vehicles are traveling in the same direction with direct impact on the sides of their vehicles. A fixed-object accident is an allision involving a motor vehicle in transport and a fixed object (such as a tree, utility pole, traffic signal, guard rail, bridge abutment, or similar object). A moving-object accident is a collision between a motor vehicle in transport and any other vehicle that is moveable or moving.

[16] Ice generally forms on overpasses and bridges more quickly than on other roadway surfaces because heat is conducted away from both the top and bottom of the structure. See www.atmos.washington.edu/~cliff/Roadway2.htm, July 14, 2005.

[17] Black ice is a popular term for a very thin coating of clear, bubble-free homogeneous ice that forms on pavement. It is caused by freezing temperatures at ground level and warmer conditions in the upper atmosphere, including wet ground conditions and rapidly falling temperatures. Federal Highway Administration, *Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Maintenance Personnel* (Washington, DC: FHWA, 1996) 55.

pickup truck was traveling in the center lane of I-95 north at a driver-estimated speed of 70 mph when it slid on an icy spot. The vehicle entered the median, struck the median barrier, and rolled over 1 1/2 times. The police report stated that—at the time of this accident—the weather was clear, the traffic was moderate to light, the area was unlit and dark, and the center and right lanes were clear with some icy patches. The report also mentioned that while the officer was traveling to the accident scene at speeds between 60 and 65 mph, the patrol car slid on the icy roadway, causing the officer to slow to 55 mph.

There were other reports of slippery conditions on I-95 that morning. About 2:38 a.m., the Bridgeport Operations Center logs recorded CSP troopers describing I-95 as "extremely slippery" and requested that ConnDOT be called to sand and plow the roadway east of exit 19. The troopers discussed coordination efforts for jackknifed trucks near northbound exit 23 and southbound exit 29. They also mentioned other accidents and abandoned vehicles on I-95.

A paramedic enroute from Fairfield University to Bridgeport Hospital about 4:57 a.m. stated that his ambulance had fishtailed as he drove at 40 mph on I-95 north, between exits 22 and 29. He further stated that traffic had been passing him at 50 to 60 mph. He started receiving calls about the Fairfield accidents at 5:10 a.m. and drove the last ambulance that was dispatched. Upon arrival at the scene, he found the roadway to be "extremely slippery" and had trouble walking in the area.

ConnDOT Maintenance District #3, section #33, Stratford maintenance facility (crew 338), was responsible for treating the accident area of I-95 during snow and ice conditions. At 10:45 p.m. on January 16, the section #33 supervisor was notified by the Newington Operations Center of an AccuWeather report for flurries and light snow, with accumulations of up to 1 inch. About 12:50 a.m., the supervisor decided to proceed with 25-percent coverage of the area.[18] Two trucks were sent out to cover I-95, between exits 18 and 31. Three other trucks were sent to cover Route 25, Route 8, and secondary routes.

The supervisor stated that the two trucks assigned to I-95, from exits 31 to 18, were loaded with a 7:2 mixture of sand and salt by 1:30 a.m. The ConnDOT *2002/2003 Snow and Ice Guidelines* define a 7:2 mixture as consisting of 1,264 pounds of sand and 300 pounds of salt per two-lane mile.[19] The trucks began to apply a continuous treatment to the southbound lanes of I-95 before looping back to treat the northbound lanes. During its run, the lead truck also treated an incident area on I-95 south near bridge 99 so that it could be opened to traffic. This area had been closed due to a construction accident that caused a light pole to fall across three lanes. The trucks returned to the Stratford maintenance facility between 3:00 and 3:30 a.m. to refill for a second

[18] On six-lane highways such as I-95, 25-percent coverage requires two trucks, 50-percent coverage requires three trucks, and 100-percent coverage requires five trucks.

[19] The *Snow and Ice Guidelines* allow for this mixture to be used in lieu of straight salt on multilane highways when a complete assignment of trucks is not dispatched. Connecticut Department of Transportation, *2002/2003 Snow and Ice Guidelines*, Bureau of Engineering and Highway Operations, Office of Maintenance (Hartford, CT: ConnDOT, 2002) 10.

treatment of the same area. The total amount of 7:2 mixture applied to this area of I-95 prior to the Fairfield accidents was 20 to 25 cubic yards.[20] As they applied the second treatment on the roadway, both truck drivers reportedly saw the vehicle involved in the 3:56 a.m. accident being loaded onto a flatbed trailer.

According to the ConnDOT transportation maintenance director, the *Snow and Ice Guidelines* provide instructions for 100-percent coverage only,[21] which requires a full complement of trucks. The guidelines recommend that straight salt be used when treating multilane highways; the 7:2 mixture may be used "when the complete assignment of trucks [has] not been called out or if conditions warrant." The guidelines do not indicate when a complete assignment of trucks is unnecessary, nor do they specify treatment procedures for such occasions.

The maintenance districts have unwritten, informal procedures for roadways during lesser storm conditions. The maintenance director stated that the criteria for implementing 25-, 50-, and 100-percent treatment coverage is "very subjective" and that it is the section supervisor's responsibility to determine coverage for a particular storm. Once a decision is made, the section supervisor monitors road conditions by traveling the roadway and communicating with the treatment trucks.

AASHTO recommends that State highway maintenance officials responsible for snow and ice control treatment establish a level-of-service (LOS) program for identifying and managing storms.[22] According to AASHTO, LOS refers to

> Operational guidelines establishing maintenance activities associated with the prevention and removal of snow and ice from roadways. LOS may establish a prescribed end-of-storm condition, intermediate stages acceptable while obtaining that condition, or the frequency of snow and ice control maintenance operations.

LOS is based on factors such as storm severity, temperature, traffic data, road classification, treatment materials used, maintenance coverage and cleanup time, and available equipment. Appendix B includes excerpts from the ConnDOT *2002/2003 Snow and Ice Guidelines*, along with sections from the LOS guidelines published by AASHTO and the FHWA.

Both New York and Massachusetts—which border Connecticut and have similar winter weather—have maintenance guidelines that include LOS programs. When specifying treatment application rates, the New York guidelines[23] account for factors such as roadway type, traffic volume and speed, type of precipitation and accumulation rate,

[20] According to the *Snow and Ice Guidelines*, 1 cubic yard of the 7:2 mixture weighs 2,503 pounds.

[21] For 100-percent treatment coverage, ConnDOT recommends echelon plowing with a full complement of five trucks. "Echelon" refers to the staggered formation of plow trucks, similar to the formation of flying geese. ConnDot *Snow and Ice Guidelines*, 14.

[22] American Association of State Highway and Transportation Officials, *Guide for Snow and Ice Control* (Washington, DC: AASHTO, 1999) 81–82.

[23] New York State Department of Transportation, *Highway Maintenance Guidelines, Snow and Ice Control* (Albany, NY: NYSDOT, 1993) 19.

and pavement temperature. The New York LOS program also provides guidance on how quickly roadway treatment should be completed and on the factors that necessitate followup applications. Under the conditions on the morning of the Fairfield accidents, the New York LOS program would have called for an initial application of 225 pounds of straight salt per mile per lane.

The LOS program in Massachusetts[24] relies mainly on air temperature and its effect on precipitation characteristics to determine treatment. According to the *Maintenance Manual*, when air temperature is between 25 and 34º F and rising, the initial roadway treatment should be “the application of straight chloride at the rate of 240 pounds per lane mile” (condition 1). At temperatures between 20 and 32º F, the initial treatment should be an “application of straight chloride or the mixture of calcium chloride and sodium chloride at the rate of 240 pounds per lane mile” (condition 2). Under conditions where the temperature is below 25º F, the pavement should be plowed until the shoulders and lanes are clear. Once the temperature rises to 28 to 34º F, “The application of sodium chloride at the rate of 240 pounds per lane mile may be necessary to prevent icing” (condition 3). The *Maintenance Manual* also provides guidelines for plowing and retreating the roadway. Appendix B contains additional information from the New York and Massachusetts maintenance guidelines.

In studying the use of abrasive (sand) and chemical (salt) mixtures, AASHTO found that abrasives only temporarily increase road traction. According to AASHTO, “The sole function of abrasives is to improve traction, which may be short-lived because traffic will rapidly disperse abrasives and additional frozen precipitation will cover the application treatment.” AASHTO cites a conclusion by the Ontario Ministry of Transport that “the highway sections treated with straight salt required fewer applications than sections treated with salt/abrasives mixtures, while achieving the same level of service.”[25]

The FHWA *Manual of Practice for an Effective Anti-icing Program*[26] states that abrasives do not support the fundamental objectives of anti-icing[27] or deicing, though some conditions warrant the use of abrasives, such as when temperatures are so low as to slow chemical action or when snow or ice is strongly bonded to the pavement. It explains that the sole function of abrasives is to increase the coefficient of friction, and that this benefit is likely to be short-lived due to the effects of traffic. The manual further states that

> There is generally no advantage gained from the routine use of abrasives in an anti-icing program. When anti-icing operations have successfully prevented or mitigated the hazards of packed snow, for example, straight abrasives applications will provide no significant increase in friction or improvement in pavement condition. Further, a mix of abrasives and chemical will usually be no more effective as an anti-icing treatment during snowstorms than the same amount of

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[24] Massachusetts Highway Department, *Maintenance Manual*, Chapter 5, Division 4 (Boston, MA: 1996).

[25] AASHTO, 81–82.

[26] FHWA, 6.

[27] Anti-icing refers to the timely application of a chemical freezing-point depressant to prevent the formation or development of bonded snow and ice.

> chemical placed alone. It even appears that the use of abrasives in the mix can be detrimental to the effectiveness of the chemical. Because of the cost associated with both application and clean-up of roads and drainage facilities, and because of the potential airborne dust problem accompanying their use, abrasives applications should not be a routine operation of an anti-icing program.

The Massachusetts guidelines mention the use of sand only when necessary during spot treatments under condition 2, upon completion of plowing and continuous treatment with straight salt. The New York *Highway Maintenance Guidelines* include specific comments regarding the use of mixtures of abrasives (salt) and chemicals.[28] New York cautions that abrasives reduce the effectiveness of salt. Further, the guidelines state that

> Although snow and ice surfaces that have been treated with abrasives are safer than untreated snow or ice surfaces, they are not as safe as bare pavement. Traffic quickly diminishes the effect of abrasives and frequent re-application is necessary. This adds significantly to the overall cost and still provides a less safe surface than the bare pavement that could have been achieved with pure salt.

In 2001, the Iowa Department of Transportation and the Iowa Research Board examined the use of abrasives for winter maintenance. The State concluded that "abrasives applied to roads where significant traffic travels at high speeds [above 30 mph] are swept off the road rapidly, remaining in place (and providing friction enhancement) for somewhere between 10 and 100 vehicle passages, at most."[29]

Work Zone Construction

The 4:50 a.m. and 5:01 a.m. accidents occurred in a work zone on I-95. Signs displaying "construction work zone, reduce speed to 45 mph" were located approximately 4,525 feet in advance of the northbound accident scene on the outside shoulder and median. A regulatory "speed limit 45" sign[30] was also located approximately 2,413 feet in advance of the accident scene. The actual construction area began about 660 feet south of the exit 24 northbound off-ramp and ended about 340 feet north of the exit 24 on-ramp—a total distance of 3,983 feet. Construction began on March 26, 2001, and is scheduled for completion in late 2005.

According to ConnDOT, the goals of the Fairfield construction project were to eliminate the grass median and provide full shoulders (emergency breakdown lanes), to install concrete median barriers and improved drainage facilities, and to rehabilitate the concrete pavement and bridge decks. The construction project was divided into three stages.

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[28] NYSDOT, 19.

[29] W. A. Nixon, *The Use of Abrasives in Winter Maintenance: Final Report of Project TR 434*, IIHR Technical Report No. 416 (Ames, IA: Iowa Department of Transportation and Iowa Research Board, 2001) 21.

[30] The purpose of a regulatory sign is to inform highway users of traffic laws or regulations and to indicate the applicability of legal requirements that would not otherwise be apparent. Federal Highway Administration, *Manual on Uniform Traffic Control Devices (MUTCD)*, (Washington, DC: FHWA, 2003).

Stage 1 construction was approximately 70 percent complete at the time of the accidents. It included work within the right shoulder in both directions of travel, including parapet[31] modifications on two existing bridges and reconstruction of the right shoulder in some areas. This work required placement of a portable concrete barrier along the right shoulder, beginning before each bridge, to protect the affected work zones. During stage 1, a decision was made to resurface the northbound and southbound lanes of I-95. The resurfacing of the highway was not expressly indicated in the preconstruction plans approved by ConnDOT.

Prior to the initiation of stage 1, a 32-inch-high permanent concrete barrier was situated along the left edge of the southbound shoulder of I-95. It was embedded into the roadway pavement structure and incorporated drainage slots to allow water to reach the catch basins in the center of the median. According to ConnDOT, the location of the barrier created a problem because the existing asphalt overlay was to be milled,[32] leaving a depression of 5 inches or more. The drainage slots in the permanent barrier would have been too high to allow water to drain properly, subjecting the roadway to flooding during rainstorms.

Milling of the existing pavement was shown on the maintenance and protection of traffic plans, but the plans did not include details on how to handle the permanent median barrier during the milling operation. ConnDOT decided to remove the barrier to prevent the possibility of flooding and to place a portable concrete barrier away from the road and in the center of the 26-foot-wide depressed earthen median.

The portable concrete barrier consisted of 20-foot-long, 32-inch-tall concrete segments. The base of each segment was 24 inches wide, and the top was 6 inches wide. Each segment weighed 8,000 pounds and was connected to adjacent segments using a pin-and-loop joint. Unlike the embedded permanent barrier, the portable concrete barrier was not anchored to the surface of the earthen median. The AASHTO *Roadside Design Guide* gives no guidance on the placement of portable concrete barriers on unpaved surfaces. It does state that "roadside barriers perform most effectively when they are installed on slopes of 1 foot vertical to 10 foot horizontal (1/10 feet) or flatter."[33] Safety Board investigators measured the median cross-slope and found that it was flatter than the specified parameter, varying from 1/12 feet to 1/15 feet.

Furrow marks in the northbound median indicated that the 1996 Freightliner tractor flatbed semitrailer struck the concrete median barrier at an angle of about 23º. The vehicle overturned and overrode the 32-inch-high barrier, deflecting the five overturned barrier segments as much as 3 feet toward the southbound lanes. One segment was visibly cracked and separated down the middle. Postaccident photos of the damaged concrete barriers revealed that the pins holding segments together were severely deformed; in most

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[31] A parapet is a low protective wall or railing along the edge of a raised structure.

[32] Milling is the process of mechanically removing asphalt.

[33] American Association of State Highway and Transportation Officials, *Roadside Design Guide* (Washington, DC: AASHTO, 2002) 5-31.

cases, the pins remained within the loops. The double loops were deformed marginally but remained attached to each barrier segment.

The type of portable concrete barrier used at the accident site was the standard size for the separation of traffic. A standard median barrier is generally considered to be a 32-inch-high concrete barrier capable of withstanding a collision with a 4,400-pound truck. A high-performance median barrier is generally considered to be at least 42 inches tall and capable of withstanding a collision with a 17,400-pound single-unit truck, as specified in National Cooperative Highway Research Program (NCHRP) Report 350.[34] Appendix C summarizes the testing requirements for standard and high-performance concrete barriers.

Although the AASHTO *Roadside Design Guide* does not give specific guidance or warrants on the use of high-performance median barriers versus standard median barriers, it does provide the following general guidelines:[35]

> As with roadside barriers, most median barriers have been developed, tested, and installed with the intention of containing and redirecting passenger vehicles and pickup trucks. Some highway agencies have identified locations where heavy vehicle containment was considered necessary and have designed and installed high-performance median barriers having significantly greater capabilities than commonly used designs. Factors most often considered in reaching a decision on such barrier use include:
>
> - High percentage or large average daily number of heavy vehicles.
> - Adverse geometrics (horizontal curvature).
> - Severe consequences of vehicular (or cargo) penetration into opposing traffic lanes.

At the time of the Fairfield accidents, the contractor had not started stage 2 of the highway construction project, which included reconstruction of the median and left shoulder of I-95 north. This work consisted of shifting traffic 3 to 6 feet from the existing median and placing a portable concrete barrier along the entire left shoulder; excavating the existing median; installing a new 45-inch-high permanent concrete barrier; replacing the median decking on the two bridges; paving the median/left shoulder; and removing the portable concrete barrier.

Stage 2 would have required the contractor to move the portable concrete barrier from the center of the median back to the left edge of the southbound shoulder. An additional portable concrete barrier would have been needed on the left edge of the

[34] The NCHRP was created to conduct research in acute problem areas that affect highway planning, design, construction, operation, and maintenance. FHWA policy requires the use of devices on the National Highway System that have been successfully tested in accordance with the guidelines contained in NCHRP Report 350**.** National Cooperative Highway Research Program, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, NCHRP Report 350 (Washington, DC: Transportation Research Board, National Research Council, 1993) 16.

[35] AASHTO *Roadside Design Guide*, Section 6.3, 6-2.

northbound shoulder. The purpose of the two rows of barriers was to protect workers during construction of the 45-inch-high permanent concrete median barrier.

Following the accidents, ConnDOT implemented a policy for reviewing and approving construction revisions. The policy requires that revisions to a construction contract (such as resurfacing main travel lanes, paving shoulders, adding drainage, adding signage and delineation, or installing temporary pavement to improve cross-slopes) be implemented only after review and approval by the ConnDOT Offices of Construction and Engineering. Information submitted for review must include details of the revision, justification, exact location, approximate costs, and completion date.

Stage 3 consisted of removing the portable concrete barrier along the left edge of I-95 south, applying roadway base materials, and paving the median/left shoulder.

Lighting

According to an FHWA study, roadway lighting "provides improved visibility for users of roadways and associated facilities. It reduces crashes by helping drivers obtain sufficient (visual) information . . . [and] supplements vehicle headlights, when warranted."[36] Highway lighting was not operational on the northbound or southbound lanes of I-95 at the time of the accidents, as verified by a CSP video, witness statements, and pictures taken immediately following the events.

The lighting outage was due to a construction accident that had occurred between midnight and 12:30 a.m. on January 17, at bridge 99, located 1 mile north of the Fairfield accident site. An excavator being loaded onto a flatbed trailer had hit a light pole, which fell across the three southbound lanes and tripped the southbound circuits, extinguishing lights from the Grasmere substation northward to bridge 99, a distance of approximately 8,297 feet. A total of 86 light poles were affected—35 on I-95 south, 33 on I-95 north, and 18 along the exit ramps. By 9:00 a.m. that morning—within 4 hours of the Fairfield accidents—a contractor had fixed the damaged wiring of the downed light pole. The highway lights for the northbound and southbound lanes were turned on at the Grasmere substation by 10:30 a.m. The accidents involving the 1996 Freightliner and the Chevrolet occurred approximately 3,205 feet north of the substation.

The State of Connecticut holds contractors liable for damage they cause to any part of the highway, including appurtenances, slopes, pavements, and structures.[37] At the time of the Fairfield accidents, the State had no standards or procedures that addressed how soon highway lights had to be repaired. ConnDOT had no written policy requiring a contractor to notify the agency when an illumination system was damaged. ConnDOT stated that it had an informal policy that lighting repairs be completed within 3 days, though it was not enforced.

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[36] P. Hasson and P. Lutkevich, "Roadway Lighting Revisited," *Public Roads*, Vol. 65, No. 6 (May/June 2002). See <tfhrc.gov/pubrds/02may/07htm>, July 14, 2005.

[37] Connecticut Department of Transportation, *Standard Specifications for Roads, Bridges, and Incidental Construction*, Form 815, Article 10.00.07 (Hartford, CT: ConnDOT, 1995) 456.

Following the accidents, ConnDOT added a special provision to its standard specifications that requires a contractor to immediately notify the agency of a lighting outage or pole knockdown. The contractor is responsible for repairing the lighting system before the normal nighttime turn-on of the lights. If this cannot be achieved, the lighting must be operational prior to the next normal nighttime turn-on, within a maximum of 24 hours.

Variable Message Signs

ConnDOT had placed 17 variable message signs (VMSs) along the I-95 corridor. (See appendix D for sign placement.) Eleven signs were located on I-95 north, and six were located on I-95 south. Northbound, the nearest VMSs were located approximately 3.1 miles (VMS #55) and 4.67 miles (VMS #54) in advance of the 1996 Freightliner and Chevrolet accident sites, respectively. At the time of the two accidents, these two signs were not in use and did not display any messages.

The 1996 Freightliner accident occurred about 4:50 a.m.—at which time the Bridgeport Operations Center was notified that the left and center southbound lanes of I-95 were blocked. The center was not informed that the semitrailer also obstructed the left northbound lane. The operations center activated 23 VMSs on I-95 south; I-91; Routes 1, 8, 15, and 80; and State Road 796. Table 7 shows the messages that were displayed at approximately 5:01 a.m. on VMS #75, #76, and #77, the southbound signs closest to the accident site.

Table 7. Variable message signs displayed on I-95 south at 5:01 a.m., January 17, 2003. The signs alternated between frames 1 and 2.

VMS No.	Message frame 1	Message frame 2
75, 76, 77	I-95 Closed Fairfield at exit 24	Use alternate route

The Bridgeport Operations Center received a 911 call at 5:01 a.m. regarding a northbound accident blocking the left and center lanes of I-95, at exit 24. It took steps to activate VMS #55 and #54 at 5:06 a.m. By 5:21 a.m., the two signs displayed messages warning of the accident. (See table 8.) According to ConnDOT, the delay in display of the northbound sign messages was a result of the VMS software system still completing the earlier command to activate the 23 southbound signs. The VMS system took approximately 31 minutes—from 4:50 to 5:21 a.m.—to activate all 23 southbound signs, at which time the northbound signs were activated.

Table 8. Variable message signs displayed on I-95 north at 5:21 a.m., January 17, 2003. The signs alternated between frames 1 and 2.

VMS No.	Message frame 1	Message frame 2
55	Accident at exit 24	Left and center lanes closed
54	Accident Fairfield at exit 24	(no message)

The VMS software system in place at the time of the Fairfield accidents was about 10 years old. It did not allow the simultaneous change of sign messages in both directions of travel. In January 2004, ConnDOT installed an expanded traffic management system at the Newington Operations Center to allow sign messages on the I-95 corridor to be modified simultaneously in both directions of travel. According to the ConnDOT Highway Operations Director, the new VMS system can broadcast messages to a total of 25 signs in both directions of travel within 5 minutes. The time required for the system to simultaneously activate each sign increases as the number of VMSs increases beyond 25.[38] ConnDOT expects to have a similar system installed at the Bridgeport Operations Center by early 2006.

Incident Management

The flares that the 1996 Freightliner driver reportedly saw on I-95 north had been placed there by the CSP to warn motorists away from a 3:56 a.m. accident involving an overturned vehicle in the median. Messages posted on VMS #54 and #55 provided additional warnings—"Accident exits 23–24" and "Left lane closed"—from 3:59 a.m. until the scene was cleared about 4:43 a.m. According to the CSP officer, she had parked her patrol car behind the overturned vehicle in the left lane and set out five flares in a diagonal pattern. The officer had used the wire support legs at the base of the flares to set them upright in the roadway. After the first set of flares had burned out, the officer moved her vehicle northward about 45 feet and placed two more flares side by side in the middle of the left lane, perpendicular to the direction of travel. The officer recalled that the sign for exit 25 was plainly visible when she sat in her car. She also remembered that when she left the accident scene, she drove diagonally across the lanes of the interstate so that she would be able to use the exit 25 ramp.[39] Based on the officer's description of her location, she had arranged the second flare pattern about 435 feet north of where the 1996 Freightliner crossed the median. (See figure 11.)

The two abandoned flares were located in the left lane of I-95 north; the 1996 Freightliner driver was traveling in the center lane. A wide right curve preceded the approach to the flares, and Safety Board investigators examined the possibility that the curvature of the roadway caused the driver to perceive the flares as being in his lane. Based on sight distance measurements, investigators determined that the driver would have been between 1,033 and 1,063 feet (about 0.2 mile) from the flares when they appeared to be directly in front of him.

A ConnDOT safety training bulletin for its personnel and contractors provided guidance on extinguishing flares. The bulletin—which was not intended for use outside the agency—stated that, "Before leaving the scene, make sure that lit flares have burned completely. If not and the remaining flare length permits, extinguish them by tapping the burning end on the pavement, separating the burning portion from the rest of the flare."[40] The CSP was not aware of this bulletin.

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[38] Telephone interview, Highway Operations Director, Bureau of Engineering and Highway Operations, ConnDOT, July 6, 2004.

[39] The entrance for exit 25 was about 330 feet north of the officer's location.

[40] Connecticut Department of Transportation, *Safety Training Topic of the Week, Reflectors, Emergency Flares, and Strobe Lights*, Bulletin 17 (Hartford, CT: ConnDOT, 1996).

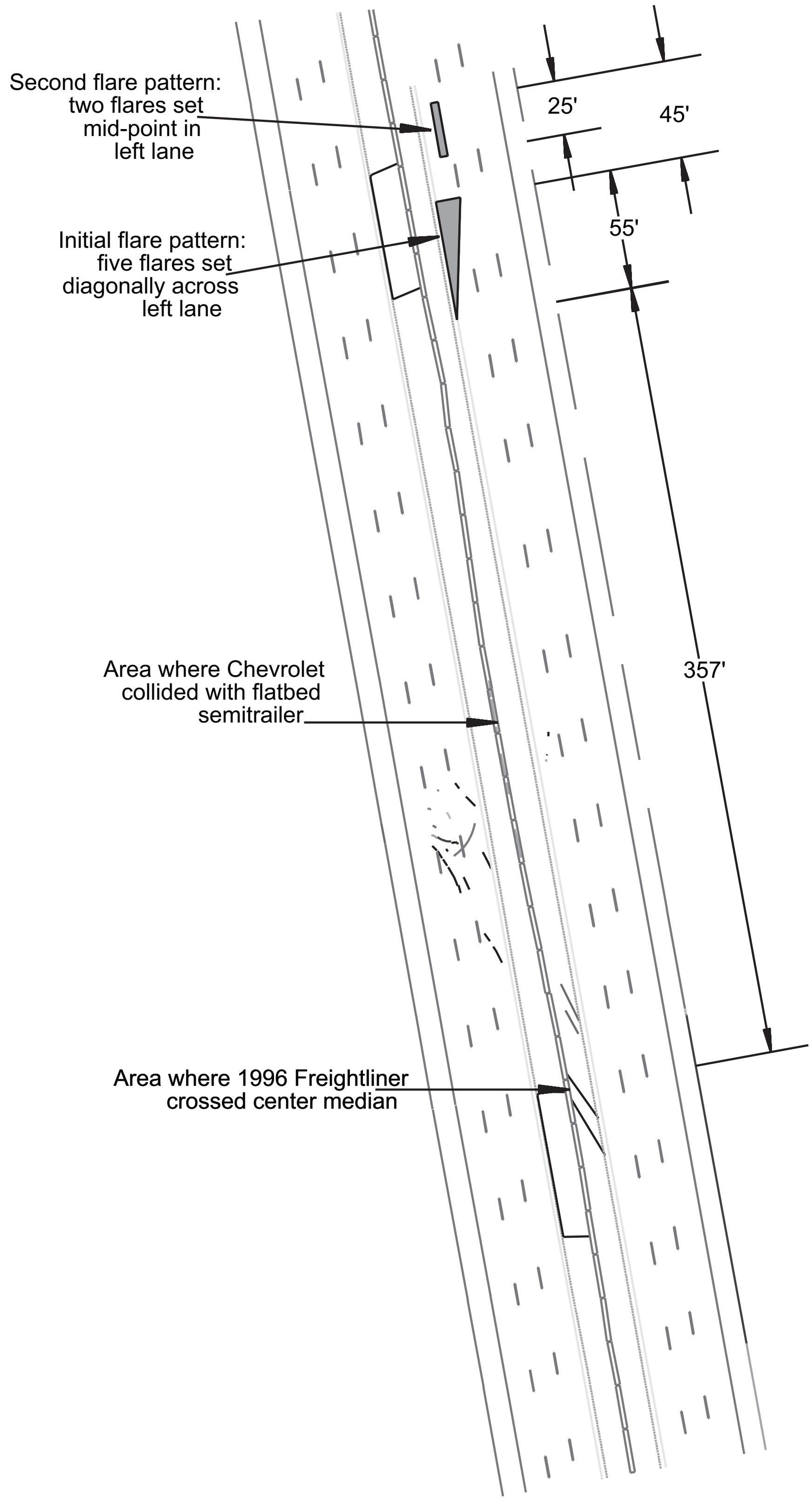

Figure 11. Diagram of flare placement.

The CSP Training Academy provides cadets with guidelines on establishing a flare pattern. The guidelines mention that the proper way to extinguish a flare is to rub it against the ground and stick it into dirt if possible—not to step on it. The guidelines specify that spiked flares[41] should be removed when a scene is cleared; they do not say that other types of flares should also be extinguished and removed.

According to the CSP, it does not train officers on incident management procedures. The State incident management policy[42] is outlined in a two-page document that calls on the public and private sectors to work together to mitigate the impact of traffic incidents. It includes no specific guidance on managing highway incidents. The Connecticut State Traffic Commission Regulations,[43] which set the standard for traffic control devices in the State, include no guidance on properly clearing an incident area so that it is safe for traffic.

The FHWA's MUTCD defines the Federal standards applicable to the installation and maintenance of traffic control devices on all streets and highways. Title 23 CFR Part 655 requires State traffic control procedures to substantially conform within 2 years to the latest edition of the MUTCD. According to the construction administrator of ConnDOT, the Connecticut State Traffic Commission Regulations were approved by the FHWA as being in "substantial conformance" to the MUTCD.

The latest edition of the MUTCD, published in November 2003, contains a new section on "Control of Traffic Through Traffic Incident Management Areas." Chapter 6I[44] defines a traffic incident as "an emergency road user occurrence, a natural disaster, or other unplanned event that affects or impedes the normal flow of traffic." It defines a traffic incident management area as an area of a highway where temporary traffic controls (TTC) are imposed by authorized officials in response to a traffic incident. According to Chapter 6I:

> The primary functions of TTC at a traffic incident management area are to move road users reasonably safely and expeditiously past or around the traffic incident, to reduce the likelihood of secondary traffic crashes, and to preclude unnecessary use of the surrounding local road system.

Chapter 6I divides traffic incidents into three general classes, based on duration:

- Major traffic incidents are expected to require more than 2 hours of incident management.
- Intermediate traffic incidents have a duration of 30 minutes to 2 hours.
- Minor traffic incidents have a duration of less than 30 minutes.

[41] A spiked flare has a spike on its end, which allows it to be embedded in the ground. This type of flare was not used for the 3:56 a.m. accident.

[42] This State policy was approved on November 5, 1992, by ConnDOT, the Connecticut Department of Motor Vehicles, the Connecticut Department of Environmental Protection, and the Connecticut Department of Public Safety (which includes the CSP).

[43] The FHWA has approved these regulations as being in "substantial conformance" to the MUTCD.

[44] MUTCD, Chapter 6I, Section 6I.01, 6I-1.

The discussion of intermediate traffic incidents includes the following guidance: "When flares are used to initiate TTC at traffic incidents, more permanent traffic control devices should replace them as soon as practical. Both the flare and its supporting device should then be removed from the roadway."[45]

Motor Carrier Information

The driver of the 1996 Freightliner was working as an owner/operator for Arrow Trucking Company, an interstate for-hire common carrier of building and oilfield materials. The company, which is based in Tulsa, Oklahoma, began business in 1968 and has terminals in Alabama, California, Ohio, Oklahoma, and Texas. Because the driver was contracted to Arrow Trucking, the company reported his safety information and relevant owner/operator data under its motor carrier number.

Roadside inspection data for the 24 months prior to January 19, 2003, indicated that Arrow Trucking had 2,625 vehicle inspections, resulting in 596 out-of-service determinations—a 22.7-percent rate. The data also indicated 3,824 driver inspections, with 266 out-of-service determinations—a 7.0-percent rate. The 2003 national average out-of-service rates were 22.9 percent for vehicles and 6.78 percent for drivers.[46] The U.S. Department of Transportation (DOT) 12-month recordable accidents[47] for Arrow Trucking indicated 67 accidents, with an accident rate[48] of 0.57, compared to the national average of 0.75.[49]

Prior to the accidents, Arrow Trucking's most recent Federal Motor Carrier Safety Administration (FMCSA) compliance review resulted in a satisfactory rating (October 1994). A compliance review is an on-site examination of records and operations to determine whether the motor carrier meets the safety criteria outlined in 49 CFR Part 385. The review covers hours of service, driver qualification, vehicle inspection and maintenance, financial responsibility, accidents, hazardous materials, and roadside vehicle out-of-service rate. Motor carriers are rated "satisfactory," "conditional," or "unsatisfactory." Carriers with an unsatisfactory rating must improve to satisfactory or conditional within 60 days or be barred from operating commercial vehicles. Additionally, carriers with an unsatisfactory rating are prohibited from contracting or subcontracting transportation services with Federal agencies. Stricter compliance regulations apply to motor carriers transporting hazardous materials or carrying 15 or more passengers in addition to the driver.[50]

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[45] MUTCD, Chapter 6I, Section 6I.03, 6I-3.

[46] Federal Motor Carrier Safety Administration, *Safety and Fitness Electronic Records (SAFER) System.*

[47] As defined by FMCSR 390.5, an accident is an occurrence involving a commercial motor vehicle operating on a highway in interstate or intrastate commerce that results in a fatality, injury, or disabling damage to one or more vehicles requiring tow from scene.

[48] Accident rate is determined by a motor carrier's recordable accidents per million miles traveled in the most recent 12-month period.

[49] See <www.fmcsa.dot.gov/rulesregs/fmcsr/regs/385appnB.htm>, July 14, 2005.

[50] Federal Motor Carrier Safety Administration, *A Motor Carrier's Guide to Improving Highway Safety: Education and Technical Assistance Program* (Washington, DC: FMCSA, 2002).

The FMCSA conducted another compliance review of Arrow Trucking after the Fairfield accidents, which resulted in a conditional rating. This determination was based on violations that included, among others:

- Failing to preserve a driver's record of duty status supporting documents for 6 months,
- Scheduling a run that would necessitate the vehicle being operated at speeds in excess of those prescribed, and
- Failing to require the driver to prepare a driver vehicle inspection report.

Appendix E provides a complete list of violations. Arrow Trucking has since corrected these deficiencies. On August 12, 2003, the FMCSA reaudited Arrow Trucking and issued the carrier a satisfactory rating.

The Safety Board examined the bill of lading, driver's logs, and trip receipts for the 1996 Freightliner driver's accident run and found no indication that the trip was scheduled in a way that would require him to exceed speed limits or violate hours-of-service regulations.

Tests and Research

Conspicuity Testing

The circular light covers and samples of the retroreflective tape mounted on the side of the 1996 Freightliner tractor flatbed semitrailer were sent for photometric analysis to the FHWA Arens Photometric and Visibility Laboratory (PVL) at the Turner-Fairbank Highway Research Center. A section of the headlight lens from the Chevrolet was also sent to the PVL.

The PVL examined the retroreflectivity[51] of the tape and the relative transmissivity[52] of the Chevrolet headlight lens. Measurements were taken both prior to and after cleaning the components. It was determined that dirt on the headlights reduced their luminous intensity by about 45 percent. In spite of dirt on the headlights and the tape, PVL measurements showed that—when the tape was illuminated by the headlights at distances of up to 558 feet under a background luminance of 100 candelas per square meter[53]—the white and red portions of the tape would have provided luminance that was 24 times and 10 times, respectively, the level required for detection with certainty.

[51] Retroreflectivity is the ability of a surface to return light to its source.

[52] Transmissivity is the ability of a material to transmit light.

[53] Luminance is a measure of the amount of light emitted or reflected by an area or surface. This level of luminance is roughly equal to ambient light 10 minutes after sunset. It is representative of a high average level of nonuniform luminance along the roadway at night.

If a driver traveling at a reference speed of 52 mph detected the tape at a distance of 558 meters, he or she would have had at least 7 seconds to perceive and react to the presence of the flatbed semitrailer in the left lane. Based on the luminance measurements and the positions of the semitrailer and the Chevrolet prior to the crash, as determined through vehicle and highway evidence, the PVL determined that the combination of high-beam headlights and retroreflective tape on the side of the trailer provided a clearly detectable signal for a normally observant and alert driver.

Speed Testing

To better understand the dynamics of the second accident, Safety Board investigators calculated the Chevrolet's speed at impact with the 1996 Freightliner flatbed semitrailer using tire marks found at the accident scene,[54] linear and rotational forces applied to the semitrailer upon impact, SDM deceleration readings, and evidence gathered during deceleration testing of an exemplar vehicle. Several methods were used to arrive at a speed estimate, including equations for determining Delta-V for in-line and 90º collisions; quadratic equations; and vector sum analysis to visually display the total momentum within the collision, impulse vectors, and principal direction of force. The calculations indicated that the speed of the Chevrolet ranged from 43 to 45 mph; vector and momentum analyses indicated a speed of 47 to 49 mph.

Deceleration Testing

On January 22, 2003, Safety Board investigators and the CSP conducted tests to help determine the deceleration rate of the Chevrolet as it traveled through the median, unpowered, after colliding with the flatbed semitrailer (postcollision separation to final rest). The test vehicle was a Ford Expedition SUV, which is similar to the Chevrolet in size and weight. The deceleration tests were conducted under two scenarios: with the test vehicle's engine off and the transmission in gear and with the engine off and the transmission in neutral. The procedure used to gather data was as follows:

1. The vehicle was accelerated to a specified speed.
2. It was steered into the center median to a path parallel to the median barrier.
3. The vehicle ignition was turned off.
4. The vehicle was allowed to coast along the median to a point parallel to the final rest position of the Chevrolet.
5. It was steered back onto the roadway and brought to a stop.

The deceleration test trials were conducted at 20, 30, and 40 mph. The test results showed an average peak deceleration of 0.039 g and an average deceleration of 0.033 g. These values were used to determine the initial speed of the Chevrolet prior to impact and its postcollision speed.

[54] The tire marks were created as the vehicle separated from the flatbed semitrailer while traveling across the pavement to the northeast into the concrete median barrier.

Flare Testing

On February 18, 2003, Safety Board investigators and the CSP tested the type of flares used at the 3:56 a.m. accident to evaluate their burn time. Two randomly selected flares were ignited simultaneously—one flare was placed horizontally on the ground, and the other was oriented vertically using the attached built-in metal stand. The horizontally oriented flare burned for about 23 minutes and 50 seconds. The vertically oriented flare burned for about 22 minutes. It was noted that the flames were bright red for most of the combustion. About 19 minutes into the vertical flare's life cycle, as the flare burned down to the band that held the built-in metal stand, the flame color changed to a dull yellow.

Previous Safety Board Actions

Barrier and Heavy Truck Compatibility

The Safety Board addressed the compatibility of heavy trucks and guardrails in a White Plains, New York, accident investigation.[55] About 12:30 a.m. on July 27, 1994, a tractor cargo-tank semitrailer loaded with 9,200 gallons of propane (a liquefied petroleum gas) was traveling east on I-287 in White Plains. The truck drifted across the left lane onto the left shoulder and struck the guardrail. The front head of the tank hit a column of the Grant Avenue overpass at a 90º angle, consistent with a vehicle rollover.

The tractor and the semitrailer separated; the front head of the tank fractured, releasing the propane, which vaporized into gas. The resulting vapor cloud expanded until it found a source of ignition—at which time, according to an eyewitness, a fireball rose 200 to 300 feet. The tank was propelled northward about 300 feet and landed on a frame house, engulfing it in flames. The driver was killed, 23 people were injured, and fire spread throughout an area within a radius of approximately 400 feet.

The median barrier at the accident site was a heavy post blocked-out W-beam barrier. The top of the rail was 27 inches above ground. Although a passenger car could have negotiated the barrier design features without experiencing stability problems, the Safety Board determined that the accident truck—with its high center of gravity and lower rollover threshold—could not. The truck might have been redirected if a 42-inch-high performance barrier had been in place closer to the edge of the shoulder or if the slope had been relatively flat from the edge of the shoulder.

[55] National Transportation Safety Board, *Propane Truck Collision With Bridge Column and Fire, White Plains, New York, July 27, 1994,* Highway Accident Report NTSB/HAR-95/02 (Washington, DC: NTSB, 1995).

The Safety Board concluded that "the minimum AASHTO guidelines for the geometric design of highways are not always satisfactory for heavy trucks, especially those with high centers of gravity . . . highways that are heavily traveled by trucks should be designed for them." The Safety Board issued the following safety recommendation to the FHWA:

> H-95-32
>
> Require that highway geometric design and traffic operations of the National Highway System be based on heavy-truck operating characteristics.

In March 1997, the FHWA responded by stating that it was in basic agreement that consideration must be given to heavy vehicles in the development of standards for the National Highway System. As such, it was supporting research under the NCHRP and had its own research program to develop the analysis tools and bases for highway standards that address the effects and requirements of heavy vehicles. It was also supporting the ongoing AASHTO efforts to develop corresponding standards and guidelines. In December 2004, the FHWA updated the Safety Board on its progress and stated that it had distributed a resource document, entitled *Supplemental Guidance on Safe Accommodation of Heavy Vehicles on U.S. Highways*, to its field offices. This document references the recent NCHRP Report 505, *Review of Truck Characteristics as Factors in Roadway Design*, and elaborates on truck barrier information in the *Roadside Design Guide*.

The FHWA believes that its *Supplemental Guidance* should raise each State's level of awareness of the continuing need to weigh both the likelihood and consequences of large truck crashes at selected highway locations—both for new construction as well as reconstruction projects. In addition, the FHWA has suggested to AASHTO that it consider incorporating information from the *Supplemental Guidance* into the next edition of the *Roadside Design Guide.*

The Safety Board agreed that the FHWA *Supplemental Guidance* should help increase State awareness of the possibility and consequences of large truck crashes when considering either new construction or reconstruction projects. The Safety Board also welcomed the recommendation that information from the *Supplemental Guidance* be included in the next edition of the AASHTO *Roadside Design Guide*. The Safety Board classified Safety Recommendation H-95-32 "Closed–Acceptable Alternate Action," recognizing that the FHWA response did not meet the full intent of H-95-32. The Safety Board expressed concern that this issue would resurface in future accident investigations.

Seat Belt Usage

In March 1997, the Safety Board held a public forum on safety improvements in societal attitudes about buckling up, better evaluation of seat belt usage, better air bag design, and evaluation of changes to air bags. As a result of this forum, the Safety Board adopted a series of recommendations on air bags and automobile occupant restraint.[56] One of the recommendations was addressed to the Governors and legislative leaders of the 50 States and U.S. Territories and to the Mayor and Chairman of the Council of the District of Columbia:

> H-97-02
>
> Enact legislation that provides for primary enforcement of mandatory seat belt use laws, including provisions such as the imposition of driver license penalty points and appropriate fines. Existing legal provisions that insulate people from the financial consequences of not wearing a seat belt should be repealed.

Connecticut is one of 21 States to have enacted primary seat belt laws. It requires that all front-seat passengers and back-seat passengers under 16 years be belted. A fine of $15 is levied for each infraction. In correspondence in 2003, the Safety Board encouraged Connecticut to pursue legislation that would require all vehicle occupants to use seat belts regardless of age, hold unbelted occupants legally responsible for their injuries, and impose significant fines and driver license penalty points for seat belt law violations. Pending further action by Connecticut, the Safety Board has classified Safety Recommendation H-97-02 "Open—Acceptable Response."

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[56] National Transportation Safety Board, *Proceedings of the National Transportation Safety Board Public Forum on Air Bags and Child Passenger Safety*, Report of Proceedings NTSB/RP-97/01 (Washington, DC: NTSB, 1997).

Analysis

In the Fairfield accident investigation, the Safety Board considered the following factors that may have caused or contributed to the severity of the initial and subsequent crashes: driver performance, survivability, highway snow and ice treatment, use and placement of median barriers, absence of highway lighting, VMS operation, and incident management. These causal and contributory issues are analyzed following a brief discussion of factors that were determined *not* to be causal to the accidents.

Exclusions

Toxicology

The results of postaccident testing of the 1996 Freightliner driver and the Chevrolet driver for the presence of alcohol and 12 drugs, including illicit and common licit drugs with known performance-impairing effects, were negative. The Safety Board concludes that neither alcohol nor drug use was a factor in either accident.

Vehicle Factors

Safety Board investigators examined both the 1996 Freightliner tractor flatbed semitrailer and the Chevrolet for mechanical defects that might have led or contributed to the 4:50 a.m. or 5:01 a.m. accidents. Neither vehicle showed evidence of component failures that might have caused the accidents. Although the Chevrolet was equipped with a brush guard, the impedance of light emittance from the headlights was negligible because only one of the smaller bars was directly over the headlight lenses. The Safety Board concludes that mechanical conditions did not cause or contribute to the accidents involving the 1996 Freightliner and the Chevrolet.

Motor Carrier Factors

At the time of the accident, the FMCSA had rated Arrow Trucking Company "satisfactory," based on a 1994 compliance review. The company had a 12-month recordable accident rate of 0.57, compared with the national average of 0.75. The motor carrier's roadside inspection out-of-service rates for drivers and vehicles did not deviate significantly from the national averages.

Following the Fairfield accidents, the FMCSA conducted another compliance review of Arrow Trucking, which resulted in a conditional rating based on scheduling runs that necessitated the vehicle being operated in excess of the speed limit and failing to preserve a driver's record-of-duty status supporting documents for more than 6 months.[57] However, the Safety Board investigation of the Fairfield accidents found that both the 1996 Freightliner driver's 72-hour history and Arrow Trucking's scheduling practices were in line with Federal hours-of-service regulations. The Safety Board concludes that motor carrier operations were not a factor in the accidents involving the 1996 Freightliner and the Chevrolet. The FMCSA reaudited Arrow Trucking in August 2003 and issued the carrier a satisfactory rating.

Emergency Response

According to the Bridgeport Operations Center logs, the CSP was dispatched to the 4:50 a.m. accident at 4:56 a.m. However, because the operations center was not told that the 1996 Freightliner flatbed semitrailer blocked the left lane of I-95 north, law enforcement and emergency vehicles were sent to the southbound lanes only—where the Freightliner tractor came to rest. The operations center received a call about the northbound accident at 5:01 a.m. and immediately informed the units responding to the 4:50 a.m. accident. Responders apportioned resources to both accidents, which were treated as one event.

According to operations center logs, the CSP arrived at the accident scene at 5:12 a.m., followed by the Fire Department and EMS at 5:18 a.m. The last passengers from the accident vehicles were transported to one of three hospitals by 6:10 a.m. Emergency responders reported that they were hampered by incomplete information about the initial accident involving the 1996 Freightliner and by the icy roadway conditions. The Safety Board concludes that the emergency response was satisfactory, despite the lack of prior information about blockage of the northbound left lane and the icy roadway conditions.

Accident Discussion

About 4:50 a.m. on January 17, 2003, light snow was falling near Fairfield, Connecticut. The driver of a 1996 Freightliner tractor flatbed semitrailer was negotiating a wide right curve in the center lane of I-95 north near exit 25, at a driver estimated speed of 50 mph, when he lost lateral control. This loss of control may have been due to the truck encountering black ice while in a wide right curve, as the driver contends, or to an evasive maneuver by the driver to avoid lighted flares in the roadway ahead, as he stated on-scene to the driver of the 2001 Freightliner. The CSP had left the flares burning after clearing a 3:56 a.m. accident.

[57] Two previous Safety Board reports discuss the time between compliance reviews and the process by which carriers are selected for reviews: (a) National Transportation Safety Board, *Motorcoach Run-Off-the-Road Accident, Tallulah, Louisiana, October 13, 2003*, Highway Accident Report NTSB/HAR-05/01 (Washington, DC: NTSB, 2005). (b) National Transportation Safety Board, *Motorcoach Run-Off-the-Road and Overturn, Victor, New York, June 23, 2002*, Highway Accident Report NTSB/HAR-04/03 (Washington, DC: NTSB, 2004).

After the driver lost lateral control, the 1996 Freightliner rotated counterclockwise and entered the median near MP 26.6, struck and overrode a portable concrete barrier, and then collided with a southbound 1997 Dodge sedan. The Dodge was struck from behind by a southbound 2001 Freightliner tractor/refrigerated trailer combination unit, which subsequently struck the 1996 Freightliner. The three vehicles came to rest in the southbound lanes. During the accident sequence, the 1996 Freightliner tractor separated from the flatbed semitrailer and rolled onto its right side. The rear portion of the semitrailer came to rest partially obstructing the left lane on the northbound side of the highway.

Approximately 11 minutes after the initial accident, a 1999 Chevrolet Tahoe SUV with nine occupants—traveling northbound in the left lane—collided with the side corner of the 1996 Freightliner flatbed semitrailer. The semitrailer intruded into the passenger compartment of the Chevrolet, fatally injuring the driver and three passengers in the left and center rear seats. Photometric tests of the retroreflective tape on the left rear side of the semitrailer suggested that the vehicle should have been visible to an alert driver, who would have had enough time (at least 7 seconds) to perceive and react to its presence on the roadway.

Driver Issues

1996 Freightliner Driver

The Safety Board examined the possibility of driver fatigue as a factor in the initial and subsequent Fairfield accidents. According to the logs of the 1996 Freightliner driver, he had been off duty for 39 hours prior to departing Mocksville, North Carolina, on January 16, 2003. He was on duty for 8.75 hours on January 16 before going off duty and resting for 8 hours. His logs for January 17 indicate that he began driving at 1:15 a.m. and had been driving for 3 hours and 21 minutes before the accident. As detailed in table 4, though there are discrepancies between the driver's logs and receipts, they do not indicate that the driver was in gross violation of the Federal hours-of-service regulations, which, at that time, limited driving to 10 hours per day and required a minimum 8-hour rest period.

The 1996 Freightliner driver was operating his vehicle at a time of day when fatigue and the physiological pressures to sleep are greatest.[58] Fatigue stemming from circadian factors—even in the absence of sleep deprivation—has been found to reduce vigilance, impair the processing of information, and slow reaction time.[59] Although the driver had rested prior to commencing his trip, psychophysiological factors related to his circadian rhythm could have predisposed him to fatigue. If he saw flares in the roadway from the earlier 3:56 a.m. accident, fatigue may have affected his decision-making ability, resulting in an inappropriate evasive response. This scenario corresponds to the 2001 Freightliner driver's comment that the 1996 Freightliner driver said that he "panicked" upon seeing the flares.

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[58] National Highway Traffic Safety Administration, *Drowsy Driving and Automobile Crashes*, DOT-HS-808-707 (Washington, DC: NHTSA, 1998).

[59] DOT-HS-808-707.

Although fatigue cannot be ruled out as a factor in the 4:50 a.m. accident, there is more support that weather-related road conditions were the principal cause of the driver's loss of lateral control. Prior to crashing into the median, the driver traveled on an overpass and negotiated a wide right turn at a self-reported speed of 50 mph. The temperature was below freezing, and it was snowing—conditions conducive to the accumulation of ice on the surface of the overpass. A string of weather-related accidents on the northbound and southbound lanes of I-95, including other jackknifed tractor-semitrailers, further suggests that roadway conditions were poor.

Several witnesses reported skidding on the roadway in the vicinity of the accident site. However, the 1996 Freightliner driver stated that he had not experienced any skidding or loss of control prior to the accident and, thus, he may not have realized the condition of the roadway until he lost control. In postaccident interviews with the CSP and Safety Board investigators, the driver attributed his loss of control to the presence of black ice on the roadway. The Safety Board concludes that the 1996 Freightliner driver lost control of his vehicle, probably as a result of traveling at a speed too great for the existing conditions of ice and snow on the roadway surface.

Chevrolet Tahoe Driver

Fatigue is more likely a contributor to the subsequent accident involving the Chevrolet. The driver's sleep schedule during the week of the accident was dictated primarily by fraternity rush activities, which lasted from 9:00 p.m. to between 3:00 and 5:00 a.m. and occurred throughout the school week. Witness statements indicated that the driver was usually in bed by 3:00 a.m. and woke up to attend classes each morning. At the time of the accident, the Chevrolet driver had been awake for over 18 hours and was driving at a time when he would normally be asleep. The early morning hours are a time of day when most individuals experience a decrease in the level of psychophysiological arousal associated with circadian rhythm. In addition, statements from surviving passengers imply that most, if not all, were asleep during the drive from New York City, which suggests a low level of stimulation within the Chevrolet.

Photometric tests of the retroreflective tape on the 1996 Freightliner flatbed semitrailer indicated that the tape should have been visible to the Chevrolet driver for at least 7.6 seconds before the collision, which was sufficient time to have induced an avoidance response. The accident scene on I-95 south may have distracted the driver. However, studies suggest that alert drivers generally do not divert their gaze from the path of travel for more than 2 or 3 seconds at a time.[60] Therefore, it seems more likely that the Chevrolet driver's vigilance was affected by microsleep or inattention brought on by

[60] T. Dingus, D. McGehee, M. Hulse, S. Jahns, N. Manakkal, M. Mollenbauer, and R. Fleischman, *TRAVTEK Evaluation Task C3, Camera Car Study, Project Report*, FHWA-RD-94-076 (Washington, DC: FHWA, 1995).

fatigue. Research indicates that response lapses resulting from microsleep[61] may occur as fatigue or pressure for sleep increases with time and circadian rhythm.[62]

A witness stated that the Chevrolet driver did not appear to brake or swerve to avoid the flatbed semitrailer. Although the absence of roadway lighting might have limited the driver's ability to fully recognize the scene ahead, some sort of avoidance maneuver would have been expected had he detected an unknown object in his lane of travel. The Safety Board concludes that the Chevrolet driver probably did not perceive the flatbed semitrailer in the left lane of I-95 north due to a combination of fatigue, distraction from the median crossover accident in the southbound lanes, and the absence of artificial highway lighting. The Safety Board will advise the North American Interfraternity Conference, the National Pan-Hellenic Conference, the National Pan-Hellenic Council, and the National Association of Latino Fraternal Organizations of the importance of developing and implementing activity-scheduling policies that eliminate or reduce the operation of motor vehicles by fatigued drivers.

Survivability

Interviews and physical evidence indicated that only the Chevrolet driver and the front passenger were wearing seat belts. The seven passengers in the rear seat and cargo area were not restrained, though seat belts were available for three rear-seating positions. The cargo area was not designed to carry passengers, though it is legal to do so in Connecticut.

The Chevrolet airbag did not deploy. SDM data indicated that the Chevrolet decelerated 29 mph over a span of 272.5 milliseconds. This relatively long crash pulse is consistent with an underride accident,[63] in which "soft" components of the vehicle (such as the hood, A-pillar, and roof) are engaged. The deployment of the airbag would not have affected survivability because of the intrusion of the flatbed semitrailer into the Chevrolet passenger compartment.

Although the surviving passenger in the front seat was seriously injured, the lap/shoulder safety belt sufficiently restrained him to prevent fatal impact with the windshield, roof, and dashboard. The driver succumbed to massive head injuries, but the three fatally injured passengers in the rear seats may have survived had they been properly restrained and had the vehicle not been overloaded. The Chevrolet's impact with the 1996 Freightliner flatbed semitrailer threw the passengers up and forward, resulting in serious facial, cranial, and upper torso injuries. One passenger seated on the left side of the back

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[61] Microsleep is a period of sleep generally lasting from 3 to 15 seconds. V. L. Tirunahari, S. A. Zaidi, R. Sharma, J. Skurnick, and H. Ashtyani, "Microsleep and Sleepiness: A Comparison of Multiple Sleep Latency Test and Scoring of Microsleep as a Diagnostic Test for Excessive Daytime Sleepiness," *Sleep Medicine*, Vol. 4, No. 1 (2003): 63–67.

[62] C. D. Wylie, T. Shultz, J. C. Miller, M. M. Mitler, and R. R. Mackie, *Commercial Motor Vehicle Driver Fatigue and Alertness Study, Project Report*, FHWA-MC-97-002 (Washington, DC: FHWA, 1996).

[63] In an "underride" crash, a portion of a passenger vehicle slides under another vehicle.

seat was partially ejected. The Safety Board concludes that the likelihood of occupant survival would have significantly improved if the Chevrolet had been occupied by a maximum of five persons, rather than nine, and if all occupants had been wearing seat belts.

Connecticut is one of the more progressive States with regard to primary seat belt laws. According to the National Center for Statistics and Analysis of the National Highway Traffic Safety Administration (NHTSA), in 2004, belt use in primary States was 11 points higher than in secondary States (84 percent versus 73 percent). However, the primary seat belt law in Connecticut applies only to front-seat passengers and to rear-seat passengers between 4 and 16 years of age. The fine for each infraction is only $15, which probably is not prohibitive enough to encourage compliance by all roadway users. Nationwide, it is estimated that safety belts save 13,000 lives each year, while 7,000 die because they did *not* use belts.[64]

Earlier this year, Connecticut legislators considered requiring safety belt usage in all seating positions regardless of age; however, they did not pass this bill into law. The Safety Board encourages Connecticut to reconsider applying its primary seat belt law to both front and back seating positions. Therefore, the Safety Board is reiterating Safety Recommendation H-97-02 to the Governor and legislative leaders of Connecticut, urging them to enact legislation that provides for primary enforcement of mandatory seat belt use laws, including provisions such as the imposition of driver license penalty points and appropriate fines, and to repeal existing legal provisions that insulate people from the financial consequences of not wearing a seat belt.

Highway Conditions

ConnDOT Maintenance District #3, section #33, Stratford maintenance facility, was responsible for treating the heavily traveled section of I-95 where the Fairfield accidents occurred. In the late evening of January 16, 2003, after being notified of a weather report calling for flurries and light snow with accumulations of up to 1 inch, the section #33 supervisor sent two trucks with a 7:2 sand and salt mixture to treat the roadway between exits 18 and 31. According to the ConnDOT *Snow and Ice Guidelines*, a 7:2 mixture is an application of 1,264 pounds of sand and 300 pounds of salt per two-lane mile.[65]

The ConnDOT *Snow and Ice Guidelines* state that a 7:2 sand and salt mixture can be used on multiple-lane roadways in lieu of straight salt when a complete assignment of trucks (100-percent coverage) has not been dispatched, as was the case on January 17. Between 1:00 and 4:00 a.m., the two trucks made two applications to the northbound and southbound lanes of I-95. Despite these roadway treatments, witnesses reported that they

[64] National Highway Traffic Safety Administration, *Initiatives to Address Safety Belt Use* (Washington, DC: NHTSA, 2003) 6.

[65] ConnDOT *Snow and Ice Guidelines*, 10.

continued to experience hazardous driving conditions that morning, and some even reported that they saw no evidence that I-95 had been treated.

ConnDOT maintenance districts base roadway treatment decisions on the ConnDOT *Snow and Ice Guidelines*, which address only 100-percent treatment coverage. They provide no written instructions for determining when conditions require full treatment versus lesser action, nor do they include information on 25- or 50-percent coverage applications. Lacking direction from the guidelines, the section #33 supervisor had to make a subjective decision about roadway treatment and coverage, and he may not have adequately considered the weather, traffic, and other roadway-related factors to ensure safety on I-95.

Despite the roadway treatment ordered by the supervisor, as many as 18 other accidents reportedly occurred on I-95 in the vicinity of the Fairfield collisions between midnight and 4:50 a.m. on January 17. The persistence of such hazardous conditions suggests that, by failing to provide formal guidance, ConnDOT left the section #33 supervisor ill-equipped to make critical roadway snow and ice treatment decisions.

The ConnDOT guidelines cannot be considered an LOS program because they do not specify treatment strategies for different levels of storm severity. Other highway authorities have determined that officials need more detailed guidance when making snow and ice treatment decisions. Both AASHTO and the FHWA advocate that LOS programs provide such assistance. In general, LOS programs are designed to provide increased precision and thoroughness in developing and applying appropriate snow and ice treatments on roadways. AASHTO recommends that State highway maintenance officials establish LOS programs to provide a framework for making treatment decisions. According to AASHTO, the LOS determination should be based on analyzing a number of preestablished factors, which may include road classification, traffic data, and available personnel and resources, as well as special circumstances and conditions affecting the roadway.

Both New York and Massachusetts—which border Connecticut and have similar winter weather—have LOS programs. Under New York's regular LOS, precipitation with a high ice content, which was the case at the Fairfield accident area during the early morning hours of January 17,[66] would probably have called for an initial application of 225 pounds of straight salt per mile per lane. The New York LOS also provides guidance on followup applications, depending on various factors, including observation of conditions and the roadway's response to treatment.

The Massachusetts LOS program has three service conditions. Condition 2 would probably have applied to the situation on I-95 in the vicinity of the Fairfield accidents. The weather reports and observations for the Fairfield area indicated that temperatures were in the range of 20º F, with light precipitation, resulting in roadway ice. Condition 2 is defined as, "Air temperature 20 degrees Fahrenheit to 32 degrees Fahrenheit, pavement wet or

[66] The regular LOS would have applied, despite the fact that the roadway was treated between 10:00 p.m. and 4:00 a.m., because I-95 had an ADT volume greater than 50,000.

icing precipitation, rain, snow, sleet, or freezing rain. Under this condition, ice is likely to form on the pavement."[67] For condition 2, the initial treatment specified is "straight chloride" or a mixture of calcium chloride and sodium chloride at the rate of 240 pounds per lane mile. The LOS also specifies additional action based on results of the initial application.

The Safety Board cannot definitively state that the applicable treatments specified under the New York and Massachusetts LOS programs would have sufficiently improved roadway conditions to have prevented the January 17 accidents along this section of I-95. However, both of these State LOS programs would have identified icing as the main roadway problem and would have prescribed specific treatments. Had the ConnDOT *Snow and Ice Guidelines* included an LOS program addressing factors such as temperature, precipitation rate, and traffic flow, the supervisors may have made a more accurate assessment of roadway conditions and decided to employ more intensive or different treatments than the minimal application of a 7:2 sand and salt mixture.

Also, the New York and Massachusetts LOS programs both provide guidance on reassessing and readdressing roadway conditions after the initial application. A written program based on LOS would have provided the ConnDOT supervisors with criteria for evaluating the effectiveness of treatment, which might have led to a modification in coverage. The ConnDOT maintenance crew drivers observed at least one weather-related accident during their runs, and the CSP reported that roadways continued to be slippery despite treatment. Had the ConnDOT *Snow and Ice Guidelines* included an LOS program calling for evaluation of the effectiveness of roadway treatment, the supervisors may have initiated 50-percent treatment coverage, rather than 25 percent. Such remedial action could have improved roadway conditions. The Safety Board concludes that a well-designed LOS program would have guided ConnDOT supervisors in selecting a predetermined treatment option designed to address specific roadway conditions, such as moderate snow and ice, and would have helped them evaluate the effectiveness of treatment.

Evidence suggests that the specific response measure ConnDOT selected—application of a 7:2 mixture of sand and salt—was not the optimal choice for the light snow and icy roadway conditions prevailing on I-95 near Fairfield in the early morning hours of January 17. According to AASHTO and the FHWA, abrasives only temporarily improve roadway traction because they are rapidly dispersed by traffic and can be covered by additional precipitation. AASHTO studies indicate that fewer applications of straight salt are required than of a mixture of abrasives and salt to achieve the same level of roadway improvement. Moreover, the FHWA *Manual of Practice for an Effective Anti-Icing Program* indicates that abrasives do not aid in deicing pavement and that combining abrasives with chemicals can reduce the efficiency of treatment.[68] As noted above, for the conditions that applied at Fairfield, both the New York and Massachusetts

[67] Massachusetts Highway Department, *Maintenance Manual*, 42.

[68] See <www.fhwa.dot.gov/reports/mopeap/mop0296a.htm>, July 14, 2005.

LOS programs would have called for the application of straight salt rather than a mixture of abrasives and salt.

The snowfall on the night of January 16–17 was light, which probably influenced ConnDOT's decision to initiate minimum (25 percent) treatment coverage. However, over time, even light snowfall could have overlaid the 7:2 mixture and reduced the capacity of the sand to provide traction. Also, though traffic was not heavy during the early morning hours, the traveling speed was likely sufficient to rapidly disperse the minimal amount of 7:2 mixture applied. CSP transcripts and witness statements indicated that—despite roadway treatment—the pavement remained slippery and hazardous, and accidents continued to occur. The Safety Board concludes that the sand and salt mixture that ConnDOT used to treat the light-to-moderate snow and icy roadway conditions prevailing in the early morning hours of January 17, 2003, was not as effective as straight salt because such a mixture tends to be more rapidly dispersed by high-speed traffic. The Safety Board believes that ConnDOT should develop an LOS program in accordance with FHWA and AASHTO guidance and incorporate the program elements, including a discussion of the limited usefulness of abrasives for roadway treatment, into the *Snow and Ice Guidelines*.

The Safety Board will also inform AASHTO of the circumstances of this accident and will advise the association to encourage its members to implement LOS programs that use the most effective snow and ice treatment materials for given weather, roadway, and traffic conditions in accordance with the FHWA *Manual of Practice for an Effective Anti-icing Program* and the AASHTO *Guide for Snow and Ice Control*.

Median Barrier

When the driver of the 1996 Freightliner tractor flatbed semitrailer lost control of his vehicle near MP 26.6, the truck entered into a counterclockwise skid toward the unpaved and depressed highway median. It collided with and overrode a 32-inch-high portable concrete barrier system. The collision overturned and laterally deflected five barrier segments toward the south and visibly cracked one segment. The Safety Board examined issues associated with the type of barrier used at the accident site and its placement on an unpaved surface.

In 2002, heavy trucks accounted for between 26 and 28 percent of the 125,300 vehicles that traveled daily on the accident segment of I-95. However, the 32-inch-high standard portable concrete median barrier in use at the accident site was designed only to redirect cars and private-use trucks under 4,400 pounds. Safety Board investigators calculated that the 1996 Freightliner, including the compressors and the flatbed semitrailer, weighed over 42,000 pounds and had a center of gravity approximately 4 inches higher than the top of the median barrier. In addition:

- The cross-slope of the depressed median placed the truck at an angle, which increased its propensity to roll toward the barrier, creating an unstable condition.
- The unembedded barrier allowed the truck to tip and override it.

High-performance median barriers at least 42 inches high are heavier than standard portable barriers and are designed to redirect heavy trucks, such as the 1996 Freightliner. These barriers exceed the center-of-gravity height of heavy trucks, making them less likely to overturn or be overridden during a collision, such as that which occurred in Fairfield. However, there is no specific guidance regarding the use of such barriers.

The AASHTO *Roadside Design Guide* provides general information on standard and high-performance median barriers, but it does not include specific warrants for deciding when high-performance barriers are applicable (such as accident history, roadway geometry, ADT volume, or percentage of heavy truck traffic). As a result, States may not be aware of the safety benefits of high-performance barriers. The Safety Board concludes that the AASHTO *Roadside Design Guide* lacks specific guidance on the use of high-performance barriers, making it difficult for State transportation agencies to determine the circumstances, such as those present in the Fairfield accidents, in which such barriers should be used. The Safety Board believes that AASHTO should establish warrants in the *Roadside Design Guide* regarding the selection and use of high-performance barriers, including 42- and 50-inch concrete barriers, that are capable of redirecting heavy trucks.

The Safety Board previously addressed the incongruity between heavy trucks and roadside barrier design guidelines in the White Plains, New York, accident investigation report, in which it recommended that the FHWA "require that highway geometric design and traffic operations of the National Highway System be based on heavy-truck operating characteristics" (Safety Recommendation H-95-32).[69]

Since the issuance of this recommendation, crash tests have been conducted on high-performance permanent concrete bridge railings of 42 inch height or greater, using a 79,400-pound van-type tractor-trailer and an 80,120-pound tanker-type tractor-trailer. Although the FHWA has not issued specific warrants on the use of high-performance barriers, the agency did issue a memorandum to its regional administrators to encourage States to use these barriers on urban freeways, on other freeway systems with significant volumes of heavy vehicles, on sharp curves, on interchange ramps with lower design speeds, and for shielding bridge piers susceptible to damage from heavy vehicle impacts.

The FHWA requires that barriers used on the National Highway System be successfully tested in accordance with the crash test guidelines contained in NCHRP 350.[70] The Safety Board welcomes the progress that has been made in the testing and promotion of permanent high-performance barrier systems. However, specific warrants on

[69] NTSB/HAR-95/02.

[70] NCHRP Report 350, 7.

the use of portable barrier systems are still lacking, and the Fairfield accidents demonstrate the need for expanded impact test scenarios.

At the location of the Fairfield accidents, the portable concrete median barrier was placed on an unpaved surface and was not anchored to the ground. Even though contractors commonly place portable concrete barriers on unpaved surfaces for the short term to complete highway construction projects, no impact tests have been carried out to measure the effectiveness of this practice. Moreover, no impact tests have been conducted on any type of portable high-performance barrier on unpaved surfaces. The AASHTO *Roadside Design Guide* gives little guidance on the placement of portable concrete median barriers on unpaved surfaces.

The mass of a portable concrete barrier and the frictional properties between it and the underlying surface can be critical in preventing movement or overturn. But until impact testing is conducted on barriers placed on unpaved surfaces, it will be difficult to quantify the manner in which the frictional properties or slopes of unpaved surfaces affect barrier performance. The Safety Board concludes that the current Federal impact testing parameters for portable concrete median barriers are inadequate because they do not account for the use of the barriers on unpaved surfaces. The Safety Board believes that the FHWA should conduct crash testing of standard and high-performance portable concrete median barriers on unpaved surfaces to determine whether they meet the test level criteria of NCHRP Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. Upon completion of FHWA testing of standard and high-performance portable concrete median barriers on unpaved surfaces, as requested above, AASHTO should provide clear guidance in the *Roadside Design Guide* on the placement of portable concrete median barriers on unpaved surfaces.

The roadway resurfacing project ongoing in January 2003—for which the portable concrete barrier was placed in the center of the median—was not part of the original ConnDOT construction plans. Because ConnDOT had no procedure for reviewing revisions to projects under construction, a traffic control plan had not been drawn up for the resurfacing project. Had the project been included in a traffic control plan and reviewed by a highway engineer, an alternative may have been identified that would have avoided relocating the median barrier to an unpaved and sloped surface for which it was not designed.

For example, the resurfacing project could have been accomplished in two stages:

- Resurfacing the northbound lanes first, while keeping the median barrier located along the left edge of the southbound shoulder.
- Relocating the median barrier to the left edge of the northbound shoulder prior to resurfacing the southbound lanes.

This two-stage approach would have required the barrier to be moved only once and would have prevented the flooding that might occur from milling the adjacent roadway. Figure 12 shows a cross-section of the positioning of the portable concrete barrier prior to the Fairfield accidents. Figure 13 illustrates how a two-stage process would have avoided placing the barrier on the unpaved median.

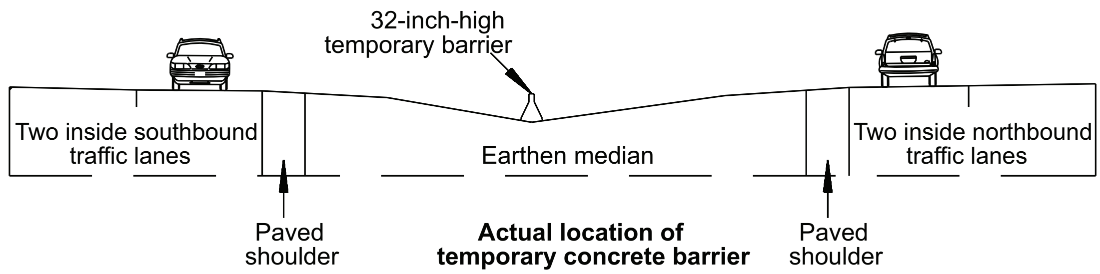

Figure 12. Cross-section of positioning of portable concrete barrier at time of accidents.

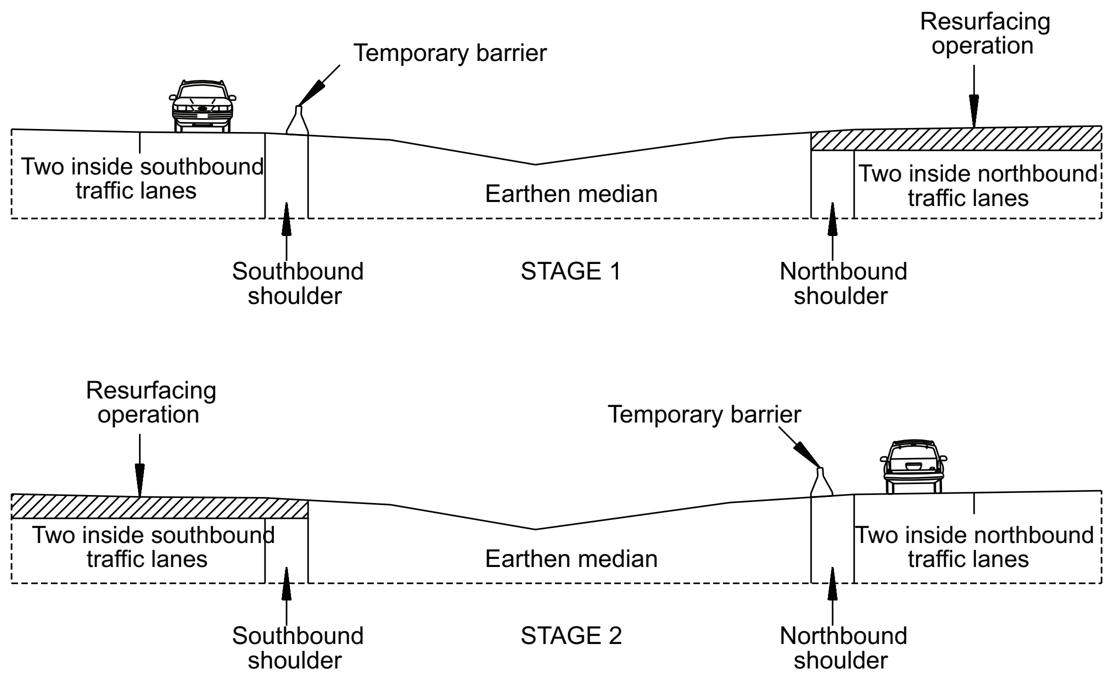

Figure 13. Cross-section of I-95 illustrating exemplar stages 1 and 2 of resurfacing project. (Not to scale. View limited to two inside lanes for clarity.)

As a result of the Fairfield accidents, ConnDOT has adopted a procedure for reviewing and approving revisions to construction projects. This new procedure requires that the Offices of Construction and Engineering explicitly approve any proposed revision to a construction contract. All construction revision submissions must include reasons for the change, proposed procedures, affected locations, cost estimates, and a completion date. Requiring that highway engineers, knowledgeable in State and national guidelines, review proposed revisions to construction projects should mitigate practices that contradict, or are not covered by, established guidelines for highway construction.

Although a two-stage construction project might have been more expensive and required more time, it would have kept the median barrier on a flat paved surface, for which it was designed. Had a review procedure been in place or the two-stage resurfacing process described above been implemented, the portable concrete barrier would have been located on the shoulder of I-95 north during resurfacing of the southbound lanes, and not on the depressed earthen median. It is not possible to determine whether the 1996 Freightliner would have overridden a standard median barrier on the northbound shoulder, but at least the barrier would have been located on a flat paved surface, and it may have been more effective in redirecting the tractor flatbed semitrailer. The Safety Board concludes that had ConnDOT had a procedure in place for reviewing and approving revisions to construction projects, a traffic control plan could have been developed that would not have required relocating the median barrier to an unpaved surface for which it was not designed and on which it may have been less effective.

Highway Lighting

Due to a construction mishap that occurred between midnight and 12:30 a.m. on January 17, 2003, the highway lights on either side of I-95 at the accident site were inoperable. ConnDOT Standard Specifications[71] stated that the contractor was responsible for the repair or replacement of highway safety lighting in a construction work zone whenever the damage was caused by the contractor's operations or negligence. The specifications did not require that the contractor notify ConnDOT of lighting outages or pole knockdowns or provide a time frame for the completion of repairs. According to ConnDOT, the contractor was expected to repair damage to highway illumination as soon as practically possible, but neither the specifications nor the construction contracts provided clear or binding guidance.

It is not clear to what extent the lack of roadway lighting contributed to the collision between the Chevrolet and the 1996 Freightliner flatbed semitrailer. Based on Safety Board examination of the lighting filaments of the Chevrolet headlamps, the high beam headlights were on. Reflectivity analyses indicated that the retroreflective tape on the semitrailer should have been visible to the Chevrolet driver from a distance that would have allowed him to slow down and maneuver his vehicle around the obstruction. However, the purpose of roadway lighting is to improve visibility by supplementing vehicle headlights and to allow drivers to obtain sufficient visual information.[72] Roadway lighting would have illuminated a larger area of the roadway than a vehicle's headlights alone and may have helped an alert driver interpret an obstruction. The Safety Board concludes that the absence of roadway lighting may have affected the Chevrolet driver's ability to recognize and avoid the flatbed semitrailer obstructing the left lane of I-95 north.

[71] Connecticut Department of Transportation, *Standard Specifications for Roads, Bridges, and Incidental Construction*, Form 815, Section 10.00.07 (Hartford, CT: ConnDOT, 1995) 456.

[72] Patrick Hasson and Paul Lutkevich, "Roadway Lighting Revisited," *Public Roads*, Vol. 65, No. 6 (May/June 2002).

Since the accident, ConnDOT has added a special provision to its *Standard Specifications for Roads, Bridges, and Incidental Construction* requiring a contractor to immediately notify the agency of a lighting outage or pole knockdown and to repair the outage within 24 hours. The Safety Board recognizes that this provision would not have changed the circumstances of the Fairfield accidents. However, the requirement does improve the procedures in place and the communication between ConnDOT and its contractors regarding the timeliness of lighting repair.

Variable Message Signs

The initial accident involving the 1996 Freightliner tractor flatbed semitrailer occurred about 4:50 a.m. The 911 call received by the Bridgeport Operations Center at that time described the accident as occurring in the left and center lanes of I-95 south, but did not mention that the back of the semitrailer also blocked the left lane of I-95 north. The operations center took steps to update the 23 southbound VMSs on I-95 and connecting routes to warn motorists of the accident. The VMS system took 31 minutes, from 4:50 to 5:21 a.m., to update these signs.

About 5:06 a.m., after learning of the subsequent accident involving the Chevrolet, the Bridgeport Operations Center programmed the northbound VMSs to warn motorists of the accident. However, because the VMS system could not simultaneously modify messages in both directions of travel, the system did not display the warnings until 5:21 a.m., after all of the southbound signs had been updated. Given the lag time associated with updating the message system, even if the operations center had received complete information on the initial Freightliner accident, the VMSs on I-95 north are unlikely to have been updated in time to benefit the Chevrolet driver. The Safety Board concludes that the length of time required for updating the VMSs, and the limitations of the antiquated system in simultaneously modifying messages in both directions of travel, compromised ConnDOT's capability of providing real-time safety-critical traffic information to motorists.

The sluggishness of the VMS system in place at the time of the accidents clearly decreased its effectiveness in providing real-time traffic information to the traveling public. In January 2004, ConnDOT installed an expanded traffic management system at its Newington Operations Center that allows sign messages on the I-95 corridor to be modified simultaneously in both directions of travel.[73] This new VMS system can modify up to 25 VMSs within 5 minutes.

Using the estimated speed of the Chevrolet and the update rate of the new VMS system, Safety Board investigators determined that if ConnDOT had had the new traffic management system in place before the accidents, the Chevrolet driver would have had an opportunity to see the northbound VMS #55 message, "Accident at exit 24, left and center

[73] Highway Operations Director, Bureau of Engineering and Highway Operations, Connecticut Department of Transportation, telephone interview, July 6, 2004.

lane closed." Because VMS #55 was located about 3.1 miles in advance of the accident scene, the Chevrolet driver would have had about 4 minutes of notice and might have been able to avoid the flatbed semitrailer in the left lane.

Incident Management

At 3:56 a.m. on January 17, 2003, a vehicle overturned on I-95 north, about 400 feet northeast of where the 1996 Freightliner tractor flatbed semitrailer would override the median barrier and cross into the southbound lanes almost 1 hour later. An on-scene CSP officer stated that she had parked her patrol car behind the overturned vehicle and arranged five flares in a diagonal pattern in the left lane. After the first set of flares had burned out, the officer positioned two more flares behind her vehicle. The accident scene was cleared around 4:43 a.m., with the two flares still burning on the roadway. The flares continued to burn for several minutes. It was these flares that the 1996 Freightliner driver reportedly attempted to avoid. The driver of the 2001 Freightliner tractor/refrigerated trailer involved in the southbound accident with the 1996 Freightliner stated that he, too, had seen the flares burning on I-95 north.

The 1996 Freightliner driver was negotiating a wide right curve while in the center lane when he reportedly saw the flares and "panicked," as he explained to the 2001 Freightliner driver at the time. However, the 1996 Freightliner driver also blamed black ice—and not the flares—for initiating the 4:50 a.m. accident.

To explore the possibility that the flares played a role in this accident, the Safety Board examined whether the curvature of the roadway led the 1996 Freightliner driver to perceive the flares as being in his lane. Measurements of sight distance indicated that the driver would have been roughly 1,050 feet from the flares when they appeared to be directly in front of him. According to the driver, he was traveling about 50 mph at the time of the accident, or about 73 feet per second. Given these numbers, it would have taken him about 14 seconds to reach the flares, which was more than enough time to assess the situation and safely maneuver around the obstacle. However, the Safety Board cannot be certain when the driver saw the flares; in addition, situational factors—such as the absence of highway lighting, weather conditions, and the state of the flares themselves—might have influenced his identification and perception of the flares. Even so, the CSP should have removed the flares from the 3:56 a.m. accident scene as part of prudent incident management protocol; leaving the flares to burn out posed a danger to motorists.

In the course of examining whether the flares contributed to the 4:50 a.m. accident, Safety Board investigators learned that the CSP did not have an incident management policy and did not train its officers on incident management procedures. Connecticut had adopted a two-page incident management policy in 1992 that called for coordination among State agencies, including ConnDOT and the Department of Public Safety, in which the CSP resides. However, the State did not develop an accompanying process or guidelines for the agencies to follow in the event of a traffic incident.

A formally documented incident management process that specifies the roles of each agency and the procedures to be followed under particular weather, traffic, and incident situations could lead to a swifter and safer response. Had such a process been in place on January 17, 2003, the CSP might have followed more thorough procedures for safely clearing the scene after the 3:56 a.m. accident, including proper disposal of the flares.

In November 2003, the national MUTCD was amended to include a chapter on the control of traffic through incident management areas. Among the primary functions of traffic incident management is to move road users quickly and safely around an incident and to reduce the likelihood of secondary traffic accidents. The new chapter contains guidelines for managing different levels of incidents, along with traffic control procedures to promote expediency and safety.

The process outlined in the MUTCD would be a useful addition to the Connecticut State Traffic Commission Regulations, which contain the State traffic control standards. This information would also help increase CSP awareness of proper incident management procedures. The Safety Board concludes that a formally documented incident management process would assist the CSP and other State agencies in more effectively conducting and coordinating activities and thereby reduce the occurrence of secondary accidents, such as the Chevrolet's collision with the 1996 Freightliner flatbed semitrailer. The Safety Board believes that ConnDOT should revise its State Traffic Commission Regulations to include the control of traffic through traffic incident management areas, as described in the MUTCD. Additionally, the Safety Board believes that ConnDOT should work with the Connecticut Department of Public Safety to provide coordinated training on traffic incident management for both its own staff and that of the CSP.

Conclusions

Findings

1. Neither alcohol nor drug use was a factor in the accidents involving the 1996 Freightliner and the Chevrolet, and neither mechanical conditions nor motor carrier operations caused or contributed to either accident.

2. The emergency response was satisfactory, despite the lack of prior information about blockage of the northbound left lane and the icy roadway conditions.

3. The 1996 Freightliner driver lost control of his vehicle, probably as a result of traveling at a speed too great for the existing conditions of ice and snow on the roadway surface.

4. The Chevrolet driver probably did not perceive the flatbed semitrailer in the left lane of Interstate 95 north due to a combination of fatigue, distraction from the median crossover accident in the southbound lanes, and the absence of artificial highway lighting.

5. The likelihood of occupant survival would have significantly improved if the Chevrolet had been occupied by a maximum of five persons, rather than nine, and if all occupants had been wearing seat belts.

6. A well-designed level-of-service program would have guided Connecticut Department of Transportation supervisors in selecting a predetermined treatment option designed to address specific roadway conditions, such as moderate snow and ice, and would have helped them evaluate the effectiveness of treatment.

7. The sand and salt mixture that the Connecticut Department of Transportation used to treat the light-to-moderate snow and icy roadway conditions prevailing in the early morning hours of January 17, 2003, was not as effective as straight salt because such a mixture tends to be more rapidly dispersed by high-speed traffic.

8. The American Association of State Highway and Transportation Officials *Roadside Design Guide* lacks specific guidance on the use of high-performance barriers, making it difficult for State transportation agencies to determine the circumstances, such as those present in the Fairfield accidents, in which such barriers should be used.

9. The current Federal impact testing parameters for portable concrete median barriers are inadequate because they do not account for the use of barriers on unpaved surfaces.

10. Had the Connecticut Department of Transportation had a procedure in place for reviewing and approving revisions to construction projects, a traffic control plan could have been developed that would not have required relocating the median barrier to an unpaved surface for which it was not designed and on which it may have been less effective.

11. The absence of roadway lighting may have affected the Chevrolet driver's ability to recognize and avoid the flatbed semitrailer obstructing the left lane of Interstate 95 north.

12. The length of time required for updating the variable message signs, and the limitations of the antiquated system in simultaneously modifying messages in both directions of travel, compromised the Connecticut Department of Transportation's capability of providing real-time safety-critical traffic information to motorists.

13. A formally documented incident management process would assist the Connecticut State Police and other State agencies in effectively conducting and coordinating activities and thereby reduce the occurrence of secondary accidents, such as the Chevrolet's collision with the 1996 Freightliner flatbed semitrailer.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the 4:50 a.m. accident was the 1996 Freightliner's loss of lateral stability, probably due to the operator driving too fast for conditions and to the presence of black ice on the roadway. Contributing to the accident were the inadequate roadway treatment provided by the Connecticut Department of Transportation in response to inclement weather and also its failure to provide a median barrier capable of preventing crossovers by heavy vehicles. The probable cause of the 5:01 a.m. accident was the failure of the Chevrolet driver to identify and avoid the flatbed semitrailer due to fatigue, in conjunction with the distraction from the median crossover accident in the southbound lanes.

Recommendations

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

New Recommendations

To the Federal Highway Administration:

Conduct crash testing of standard and high-performance portable concrete median barriers on unpaved surfaces to determine whether they meet the test level criteria of National Cooperative Highway Research Program Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. (H-05-27)

To the Connecticut Department of Transportation:

Develop a level-of-service program in accordance with Federal Highway Administration and American Association of State Highway and Transportation Officials guidance and incorporate the program elements, including a discussion of the limited usefulness of abrasives for roadway treatment, into the *Snow and Ice Guidelines*. (H-05-28)

Revise your State Traffic Commission Regulations to include the control of traffic through traffic incident management areas, as described in the Federal Highway Administration *Manual on Uniform Traffic Control Devices*. (H-05-29)

Work with the Connecticut Department of Public Safety to provide coordinated training on traffic incident management for both your own staff and that of the Connecticut State Police. (H-05-30)

To the American Association of State Highway and Transportation Officials:

Establish warrants in the *Roadside Design Guide* regarding the selection and use of high-performance barriers, including 42- and 50-inch-high concrete barriers, that are capable of redirecting heavy trucks. (H-05-31)

> Upon completion of Federal Highway Administration testing of standard and high-performance portable concrete median barriers on unpaved surfaces, as requested in Safety Recommendation H-05-27, provide clear guidance in the *Roadside Design Guide* on the placement of portable concrete median barriers on unpaved surfaces. (H-05-32)

Reiterated Recommendation

The National Transportation Safety Board also reiterates the following recommendation:

To the Governor and legislative leaders of Connecticut:

> Enact legislation that provides for primary enforcement of mandatory seatbelt use laws, including provisions such as the imposition of driver license penalty points and appropriate fines. Existing legal provisions that insulate people from the financial consequences of not wearing a seat belt should be repealed. (H-97-02)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARK V. ROSENKER
Acting Chairman

ELLEN ENGLEMAN CONNERS
Member

DEBORAH A. P. HERSMAN
Member

Adopted: November 16, 2005

Appendix A

Investigation

The National Transportation Safety Board was notified of the Fairfield, Connecticut, accident on January 18, 2003. An investigative team was dispatched with members from the Washington, D.C.; Atlanta, Georgia; and Arlington, Texas, offices. Groups were established to investigate highway, vehicle, and survival factors; motor carrier operations; and human performance.

The Federal Highway Administration, Connecticut Department of Transportation, Connecticut State Police, Yale University, General Motors Corporation, Freightliner Corporation, Arrow Trucking Company, BH Trucking Company, Fontaine Trailer Company, M. DeMatteo/Brunalli Construction Company, and DMJM+Harris were parties to this investigation.

No public hearing was held; no depositions were taken.

Appendix B

Snow and Ice Removal Guidelines

FHWA Anti-Icing Program

According to the Federal Highway Administration (FHWA) *Manual of Practice for an Effective Anti-icing Program*:[1]

> The extent to which maintenance services will be provided to a road section is determined by management by the assignment of a level of service. The LOS will largely be determined by the importance of the road, and hence the average daily traffic.

The FHWA also studied the use of abrasives (sand)/chemical mixtures:[2]

> Further, a mix of abrasives and chemical will usually be no more effective as an anti-icing treatment during snowstorms than the same amount of chemical placed alone. It even appears that the use of abrasives in the mix can be detrimental to the effectiveness of the chemical. Because of the cost associated with both application and clean-up of roads and drainage facilities, and because of the potential airborne dust problem accompanying their use, abrasives applications should not be a routine operation of an anti-icing program.

AASHTO Guide for Snow and Ice Control

The American Association of State Highway and Transportation Officials (AASHTO) *Guide for Snow and Ice Control* recommends that State highway maintenance officials responsible for snow and ice control establish a level-of-service (LOS) program:[3]

> Because of the need for continued mobility and safety on the roads, it is important that snow and ice control programs establish a level of service that satisfies the customers and is attainable with available budget and resources. Level of Service (LOS) refers to operational guidelines establishing maintenance activities associated with the prevention and removal of snow and ice from roadways. LOS may establish a prescribed end-of-storm condition, intermediate stages acceptable while obtaining that condition, or the frequency of snow and ice control maintenance operations. LOS results from an analysis of:
>
> - agency snow and ice control policy;
> - road classification;

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[1] Federal Highway Administration, *Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel* (Washington, DC: FHWA, June 1996) 3. See <www.fhwa.dot.gov/reports/mopeap/mop0296a.htm>, July 14, 2005.

[2] FHWA, 6.

[3] American Association of State Highway and Transportation Officials, *Guide for Snow and Ice Control* (Washington, DC: AASHTO, 1999) 5.

- traffic data;
- maintenance coverage time periods defined for various operations, including clean-up operations;
- equipment types and amounts;
- location of facilities;
- personnel rules and regulations;
- materials used; and
- special circumstances and conditions.

AASHTO also studied the use of abrasives (sand)/chemical mixtures and stated that:[4]

Abrasives or a mix of abrasives and chemicals are commonly used for many snow and ice control operations. The sole function of abrasives is to improve traction, which may be short-lived because traffic will rapidly disperse abrasives and additional frozen precipitation will cover the application treatment.

The advantages and disadvantages of abrasives must be understood. Advantages include low first costs; some immediate, although temporary, increased traction on slippery surfaces; potential usage at low temperatures when some chemicals are ineffective; and visible evidence of road crew actions. Disadvantages of abrasives include frequent reloading due to low distance of coverage per truckload; reapplication required due to traffic and precipitation; adverse effects on cars such as damage to windshields and body finishes; significant cleanup efforts of roads and drainage facilities following storms and the winter season; adverse effects on the air quality through increased airborne particulate matter (PM problem); and adverse effects on watercourse ecosystems.

The problem resulting from the use of mixtures of abrasives and chemicals is challenging. The Ontario Ministry of Transport concluded that mixing salt with abrasives above the level needed to prevent stockpile freezing improves neither the abrasive qualities of straight sand nor the deicing qualities of straight salt. In addition, they found the highway sections treated with straight salt required fewer applications than sections treated with salt/abrasives mixtures, while achieving the same level of service.

The FHWA T&E 28 study found that a mixture of abrasives and chemical applied during snowstorms as an anti-icing treatment will be no more effective than the same amount of chemical placed alone. The study findings suggest that the use of abrasives in the mix can be detrimental to the effectiveness of the chemical and that abrasives applications should not be routine operations of an anti-icing program because of the negative attributes associated with its use.

[4] AASHTO, 81–82.

Connecticut Snow and Ice Guidelines

In a partial coverage storm, the Connecticut Department of Transportation (ConnDOT) recommends the use of a 7:2 mixture of sand and salt. According to the ConnDOT *Snow and Ice Guidelines*:[5]

> Seven (7) parts of sand to 2 parts of salt will be the primary mix on all two-lane highways and ramps. (Highways–1264 pounds sand and 300 pounds salt per two-lane mile; Ramps–1685 pounds sand and 400 pounds salt per two-lane mile.) This mix may also be applied to the multi-lane system at the same rate as the two-lane system at the beginning of the storm when the complete assignment of trucks [has] not been called out or if conditions warrant. Such applications will be in lieu of straight salt, not in addition to straight salt.

The *Snow and Ice Guidelines* recommend echelon[6] plowing for six-lane routes. Echelon plowing requires a full callout of trucks (100-percent coverage):[7]

> Two trucks of the echelon group shall apply salt to the entire run. One truck will spread a 4-cubic yard load of salt on the centerline of two lanes at the rate of 432 pounds per two-lane mile for a distance of 20 miles. The second truck will spread a 2-cubic-yard load of salt on the third lane at the rate of 216 pounds per two-lane mile for a distance of 20 miles. When abrasives are required, trucks 3 and 4 shall each spread a 5.5-cubic-yard load of straight sand to one-half the run (10 effective two-lane miles) at the rate of 1430 pounds per two-lane mile; the fifth truck shall apply a 5.5-cubic-yard load of straight sand to the third lane at the rate of 715 pounds per two-lane mile.

New York State Snow and Ice Guidelines

The New York State Department of Transportation (NYSDOT) *Highway Maintenance Guidelines, Snow and Ice Control*, recommends snow control goals given the constraints of operational resources and the character of the snow event:[8]

> The snow control goals will vary with traffic volume and other considerations. Furthermore, the level of service provided will vary with the snow control goals determined to be appropriate given the existing conditions. Regular level of service should be provided on all classes of highway between 4:00 a.m. and 10:00 p.m. Monday thru Friday, and at all times on highways having Average Daily Traffic (ADT) of 50,000 vehicles per day or more. Modified level of service should be provided on all highways except those having ADTs of 50,000 vehicles per day or more in all time periods except those defined under “regular level of service.”

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[5] Connecticut Department of Transportation, *2002/2003 Snow and Ice Guidelines*, Bureau of Engineering and Highway Operations, Office of Maintenance (Hartford, CT: ConnDOT, 2002) 10.

[6] For echelon plowing, the trucks are arranged in a staggered formation along the lanes.

[7] ConnDOT, 14.

[8] New York State Department of Transportation, *Highway Maintenance Guidelines, Snow and Ice Control* (Albany, NY: NYSDOT, 1993) 8–9.

Snow Control Goals, Regular Level of Service[9]

Highway class	Accumulation at which plowing should begin (inches)	Elapsed time after event end that full width of pavement should be plowed (hours)
A1	0.50 to 2.50	1.5
A2, B, C	1.00 to 3.00	2.0
D	1.50 to 4.00	3.0

Snow Control Goals, Modified Level of Service

Highway class	Accumulation at which plowing should begin (inches)	Elapsed time after event end that full width of pavement should be plowed (hours)
A1	0.75 to 3.00	2.0
A2, B, C	1.50 to 3.50	3.0
D	2.00 to 4.50	4.0

NYSDOT recommends specific guidelines for the application of salt for light-to-moderate accumulating snow and rapidly accumulating dense snow:[10]

> Light to moderately accumulating normal snow–The initial application shall be 225 pounds of salt per mile, per lane. Follow-up applications shall be as necessary, and at 115 pounds of salt per mile, per lane. If the pavement temperature is over 30 degrees Fahrenheit and/or traffic volume is high, the initial application rate may be reduced.
>
> Rapidly accumulating dense snow, freezing rain, pack, glaze and sleet (high ice content)–The initial application shall be 270 pounds of salt per mile, per lane. Follow-up applications shall be as necessary, and the rate of application will vary with the observed condition of the snow or ice on the pavement surface. If surface is still glazed or packed, the follow-up application shall be 270 pounds of salt per mile, per lane (the same as the initial application). If the surface is mealy or slushy, the follow-up application shall be 115 pounds of salt per mile per lane.

The *Highway Maintenance Guidelines* offer the following guidance on the use of abrasives (sand)/chemical mixtures:[11]

> The use of "sweetened" mixtures like 50-50 (1 part abrasives and 1 part salt) is wasteful and inefficient. If spread at the normal application rate for abrasives, this mixture will place 40% more salt on the road than a normal application of pure salt. The effectiveness of that salt is reduced by the presence of the abrasives.
>
> Abrasives, overall, are more costly (based on initial application, reapplication, cleanup and other factors) and less safe to use than salt (if abrasives were used

[9] Class A1 denotes expressways with low average running speeds, with traffic volumes that reach or exceed design capacity, such as the Long Island Expressway. Class A2 denotes expressways with high average running speeds and a one-way design hourly volume of 500 or more vehicles per hour. Class B denotes major State highways with a one-way design hourly volume from 200 to 500 vehicles. Classes C and D denote minor State highways with a one-way design hourly volume of less than 200 vehicles or with a very low traffic volume, respectively.

[10] NYSDOT, 17.

[11] NYSDOT, 19.

where salt would otherwise work). Abrasives are applied at 3-1/3 times the rate of salt. When the cost of necessary salt in the abrasives and mixing costs are considered, the per application cost of abrasives is about equal to that of salt.

Although snow and ice surfaces that have been treated with abrasives are safer than untreated snow or ice surfaces, they are not as safe as bare pavement. Traffic quickly diminishes the effect of abrasives and frequent re-application is necessary. This adds significantly to the overall cost and still provides a less safe surface than the bare pavement that could have been achieved with pure salt.

Massachusetts Highway Department Maintenance Manual

The Massachusetts Highway Department *Maintenance Manual* describes three basic snow or ice conditions and the procedures to be followed under each:[12]

Condition 1: Air temperature 25 degrees Fahrenheit to 34 degrees Fahrenheit and rising. Pavement wet. Precipitation snow, sleet or freezing rain. This condition may prevail until the temperature rises through and above the critical zone (28 degrees Fahrenheit to 34 degrees Fahrenheit), in which case the precipitation will gradually change to rain and the chance of packing or icing will diminish as the storm progresses. The temperature may, however, level off at a temperature within the critical range, in which case packing or icing will take place. Actual temperatures and precipitation should be checked periodically with the forecast. The initial treatment should be the application of straight chloride at the rate of 240 pounds per lane mile. If the temperature moves at a rapid rate through the critical zone, further applications may be necessary in storms of long duration. If the temperature levels off below the critical zone and the storm continues in the form of snow and packing is imminent, it may be necessary to commence plowing and to retreat the potential pack areas with deicing chemicals.

Condition 2: Air temperature 20 degrees Fahrenheit to 32 degrees Fahrenheit, pavement wet or icing precipitation rain, snow, sleet, or freezing rain. Under this condition, ice is likely to form on the pavement. There is a distinct possibility that the precipitation will turn to snow even though it may start as rain. The initial treatment is the application of straight chloride or the mixture of calcium chloride and sodium chloride at the rate of 240 pounds per lane mile as soon as possible. If this treatment is effective, the pavement will remain wet or will be covered with a slush according to the degree to which the temperature falls. If a slush develops, it should be removed and/or chemically treated before it is hardened by freezing or by traffic. Subsequent treatment, when required, should consist of another application of chlorides or plowing, whichever is indicated. Spot sanding with treated sand may be necessary at the conclusion.

Condition 3: Air temperature below 25 degrees Fahrenheit, pavement dry, precipitation snow. Obviously this condition calls for plowing when sufficient accumulation occurs, followed by chemical treatment. Plowing should continue for the duration of the storm and until pavement and shoulders are clear. If the temperature rises through the critical zone (28 degrees Fahrenheit to 34 degrees Fahrenheit), the application of sodium chloride at the rate of 240 pounds per lane mile may be necessary to prevent icing.

[12] Massachusetts Highway Department, *Maintenance Manual*, Chapter 5, Division 4.

Appendix C

NCHRP Crash Test Criteria

Permanent Concrete Barriers

The National Cooperative Highway Research Program (NCHRP) Report 350[1] gives the full-scale crash test criteria for the safety performance of highway features, which include longitudinal barriers (or concrete barrier shapes).

NCHRP Report 350 evaluated longitudinal barriers based on six test levels. In general, the lower test levels (TL-1, TL-2, and TL-3) are applicable for evaluating longitudinal barriers to be used on lower service level roadways and certain types of work zones, while the higher test levels (TL-4, TL-5, and TL-6) are applicable for higher service level roadways or at locations that demand a special high-performance barrier.

TL-3 is the standard level to which most crash-tested barriers have been approved by the Federal Highway Administration (FHWA) for use on U.S. highways. NCHRP Report 350 defines

- TL-3 as a 4,400-pound pickup truck that is crash tested into a 32-inch-high concrete barrier at a speed of 60 mph and an impact angle of 25º.
- TL-4 as a 17,600-pound single-unit truck that is crash tested into a 32- or 42-inch-high concrete barrier at a speed of 50 mph and an impact angle of 15º.
- TL-5 as a 79,400-pound van tractor-trailer that is crash tested into a 42-inch-high concrete barrier at a speed of 50 mph and an impact angle of 15º.
- TL-6 as a 79,400-pound tanker-type tractor-trailer that is crash tested into a 90-inch-high concrete barrier at a speed of 50 mph and an impact angle of 15º.

Only one concrete barrier—the Texas T5 modified barrier—has been approved and tested for TL-6.

Table C-1 identifies the types of barriers (bridge railings) that have been crash tested with a tractor-trailer and approved under NCHRP Report 350 at TL-5 and TL-6.[2]

[1] National Cooperative Highway Research Program, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, NCHRP Report 350 (Washington, DC: Transportation Research Board, National Research Council, 1993).

[2] The FHWA Web site for NCHRP Report 350 discusses the types of bridge railings that have been crash tested with a tractor-trailer. See <safety.fhwa.dot.gov/fourthlevel/hardware/bridgerailings.htm>, July 14, 2005.

Table C-1. Barriers crash tested and approved at TL-5 and TL-6.

Barrier	Height (inches)	Test vehicle	Impact speed (mph)	Impact angle (degrees)	NCHRP 350 test level
42-inch vertical	42	50,050-lb tractor-trailer	51.4	16.2	TL-5
Concrete parapet	42	79,400-lb van tractor-trailer	50	14.5	TL-5
New Jersey Turnpike heavy vehicle	42	80,180-lb tractor-trailer	52.1	16.5	TL-5
Texas T5 modified	90	80,120-lb tanker-type tractor-trailer	51.4	15	TL-6
Texas Type HT (modified T5)	50	80,080-lb truck	48.4	14.5	TL-5
42-inch F-shape	42	50,000-lb tractor-trailer	52.2	14	TL-5

The crash tests performed for the barriers identified in table C-1 were done on a flat paved surface when accelerating the tractor-trailer to the desired speed to provide for unrestricted trajectory of the vehicle following impact. The barriers were anchored to the surface during the tests.

The performance level of each test vehicle varied with each crash test. The 50,050-pound tractor-trailer rolled over when crash tested into the 42-inch-high vertical concrete parapet. The 80,080-pound truck rolled over when crash tested into the Texas type HT (modified T5) barrier. Under TL-5 and TL-6, the crash test criteria in NCHRP Report 350 allow the vehicle to roll over.

Portable Concrete Barriers

Table C-2 identifies the types of 42-inch-high portable concrete barriers that have been crash tested and approved under NCHRP Report 350 at TL-3 and TL-4. None of the portable concrete barriers (at 32 or 42 inches high) were crash tested with tractor-trailers. The tests were performed with the barriers resting on a flat paved surface. The barriers were connected to each other either by a channel or a pin-and-loop design; however, they were not anchored to the paved surface. The barriers were connected and arranged in a series of 20. The crash test criteria under NCHRP Report 350 allow the test vehicle to penetrate the barrier, but it may not roll over—nor can the barrier cause excessive forces on the vehicle occupants.

Table C-2. Barriers crash tested and approved at TL-3 and TL-4.

Barrier	Height (inches)	Test vehicle/agency	Impact speed (mph)	Impact angle (degrees)	NCHRP 350 test level
42-inch-tall F-shape	42	17,400-lb single-unit truck/Oregon Department of Transportation	50	15	TL-4
42-inch-tall F-shape	42	4,400-lb pickup truck/Oregon Department of Transportation	60	25	TL-3

The connection between the 42-inch-tall F-shape portable concrete barriers consisted of two sets of two perforated C-shape steel channels with the open sides alernately positioned such that one leg of each channel fit between the legs of the mating channel on the adjacent barrier segment. The barriers were not connected by a pin-and-loop design.

Appendix D

Variable Message Sign Placement

I-95 North

VMS No.	Town	Location
50	Mamaroneck, NY	North of exit 18A
51	Greenwich	South of exit 3
52	Stamford	South of exit 9
53	Norwalk	South of exit 14
54	Westport	South of exit 19
55	Fairfield	North of exit 19
Scene of accident		Exit 24
57	Stratford	North of exit 31
58	Milford	North of exit 36
59	West Haven	South of exit 43
60	New Haven	South of exit 46
61	East Haven	At exit 51

I-95 South

VMS No.	Town	Location
73	Branford	South of exit 53
74	New Haven	South of exit 51
75	Milford	North of exit 40
76	Milford	North of exit 36
77	Stratford	South of exit 31
Scene of accident		Exit 24
78	Fairfield	South of exit 21

Appendix E

Arrow Trucking 2003 Compliance Review

The Federal Motor Carrier Safety Administration conducted a compliance review of Arrow Trucking following the Fairfield accidents. The review resulted in a "conditional" rating, with the following violations:

1. Using a substance abuse professional without required credentials.
2. Failing to ensure that random drug testing dates are reasonably spread throughout the calendar year.
3. Failing to maintain drug testing records for 1 year.
4. Allowing a driver with a suspended license to operate a commercial motor vehicle.
5. Failing to keep an accident register in the form and manner prescribed.
6. Failing to maintain copies of all accident reports.
7. Using a driver whose medical examination is recorded on an unauthorized medical examination form.
8. Using a driver not medically examined and certified during the preceding 24 months.
9. Failing to maintain a note relating to annual review of the driver's driving record.
10. Failing to maintain a list or certificate relating to violations of motor vehicle laws.
11. Scheduling a run that would necessitate the vehicle being operated at speeds in excess of those prescribed. *(critical violation)*
12. Requiring or permitting a driver to drive more than 10 hours.
13. Requiring or permitting a driver to drive after having been on duty 15 hours.
14. Requiring or permitting a driver to drive after having been on duty for 70 hours in 8 consecutive days.
15. False reports of records of duty status.
16. Failing to require a driver to prepare record of duty status in the form and manner prescribed.
17. Failing to require a driver to forward the original of the record of duty status within 13 days of completion.

18. Failing to preserve a driver's record of duty status supporting documents for 6 months. *(critical violation)*
19. Failing to keep maintenance records that identify the vehicle.
20. Failing to have a means of indicating the nature and due date of inspection and maintenance operations to be performed.
21. Failing to require a driver to prepare a driver vehicle inspection report. *(critical violation)*
22. Using a commercial motor vehicle not periodically inspected.
23. Using a commercial motor vehicle not periodically inspected in accordance with minimum standards.