Multivehicle Work Zone Crash on Interstate 95
Cranbury, New Jersey
June 7, 2014

Accident Report

NTSB/HAR-15/02
PB2015-105186

National
Transportation
Safety Board

NTSB/HAR-15/02
PB2015-105186
Notation 8717
Adopted August 11, 2015

Highway Accident Report

Multivehicle Work Zone Crash on Interstate 95
Cranbury, New Jersey
June 7, 2014

National
Transportation
Safety Board

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

National Transportation Safety Board. 2015. ***Multivehicle Work Zone Crash on Interstate 95, Cranbury, New Jersey, June 7, 2014*****. Highway Accident Report NTSB/HAR-15/02. Washington, DC.**

Abstract: The accident that is the subject of this report occurred about 12:55 a.m. on June 7, 2014, on Interstate 95 (the New Jersey Turnpike) near Cranbury, New Jersey. A truck-tractor semitrailer operated by Walmart Transportation LLC was traveling northbound, in the center lane of the three-lane roadway. Near milepost 71.4, the truck encountered traffic that had slowed to less than 10 mph along a construction corridor. The truck was traveling 65 mph in a work zone that had a posted speed limit of 45 mph. The truck struck the left rear of a slowly moving limo van in the center lane. A series of impacts resulted from this initial contact. The limo van came to rest overturned on its left side across the center lane. Twenty-one people in six vehicles were involved in the crash. One limo van passenger died on scene, and four other limo van passengers were seriously injured. The safety issues in this report include enacting programs to address driver fatigue; improving work zone safety, including reducing vehicle speeds; assessing the limitations of, and means of enhancing, in-vehicle forward collision warning systems; using the safety data available through critical event recording systems; increasing passenger awareness of occupant restraint systems in passenger vehicles and ensuring that vehicle modifications do not reduce safety; and creating an acceptable minimum standard of care to be provided by emergency medical responders. As a result of the investigation, the National Transportation Safety Board (NTSB) issued recommendations to the Federal Highway Administration, the National Highway Traffic Safety Administration (NHTSA), the New Jersey Department of Health–Office of Emergency Medical Services, the New Jersey State First Aid Council, the National Limousine Association, Walmart Transportation LLC, Bendix Commercial Vehicle Systems LLC, Detroit Diesel Corporation, and Meritor WABCO Vehicle Control Systems. The NTSB reiterated three recommendations to the Federal Motor Carrier Safety Administration and three recommendations to NHTSA.

For more detailed background information on this report, visit http://www.ntsb.gov/investigations/dms.html and search for NTSB accident number HWY14MH012. Recent publications are available in their entirety on the Internet at http://www.ntsb.gov. Other information about available publications also may be obtained from the website or by contacting: **National Transportation Safety Board, Records Management Division, CIO-40, 490 L'Enfant Plaza, SW, Washington, DC 20594, (800) 877-6799 or (202) 314-6551**

NTSB publications may be purchased from the National Technical Information Service. To purchase this publication, order product number PB2015-105186 from: **National Technical Information Service, 5301 Shawnee Rd., Alexandria, VA 22312 (800) 553-6847 or (703) 605-6000,** http://www.ntis.gov/

Contents

Figures

Tables

Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ACB	Active Cruise with Braking
AE	algorithm enable
ALS	advanced life support
Atlantic Transportation	Atlantic Transportation Services LLC
BASIC	Behavior Analysis and Safety Improvement Category
Bendix	Bendix Commercial Vehicle Systems LLC
BLS	basic life support
BMI	body mass index
CDL	commercial driver's license
CER	critical event report
CFR	*Code of Federal Regulations*
CIMU	Construction Incident Management Unit (NJSP)
CR	compliance review
DMS	dynamic message sign
DOT	US Department of Transportation
DVIR	driver vehicle inspection report
ECM	electronic control module
EMS	emergency medical service
EMT	emergency medical technician
EMT-B	basic emergency medical technician
EMT-I	intermediate emergency medical technician

EMT-P	paramedic
ESP	electronic stability program
FAA	Federal Aviation Administration
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMP	fatigue management program
FMVSSs	*Federal Motor Vehicle Safety Standards*
GPS	global positioning system
GVWR	gross vehicle weight rating
HOS	hours-of-service
I-95	Interstate 95
ITS	intelligent transportation system
limo van	2012 Mercedes-Benz 2500 series high-roof extended Sprinter limousine van
MCMIS	Motor Carrier Management Information System
Midwest Automotive	Midwest Automotive Designs Corporation
MP	milepost
MUTCD	*Manual on Uniform Traffic Control Devices*
NAFMP	North American Fatigue Management Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NJSP	New Jersey State Police
NJTA	New Jersey Turnpike Authority
NLA	National Limousine Association

NTSB	National Transportation Safety Board
OOS	out-of-service
OSA	obstructive sleep apnea
OTR	over-the-road
RWJUH	Robert Wood Johnson University Hospital
TMP	transportation management plan
TRB	Transportation Research Board
Walmart Transportation truck	2011 Peterbilt truck-tractor in combination with a 2003 Great Dane semitrailer, operated by Walmart Transportation LLC

Executive Summary

Investigation Synopsis

About 12:55 a.m. on Saturday, June 7, 2014, a 2011 Peterbilt truck-tractor in combination with a 2003 Great Dane semitrailer operated by the motor carrier Walmart Transportation LLC (Walmart Transportation truck) was traveling northbound on the New Jersey Turnpike (part of Interstate 95) near Cranbury, New Jersey, in the center lane of the three-lane roadway. Near milepost 71.4, the Walmart Transportation truck encountered traffic that had slowed to less than 10 mph along a construction corridor, due to closure of the center and right-hand lanes. The truck was traveling 65 mph in a nighttime work zone that had a posted speed limit of 45 mph.

The Walmart Transportation truck struck the left rear of a slowly moving 2012 Mercedes-Benz limo van (limo van) that was in the center lane. The impact from the Walmart Transportation truck accelerated the limo van forward and caused it to turn to the right. The limo van collided with a 2006 Freightliner tractor-trailer traveling in the right lane. Contact from the Freightliner and Walmart Transportation trucks forced the limo van to roll over one quarter turn onto its left (driver) side. During its roll, the limo van struck the rear of a 2011 Buick Enclave, which then struck the rear of a 2011 Ford F-150 pickup truck. The limo van came to rest overturned onto its left (driver) side across the center lane. After striking the limo van, the Walmart Transportation truck continued into the left lane and struck a 2005 Nissan Altima in the rear before colliding with a guardrail and stopping on the shoulder against a concrete barrier.

Twenty-one people in six vehicles were involved in the crash. As a result of the crash, one limo van passenger, who had been riding in the vehicle's passenger compartment, died on scene, and the other four passengers in this compartment were seriously injured. Five additional people had minor injuries.

Safety Issues

The crash investigation focused on the following safety issues:

- **Enacting programs to address driver fatigue.** When the Walmart Transportation truck driver reported to work at the Walmart Transportation distribution center in Smyrna, Delaware, at 11:00 a.m. on June 6, 2014, he had been up all night driving in his personal vehicle from his Georgia residence to his Delaware workplace, a trip of about 12 hours. When the crash occurred at 12:55 a.m. on June 7, the driver was in the sixth leg of his workday and had been on duty 13 hours 32 minutes of a 14-hour duty day. As he approached the work zone in Cranbury, he had had only about 4 hours of sleep opportunity in the preceding 33 hours. His fatigued condition diminished his awareness, and he failed to reduce his speed or respond appropriately to the slowed vehicles ahead of him, resulting in the crash. Implementation of fatigue management programs and fatigue detection technologies specifically geared to the motor carrier operating environment could help carriers better address the complexities of mitigating driver fatigue.

- **Improving work zone safety, including reducing vehicle speeds.** The crash occurred near the end of a traffic queue that had developed in an active work zone established by the New Jersey Turnpike Authority (NJTA). Although the NJTA established the work zone in accordance with federal and state requirements, the overall plan did not incorporate supplemental traffic control devices or other proactive means to monitor and warn motorists of traffic backing up within the work zone. A slow traffic queue more than a mile long developed in the advance warning zone preceding the lane closures. Just before the crash, the Walmart Transportation truck had been traveling 65 mph in the beginning of the warning zone, which had a posted speed limit of 45 mph. A technical reconstruction determined that had the Walmart Transportation truck been traveling 45 mph, it could have been stopped before it struck the limo van. Traffic control practices are available, but not currently required by regulation, that might have alerted even this fatigued driver to the need to reduce his vehicle's speed in the work zone.
- **Assessing the limitations of, and means of enhancing, in-vehicle forward collision warning systems.** The Walmart Transportation truck was equipped with a Wingman Active Cruise with Braking system made by Bendix Commercial Vehicle Systems LLC, which could have issued a precrash audible alert to the truck driver. However, because of its limited data recording capability, the system did not record any forward radar sensor data, which made both the crash and the system's performance difficult to analyze and assess. To address these system shortcomings, manufacturers of such systems could design them to be capable of storing and retrieving data in a manner useful to system performance analysis and accident investigation.
- **Using the safety data available through critical event recording systems.** Walmart Transportation deployed a telematics system on the accident truck and its other fleet vehicles that generated reports of critical safety-related driving events and forwarded them to company management. The carrier, however, did not analyze the aggregated data or use the cumulative information to improve its corporate safety program.
- **Increasing passenger awareness of occupant restraint systems in passenger vehicles and ensuring that vehicle modifications do not reduce safety.** None of the passengers in the passenger compartment of the limo van struck in this accident were wearing their seat belts when the crash occurred. The carrier operating the limo van, Atlantic Transportation Services, was based in Delaware and was operating in New Jersey at the time of the crash. In both these states, all the limo van occupants were required by law to use seat belts. No one from Atlantic Transportation Services told the occupants of the passenger compartment that they were required to wear seat belts nor were there any placards in the vehicle prompting them to wear the belts. The carrier did not have, nor was it required to have, established policies for making pretrip safety briefings. Pretrip safety briefings are beneficial to all passenger operations, but they are particularly needed in limousine service because the seating configuration in such vehicles is intended to create a relaxed social setting; in such an

environment, passengers may easily overlook the use of seat belts if not prompted by the vehicle operator. Moreover, when available, head restraints should be adjusted as appropriate to passenger height. In addition, although the modified vehicle met all Federal Motor Vehicle Safety Standards, some modifications, including the permanent barriers at the front and back of the passenger compartment and the single side door, delayed emergency evacuation of the injured passengers from the compartment. The modifications also reduced the vehicle's cargo capacity.

- **Creating an acceptable minimum standard of care to be provided by emergency medical responders.** The investigation found that the emergency response included missteps on scene due to poor communication, lack of oversight, and nonstandard patient care practices. Responders did not obtain appropriate medical resources in a timely fashion, and the standard of care provided by some responders was inadequate. Some of the injured occupants of the limo van were moved before they were properly restrained and stabilized. Such problems could be addressed by ensuring that responding agencies adhere to minimum training and practice standards.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the Cranbury, New Jersey, crash was the Walmart Transportation LLC truck driver's fatigue, due to his failure to obtain sleep before reporting for duty, which resulted in his delayed reaction to slowing and stopped traffic ahead in an active work zone and his operation of the truck at a speed in excess of the posted limit. Contributing to the severity of the injuries was the fact that the passengers seated in the passenger compartment of the limo van were not using available seat belts and properly adjusted head restraints.

Recommendations

As a result of this investigation, the National Transportation Safety Board (NTSB) makes new safety recommendations to the Federal Highway Administration, the National Highway Traffic Safety Administration (NHTSA), the New Jersey Department of Health–Office of Emergency Medical Services, the New Jersey State First Aid Council, the National Limousine Association, Walmart Transportation LLC, Bendix Commercial Vehicle Systems LLC, Detroit Diesel Corporation, and Meritor WABCO Vehicle Control Systems. The NTSB also reiterates three recommendations to the Federal Motor Carrier Safety Administration and three recommendations to NHTSA.

1 Factual Information

1.1 The Crash

1.1.1 Crash Narrative

Approximately 12:55 a.m. on Saturday, June 7, 2014, a black 2012 Mercedes-Benz 2500 series high-roof extended Sprinter limousine van (limo van) operated by Atlantic Transportation Services LLC (Atlantic Transportation) was traveling north in the center lane of the New Jersey Turnpike (a portion of Interstate 95 [I-95]) near Cranbury, New Jersey.[1] The limo van was transporting five passengers in its passenger compartment from the Dover Downs Hotel and Casino, in Delaware, back to a residence in Cresskill, New Jersey, following an evening entertainment show.[2] The president of Atlantic Transportation drove the limo van, and a second company driver was in the front passenger seat. The weather was clear and the roadway was dry.

At this time, a white 2011 Peterbilt truck-tractor in combination with a 2003 Great Dane semitrailer operated by Walmart Transportation LLC (Walmart Transportation truck) was also traveling north on the New Jersey Turnpike. The driver of the Walmart Transportation truck had reported to work at the Walmart Transportation General Merchandise Regional Distribution Center in Smyrna, Delaware, at 11:00 a.m. on June 6, 2014. At the time of the crash, the truck was en route from a Walmart Transportation location in Levittown, Pennsylvania, to Perth Amboy, New Jersey. According to the driver's electronic logbook, he departed Levittown at 12:20 a.m. When the crash occurred, the Walmart Transportation truck had traveled about 25 miles of the approximately 50-mile distance between Levittown and Perth Amboy. This trip was the sixth travel leg of the driver's workday. At the time of the crash, the driver had been on duty 13 hours 32 minutes of a 14-hour duty day.[3]

Near milepost (MP) 71.4, the limo van and surrounding traffic had slowed due to traffic congestion associated with a nighttime work zone that involved lane closures for the center and right lanes of the three-lane, northbound turnpike.[4] The limo van driver had slowed his vehicle to about 4 mph and was beginning a lane change from the center to the right lane.[5] The Walmart Transportation truck was traveling in the center lane when it struck the back left half of the limo van. Before the truck driver braked the vehicle, the Walmart Transportation truck was traveling

[1] Unless otherwise noted, all times are in eastern daylight time.

[2] The outgoing trip between Cresskill and Dover Downs had been made by the same operator, using a 2011 Chevrolet Suburban. The Suburban had picked up the passengers at 3:30 p.m. Friday afternoon (June 6, 2014). The limo van departed Dover Downs about 10:45 p.m. on June 6 for the return trip to Cresskill.

[3] Per 49 *Code of Federal Regulations* 395.3(a)(2), the 14-hour rule states that a driver cannot drive after 14 hours from the start of his or her day. This restriction does not limit the time a driver can work; it only limits the drive time after 14 hours.

[4] Based on postaccident interviews with other drivers involved in the crash, the tail lights of the vehicles in this traffic queue should have been visible to the Walmart Transportation truck driver for over 0.5 mile.

[5] The limo van had been slowed in the traffic queue, traveling between 3 mph and 11 mph, for about 34 seconds before the crash occurred. At the time of impact, the speed of the limo van was approximately 3.6–4.1 mph, as indicated by the two global positioning systems in use on the vehicle.

at 100 percent throttle at an engine-limited speed of 64–65 mph. In the last 2 seconds before impact, the truck driver applied the brakes and steered to the left, which resulted in a relative impact angle of approximately 16 degrees and an impact speed of 47–53 mph.[6]

The crash event consisted of a rapid succession of five impacts, involving six motor vehicles, concluding with the Walmart Transportation truck's running into a fixed concrete barrier. The primary impact occurred when the Walmart Transportation truck struck the limo van. The impact from the Walmart Transportation truck accelerated the limo van forward and rotated its front into the right lane, where it collided with the left side of a 2006 Freightliner tractor-trailer.[7] Contact damage indicated that the limo van was upright at the time of initial contact with the Freightliner. The presence of undercarriage gouging ahead of the right front wheel indicates some degree of sustained contact between the two vehicles, and the forward movement of the Freightliner at the time of impact contributed to the limo van's rolling over. During the limo van's rotation, its left front end struck the rear of a white 2011 Buick Enclave, which struck the outboard edge of the rear bumper of a white 2011 Ford F-150 XLT crew cab pickup truck; both of these vehicles were traveling in the center lane. The limo van rolled over onto its left (driver) side before coming to rest across the center lane. After striking the limo van, the Walmart Transportation truck continued into the left lane and struck a gray 2005 Nissan Altima in the left rear before colliding with a guardrail to the left of the travel lanes and coming to rest. Figure 1 shows the location of the crash. Figure 2 provides a diagram of the crash location and the at-rest positions of the Walmart Transportation truck, Buick Enclave, and limo van.

[6] The electronic control module and the active braking system were consistent in indicating cruising speeds for the Walmart Transportation truck of 64–65 mph. The active braking system has a more frequent sample rate and a record of impact time based on loss of radar control; therefore, the impact speed was taken from that system's data. The simulation analysis discussed in the Analysis portion of the report overlapped with the 47–53 mph speed. Due to uncertainties involved in estimating vehicle speeds when wheel slip is present, the actual collision speed may have differed slightly from the recorded speeds. The speed range data acquired from different electronic systems are shown in appendix B.

[7] The Freightliner tractor was in combination with a 2001 Utility semitrailer. The truck was operated by the motor carrier 4-Way Transport.

Figure 1. Map of Cranbury, New Jersey, crash location.

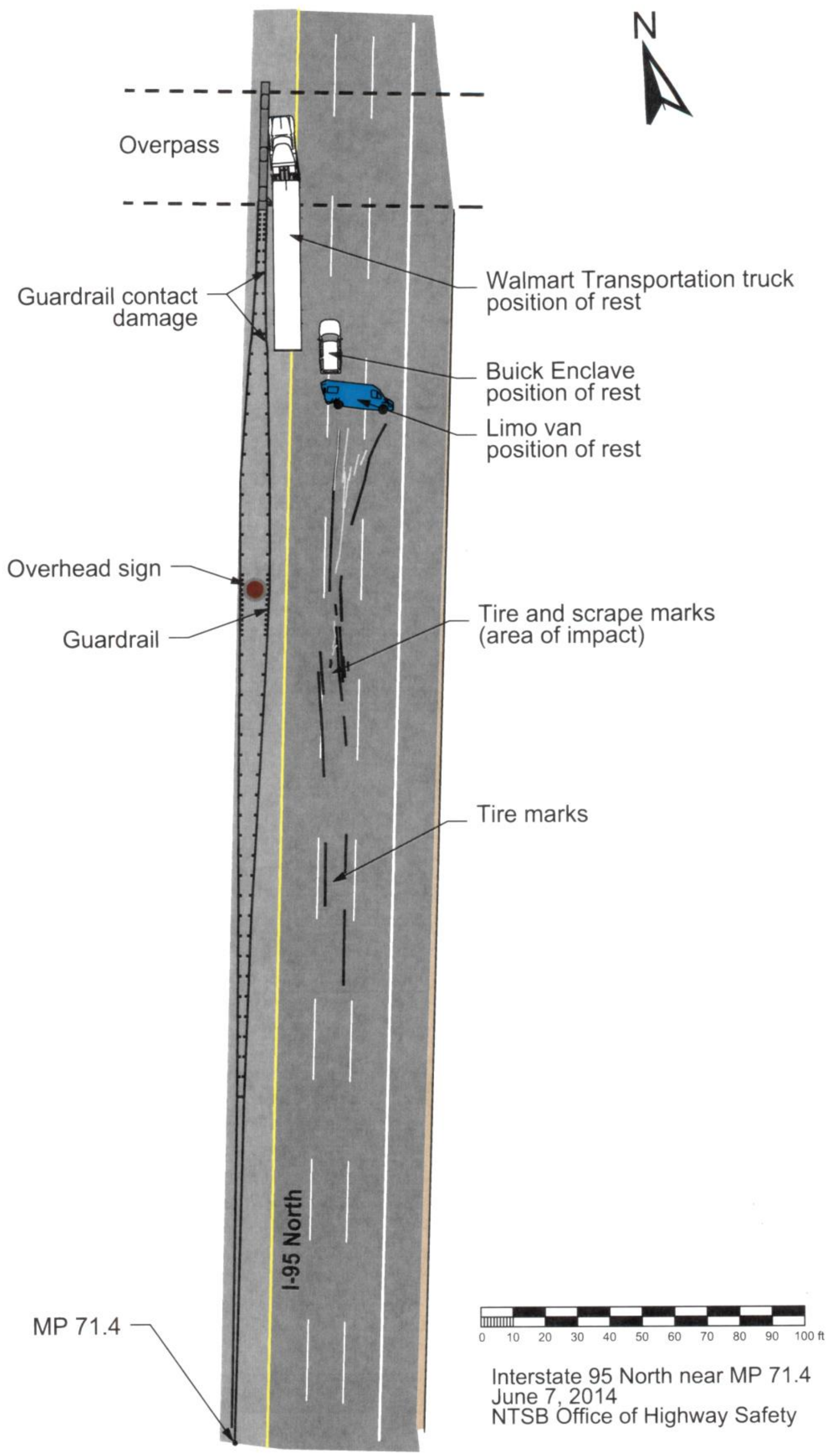


Figure 2. Crash area diagram showing final at-rest positions of the limo van, Buick Enclave, and Walmart Transportation truck. (The Freightliner truck, Ford F-150 pickup truck, and Nissan Altima all came to controlled stops farther north of the crash site, and they are not included in the diagram.)

1.1.2 On-Scene Evidence

The area where the Walmart Transportation truck struck the limo van was identified by tire friction marks and road surface gouging in the center travel lane approximately 149 feet south of an overpass (approximately 239 feet north of MP 71.4).[8] The parallel and intermittent tire friction marks, consistent with the Walmart Transportation truck's tires, started 95 feet south of the impact area and were oriented toward the northwest (moving from the center into the left lane). Side tire friction marks located between approximately 17 and 26 feet before the area of impact right (passenger) and left (driver) exhibited a distinct leftward heading. Through the area of impact, dual tire marks appeared to overlap single tire marks. Heavy scuff marks, road surface gouging, and scraping from the limo van were oriented northward within the center lane.

At final rest, the limo van was overturned onto its left (driver) side, facing eastward, perpendicular to the travel lane, approximately 92 feet north of the area of impact. The vehicle occupied the center lane with some overhang of its front into the right lane and a slight overhang of its rear into the left lane. The Walmart Transportation truck came to rest against the concrete barrier about 177 feet north of the area of impact along the left shoulder.

The Buick Enclave, which was traveling in front of the limo van in the center lane, came to final rest approximately 10 feet north of the limo van. The Ford F-150 pickup, which was traveling in the center lane in front of the Buick Enclave, and the Nissan Altima, which was traveling in the left lane, came to controlled stops north of the overpass on the left shoulder.

Police reports of the crash stated that the weather was clear and dry when the accident occurred and that the roadway was free from view obstructions.

1.2 Survival Factors

This section discusses vehicle occupant injuries, occupant protection system use and laws, and emergency medical service (EMS) operations.

1.2.1 Occupant Injury

Twenty-one people were associated with the six vehicles involved in the crash sequence. The two commercial trucks (Walmart Transportation and Freightliner) each had only one occupant, a driver; and neither driver was injured. The front cab occupants of the limo van—a driver and a relief driver—both sustained minor injuries, some of which occurred after the crash, while they were assisting with the rescue efforts. Five people, one of whom was pronounced dead at the scene, occupied the limo van's passenger compartment; the four surviving passengers sustained serious injuries. The Buick Enclave driver and passenger both sustained minor injuries. The Ford F-150 pickup truck and the Nissan Altima were each occupied by a driver and four passengers; none of these vehicle occupants were injured in the crash. Table 1 summarizes the occupant injury information for each vehicle.

[8] The overpass provides access to the New Jersey State Police barracks.

Table 1. Vehicle occupant injury summary.[a]

	Uninjured	Minor	Serious	Fatal
Walmart Transportation truck driver	1	0	0	0
Limo van driver	0	1	0	0
Limo van passengers	0	1	4	1
Buick Enclave driver	0	1	0	0
Buick Enclave passenger	0	1	0	0
Ford F-150 pickup truck driver	1	0	0	0
Ford F-150 pickup truck passengers	4	0	0	0
Nissan Altima driver	1	0	0	0
Nissan Altima passengers	3	1[b]	0	0
Freightliner truck driver	1	0	0	0
Total	11	5	4	1

[a] In this highway injury table, fatal injury is any injury that results in death within 30 days of the accident. A serious injury is one that requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; results in a fracture of any bone (except simple fractures of the fingers, toes, or nose); causes severe hemorrhages, 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. (These injury criteria are consistent with International Civil Aviation Organization injury codes, per Title 49 *Code of Federal Regulations* 830.2.)

[b] The minor injuries experienced by the Nissan Altima passenger were sustained while assisting with the on-scene evacuation of the victims from the limo van.

1.2.2 Use of Occupant Protection Systems

The Walmart Transportation truck was not equipped with driver airbags, and the driver's seat belt usage could not be determined by postaccident examination of the belt. Airbag module data from the Buick Enclave indicated that both the driver and the passenger were wearing their seat belts. The driver and passenger airbags on the Buick deployed; the side airbags did not. (The occupants of the F-150 Ford, Nissan Altima, and Freightliner truck were not significantly affected by the crash.) Data from the airbag module on the limo van indicated that the driver was not wearing his seat belt at the time of the crash; there was no load mark evidence, and the seat belt pretensioner did not deploy. The front airbags for both the driver and the front passenger deployed. The airbag control module indicated that the front passenger seat belt was in use at the time of the crash, and the seat belt pretensioner deployed.

The five captain's chairs (bucket-seat type) and the three-position bench seat in the passenger compartment of the limo van had integrated three-point seat belts and adjustable head restraints. All five passenger compartment occupants were seated in the captain's chairs. The seat belts for all five captain's chairs were in the stowed position; investigators found no evidence that the belts had been in use at the time of the crash.

The New Jersey state seat belt law (NJS 39:3-76.2f) applies to all passenger vehicles equipped with seat belts, including the limo van in this crash. On January 18, 2010, state legislation was signed requiring all vehicle occupants to use seat belts, regardless of their seating position in a vehicle. This is a primary enforcement law as it applies to front seat occupants and rear seat occupants under age 18. (The law makes the driver responsible for proper restraint use by all vehicle occupants under age 18, with specific consideration for children under the age of 8.) A primary enforcement law means that police officers may stop a vehicle and issue the driver a ticket for any unbelted occupant required to wear a seat belt, without another violation taking place. New Jersey has a secondary enforcement law for unbuckled back seat occupants 18 years and older.

The seat belt law in Delaware, the state in which Atlantic Transportation is located and incorporated, requires all vehicle occupants, including those in the back seat, to be properly restrained. It is a primary enforcement law for all ages and seating positions.

1.2.3 Emergency Communications

The Woodbridge Operational Dispatch Unit received the initial call reporting the crash at 1:00:52 a.m., and the first New Jersey State Police (NJSP) unit was dispatched at 1:02 a.m. The 911 reporting system required the state police to transfer the call to a separate fire/EMS system. A separate dispatch center, Mercer County Emergency Services Communications Center, was contacted at 1:04 a.m., and seven units (one command unit, one rescue squad, two fire engines, and three ambulances) from Hightstown and Cranbury were dispatched at 1:07 a.m.[9] The Hightstown Fire Department chief was the first emergency responder on scene at 1:14 a.m., and he assumed the role of incident commander. Two basic life support (BLS) ambulances arrived on scene at 1:15 a.m.[10] The rescue unit and a second fire engine arrived at 1:23 a.m. After a delay, the incident commander requested additional ambulances. Monroe Township Fire and First Aid dispatched two additional ambulances, one at 1:39 a.m. and one at 1:43 a.m. Both units had arrived on scene by 1:47 a.m.

By the time the rescue effort concluded, fire department units from Hightstown, Cranbury, Monroe, and East Windsor (rescue squad) and BLS first aid squads from Hightstown, Cranbury, and Monroe had participated in the response. In addition, two advanced life support (ALS) units from Robert Wood Johnson University Hospital (RWJUH) responded.[11] Air medical evacuation services in the region were provided by NorthStar, which is part of the NJSP aviation division. The NJSP requested air medical support at 1:21:05 a.m.; the call was taken by the medivac dispatch service at 1:23:39 a.m. NorthStar was dispatched at 1:29:22 a.m.

[9] The Woodbridge Operational Dispatch Unit forwarded the call to the Mercer County Emergency Services Communications Center, which was the primary dispatch service for EMS. Cranbury was added to the Mercer dispatch area in early June 2014, making this one of the first major accidents in which Mercer County dispatched Cranbury services. Dispatch times were obtained from emergency response center call records. Individual response times were obtained from unit response records.

[10] Three BLS ambulances were initially dispatched, but one was recalled within seconds because of the proximity of one of the two responding units. Similarly, a Mercer BLS ambulance was dispatched at 1:54 a.m. and then recalled at 2:09 a.m. because resources from Monroe Township had been dispatched and were available.

[11] RWJUH is in New Brunswick, New Jersey.

1.2.4 Emergency Medical Response

The diagram in figure 3 shows injury and other pertinent information for the occupants of the limo van. (The vehicle configuration and damage will be discussed in detail in section 1.3, "Vehicles.")

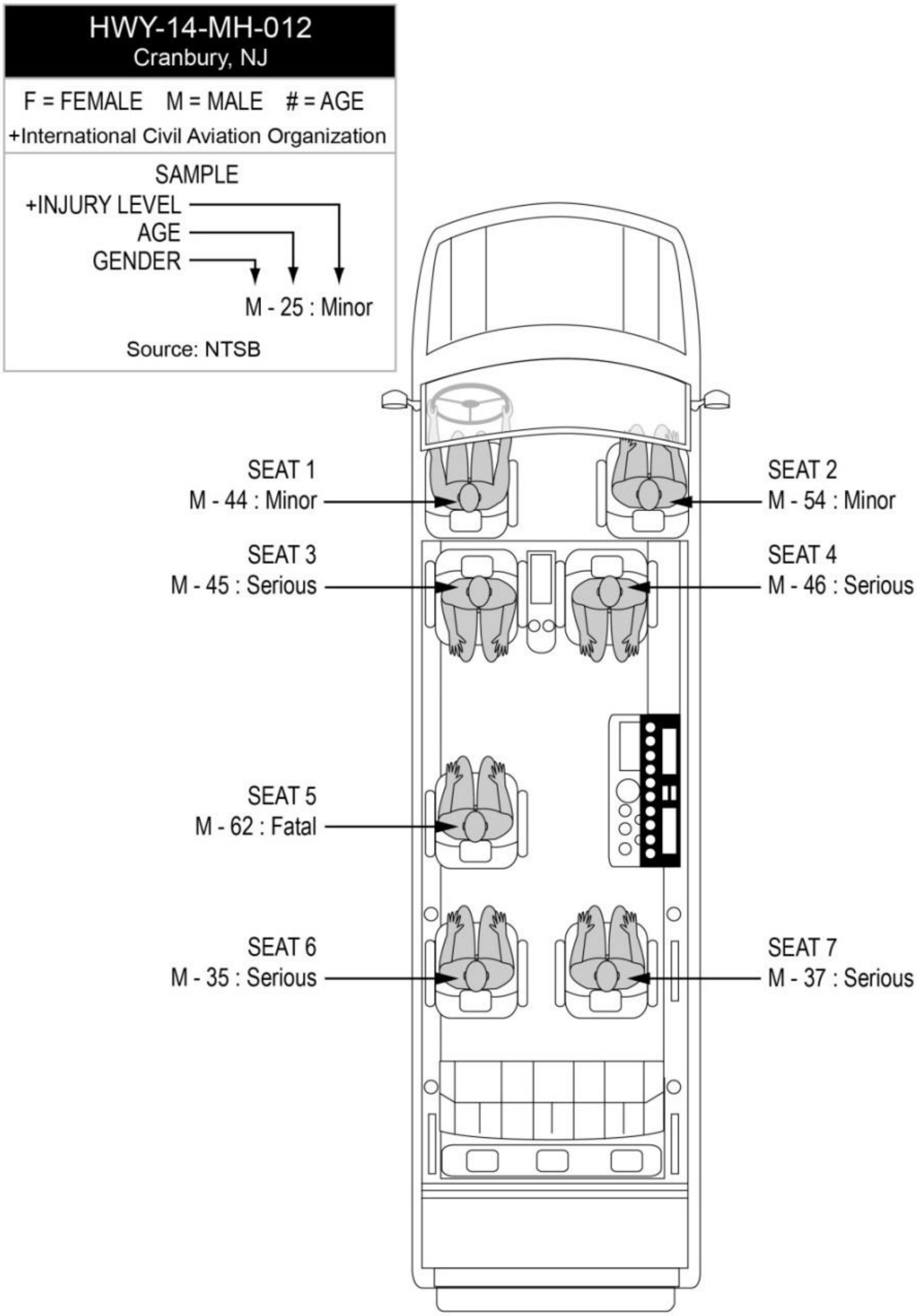


Figure 3. Interior of the limo van, showing the occupant locations and injury information.

The seating positions of the passengers in the separate passenger compartment in the back of the limo van were established based on physical evidence and interviews with the limo van driver and the passenger who occupied seat 7. The agencies that provided care or transport to the limo van occupants are detailed in table 2.

Table 2. On-scene treatment and transport agencies for each limo van occupant.

Occupant Seat #	Injury level	On-Scene Treatment	Transport
1	Minor	none	NJ state trooper to barracks (no medical)
2	Minor	none	NJ state trooper to barracks (no medical)
3	Serious	Cranbury BLS 4815	Ground: Cranbury BLS 4815 RWJUH ALS MR03
4	Serious	Hightstown BLS 4112	Ground: Hightstown BLS 4112 Air: NorthStar
5	Fatal	RWJUH ALS MR06	Ground: Middlesex County Medical Examiner
6	Serious	Monroe BLS 508 RWJUH ALS MR06	Ground: Monroe BLS 508 RWJUH ALS MR06
7	Serious	Cranbury BLS 4815 Monroe BLS 501	Loaded into Cranbury BLS 4815 Ground: Monroe BLS 501

Based on the review of records concerning the emergency medical response, National Transportation Safety Board (NTSB) investigators noted the following on-scene actions:

- Based on vehicle electronic data systems, the crash occurred at 12:55 a.m. According to EMS data, one person was pronounced dead on scene at 1:53 a.m., and the four seriously injured surviving occupants of the limo van arrived at RWJUH at 2:20 a.m., 2:25 a.m., 2:35 a.m., and 2:35 a.m. The hospital is approximately 16 miles from the crash site.
- The limo van had a sliding door on the passenger side that served as the sole means of entry to and exit from the vehicle’s passenger compartment. When the limo van came to rest, it had overturned onto the driver side, so that this sliding door was above the passenger compartment. Due to crash damage, the sliding door was jammed and inoperable. Efforts to reach the injured passengers through the vehicle’s rear door (which opened into the cargo area) were unsuccessful because there was a plywood partition between the cargo area and the passenger compartment. Similarly, there was a plywood partition between the driver and passenger compartments.[12] Responders reached the injured by passing through the cab windshield opening and then removing portions of the front plywood partition. This route was used to extricate injured passengers. The first two patients were removed from the passenger compartment of the limo van at 1:38 a.m. and 1:39 a.m.

[12] One of the passenger windows was broken out by a bystander and used for entering the van, but it was not used for passenger evacuation.

- The ambulance services initially available on scene were insufficient for the number of injured patients. Three ambulances were initially dispatched; two arrived on scene at 1:15 a.m. Additional services were requested, and two more ambulances arrived on scene at 1:47 a.m.[13]
- A volunteer emergency medical technician (EMT) on the Cranbury first aid squad, who had training in rescue and extrication, took on extrication activities by exchanging assigned roles with another firefighter, who assisted with patient care.
- The seat 3 occupant was assessed, immobilized on a backboard, and placed into a cervical collar. Paramedic notes indicated that no ambulance was available at 1:26 a.m. This injured person was given oxygen and put on a cardiac monitor at 1:35 a.m. He was loaded into an ambulance at 1:53 a.m. and left the scene at 1:56 a.m.; the injured individual arrived at the hospital and was transferred to the care of the trauma center team at 2:20 a.m.
- The seat 4 occupant had a head injury, multiple lacerations, and an open fracture of his leg. Records from the NorthStar helicopter flight nurse indicated that this injured person was delivered to the landing zone at 1:55 a.m. Two emergency responders removed the stretcher carrying the seat 4 occupant from the ambulance and walked it toward the helicopter. Medivac records noted that the injured person was lying on a backboard on the stretcher without a cervical collar or other head immobilization, was not secured to the backboard, and had no oxygen in place. Before loading him into the helicopter, the helicopter patient care team assessed the seat 4 occupant, secured him to the backboard, and applied a cervical collar. The recorded delay was 10 minutes.
- The seat 5 occupant was pronounced as deceased at the scene at 1:53 a.m. The cause of death was noted as multiple blunt force injuries.
- The seat 6 occupant was placed in a BLS ambulance at 1:56 a.m.; he was treated for bleeding, restrained, and transported to the medivac landing zone. At 2:03 a.m., the seat 6 occupant was reassessed at the landing zone while waiting for air transport. No helicopter was immediately available, so he was transported by ground ambulance and arrived at the hospital trauma unit at 2:35 a.m.
- The seat 7 occupant was able to self-extricate and was the first out of the vehicle. This occupant had internal injuries and a broken leg. He was initially loaded into an ambulance but then was removed on the directions of the incident commander, in order to transport the more seriously injured occupant from seat 3.[14] The seat 7 occupant was reported as being on a backboard and wearing a cervical collar at 1:45 a.m. He was secured to a stretcher, loaded into an ambulance, and given an initial assessment. At 1:50 a.m., he left the scene by ground ambulance and was transferred to the care of the hospital's trauma team at 2:35 a.m.

[13] These were BLS ambulances from Monroe Township.

[14] This was BLS ambulance 4815 from Cranbury Township.

1.2.5 EMS Organization and Training

In New Jersey, fire departments and first aid squads may be composed of paid professionals, volunteers, or a combination of the two. Each agency is under the jurisdiction of its local municipality. Agencies with paid personnel are required to have state certification and meet minimum standards of education and oversight. Jurisdictions with fully volunteer squads may choose to seek certification by meeting the same requirements but are not required to do so. Many first response agencies belong to an umbrella organization, the New Jersey State First Aid Council, which provides a level of standardization for first aid volunteers. The Cranbury First Aid Squad, the East Windsor Rescue Squad District 2, and the Hightstown First Aid Squad, which were among the EMS agencies involved in the response to this crash, were New Jersey State First Aid Council members.

There are three general levels of state and national certification for emergency medical technicians—basic, intermediate (or advanced), and paramedic—each with its own education requirement. A basic EMT (EMT-B) receives 120 hours of training; an intermediate EMT (EMT-I) receives additional hours of training and can supervise the application of IVs and perform advanced patient assessment; and a paramedic (EMT-P) receives 1,200–1,800 hours of training and can perform some invasive procedures and administer medications.[15]

In New Jersey, volunteers in first aid squads that have not been certified are not required to have any medical training or to maintain individual certification, although many choose to do so. Such squads may transport injured people without having any medically trained or certified personnel on board. There have been legislative attempts in recent years to increase the oversight required of EMS in the state of New Jersey, but these have not been successful.[16]

1.3 Vehicles

This section first provides information about the truck operated by Walmart Transportation LLC and the limo van, the vehicles involved in the initial collision. It includes the damage they experienced, their mechanical condition, and their equipment and configuration. The section concludes with the damage experienced by the four other vehicles involved in the crash. (See appendix C for a table summarizing the parameters for the vehicle-recorded information.)

[15] (a) According to the US Bureau of Labor Statistics, the specific training requirements for an EMT-I vary by state, although the national standard curriculum may involve between 30 and 350 training hours for formal programs. (b) The *Emergency Medical Services Education Agenda for the Future*, updated in 2000, was created by the National Association of EMS Physicians and the National Association of State EMS Directors. The agenda led to standard EMS instructional guidelines, curricula, and other guidelines. The National Standard Curricula establish levels for a “first responder,” an “EMT-basic,” an “EMT-intermediate,” and an “EMT-paramedic.”

[16] Assembly act no. 2095 was introduced in the 214th State of New Jersey Legislature on February 11, 2010, and Senate bill no. 1650 was introduced in the 215th State of New Jersey Legislature on February 16, 2012; the legislation was intended to revise the requirements for EMS delivery. The New Jersey Senate voted to approve the bill, but it was vetoed by the governor.

1.3.1 Walmart Transportation Truck

Damage. The Peterbilt truck-tractor sustained extensive front end damage, which displaced the hood and fenders. The semitrailer experienced relatively little damage. (See figure 4 for an image of the postcollision condition of the Walmart Transportation truck.)

Figure 4. Three-dimensional scan image showing damage to the Walmart Transportation truck from the driver side.

The wheel assembly of the left front steer axle was rotated to the left, outward, about 60 degrees and displaced rearward about 10–11 inches. The right front wheel was at an angle approximately 45 degrees inward from the right side of the truck-tractor. Postaccident rotation of the steering wheel did not move the front axle wheels, due to damage at the connection of the steering input shaft to the steering gear box. Examination of the damage to the steering gear box determined that the front wheels were 8.3 degrees to the left when the Walmart Transportation truck struck the limo van.

Mechanical systems. Examination and testing of the vehicle's mechanical systems revealed relatively minor problems.[17] All the tire tread depths were within the requirements for commercial vehicle tires.[18] All the tires were inflated to acceptable in-service pressures, and all the brakes were in adjustment. Although steering and front suspension components were damaged in the crash, no preexisting deficiencies were found.

Investigators reviewed the maintenance and inspection records for the Peterbilt truck-tractor and Great Dane semitrailer. A May 30, 2014, driver vehicle inspection report (DVIR) noted steering problems on rough roads. The DVIR resulted in the steering shaft being cleaned and greased. The reporting driver drove the same truck-tractor June 1–5, 2014, and noted no issues on the DVIR.

The Peterbilt truck-tractor passed an annual inspection on September 7, 2013. The Great Dane semitrailer passed an annual inspection on April 14, 2014.

[17] The only vehicle-related defects noted by the NJSP were minor inner wheel leaks on both sides of axle 4. NTSB investigators also observed some minor axle grease seepage. These conditions most likely played no role in the crash.

[18] The tread depth required is at least 4/32 inch for steer axle tires and 2/32 inch for all other tires.

Safety systems. The Peterbilt truck-tractor was equipped with a Bendix Commercial Vehicle Systems LLC (Bendix) Wingman Active Cruise with Braking (ACB) system, which was original equipment on this 2011 truck.[19] The system combines the capabilities of the vehicle's cruise control, electronic stability program (ESP), roll stability program, and antilock braking system. Once the driver switches the system on and sets cruise control, the Wingman ACB system is automatically engaged to help maintain a set following distance using a radar sensor installed on the front bumper (the sensor has a range of approximately 500 feet).[20] (See figure 5.) The system's active braking feature is available only when the cruise control is in use, but it can provide warning alerts whether or not cruise control is engaged. No radar data are recorded when cruise control is off.

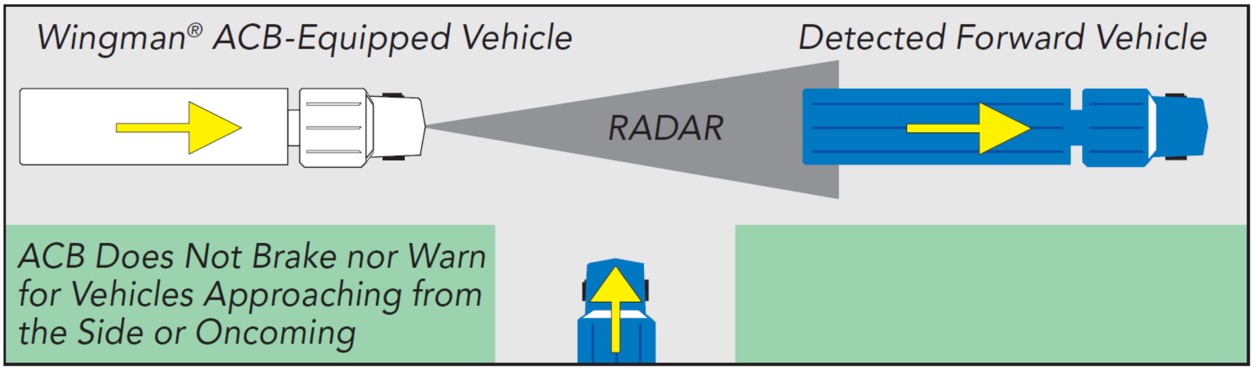


Figure 5. Bendix Wingman ACB system detecting a vehicle ahead. (Image source: Bendix system operator's manual [Bendix 2010].)

When the system is activated, interventions by either the Wingman ACB or the ESP can include automatic throttle reduction and application of up to one-third of the vehicle's potential braking power.[21] The system will not react to non-metallic or limited metallic objects (such as pedestrians and animals). Reflective objects, such as crash barriers, guardrails, work zone barricades, and tunnel entrances, may affect the radar sensor's ability to detect another vehicle. Entering a curve will reduce the system's alert times. Once the driver intervenes with more powerful braking or other evasive maneuvers, system alerts and interventions are suppressed.

The system has an in-cab display unit for communicating with the driver. Although the Wingman ACB system is mainly intended to be a following distance aid while cruise control is in use, it offers three different types of alerts to the driver, all of which are available regardless of whether cruise control is in use. These are (1) following distance alerts, (2) stationary object alerts, and (3) impact alerts. (See figure 6.)

---

[19] Bendix is currently marketing a collision mitigation technology identified as "Wingman Advanced."

[20] Following the crash, "ACB COMM ERROR" was displayed on the Wingman in-cab unit, most likely due to crash damage to the radar module that resulted in interrupted communication.

[21] The ESP is a continuously "on" system. The Wingman ACB uses the ESP to help maintain vehicle stability during automatic braking applications on slick surfaces. The Wingman ACB may be turned off by stepping on the brake or by turning off the cruise control.

Figure 6. In-cab displays of Bendix Wingman ACB system alerts showing a following distance alert, a stationary object alert, and an impact alert. (Image source: Bendix system operator's manual [Bendix 2010].)

Following distance alerts provide progressive audible and visual warnings whenever the distance between the equipped vehicle and a tracked vehicle ahead is less than the set distance and decreasing. If the following distance continues to decrease, the driver will hear more rapid audible alerts and see increasingly prominent yellow indicator lights along the left side of the Bendix display unit. Depending on system settings, the following distance alert may include a message to the driver saying "distance alert" or a similar warning phrase. In addition, when the distance interval reaches a critical point, a red light will illuminate on the instrument cluster. Once the audible alert is given, the driver must increase the distance between the vehicles for the audible alert to stop. With variations dependent on vehicle speeds and alignments, as well as system settings, the following distance alerts can have different frequencies and durations, ranging from fractions of a second to continuous.

A *stationary object alert* from the Wingman ACB system can deliver up to 3.0 seconds of warning to the driver when approaching sizable stationary objects (with reflective surfaces) that are determined to be ahead of the vehicle and in the same lane of travel. The stationary object alert may include additional yellow indicator lights along the left side of the display unit, as well as a visual message to the driver and a continuous audible tone.[22]

An *impact alert* is the most severe warning the Wingman ACB system can issue. This alert indicates that the driver must take immediate evasive action by applying more braking power and/or steering to avoid a potential collision. Activation is based on a system-calculated closure rate. The alert typically consists of a visual warning, red lights displayed across the top of the display unit, and a loud and continuous audible tone.

An NTSB recorders specialist removed the Bendix control and radar modules from the Walmart Transportation truck on June 11, 2014, and downloaded them at Bendix headquarters on June 24, 2014. Data from the download indicated that in the moments preceding the crash, the truck-tractor cruise control was not set and was not in use. Five seconds of recorded data indicated no active diagnostic trouble codes and that the Wingman system was functional and available prior to the loss-of-communication event that resulted from the collision. The audible alert status was recorded as "off" for all snapshots taken at 0.5-second intervals preceding the

[22] According to system documentation, the alerts are audibly different to assist the driver in paying full attention to the road, not the dashboard. Typically, a beeping tone means the driver is following the vehicle ahead too closely. A continuous tone means the driver should actively apply the brakes beyond the system's braking power to ensure a safe following distance.

loss of communication; the data did not indicate that any alert had been displayed to the driver prior to the accident. (See appendix B for a chart showing the data from the Walmart Transportation truck's ESP combined with a subset of its electronic control module [ECM] data.)

The vehicle was also equipped with an Omnitracs telematics system to record vehicle performance parameters synchronized with global positioning system (GPS) data. The Omnitracs system is triggered when the vehicle experiences a "hard-braking" or "stability control" event. The threshold for recording a hard-braking event is deceleration of more than 12.5 mph in 1 second. A stability control event is triggered by sudden driver steering input that could result in a rollover.[23] When either of these events occurs, the system generates a "critical event report" (CER) and sends a message to the local Walmart Transportation safety manager. According to Walmart Transportation, the safety manager reviews the CER, discusses the event with the driver, and may obtain the driver's written explanation concerning the cause of the event. In his 15 weeks of independent driving for Walmart Transportation, the accident driver had 10 CERs; 4 were hard-braking and 6 were stability control events. A hard-braking event associated with this crash took place on June 7, 2014, at 12:54:46 a.m.; it indicated a speed change of 14 mph per second.

1.3.2 Limo Van

Damage. The vehicle exterior had three distinct areas of damage—to the rear, the left (driver) side, and the right front. Severe impact damage crushed the rear of the van. The rear doors were crushed and found with the center latch closed; the hinges showed signs of being cut. The rear door windows were broken out. In addition to the forward displacement of the structure, the vehicle body exhibited a lateral shift toward the left.

The driver side of the limo van was crushed inward along its entire length, with heavy scraping, and all the windows were broken out. The right (passenger) side front fender was crushed inward, and the right front door was dented. The sliding door on the right side had damage and dents and was not operational. The windshield was missing, and the windshield frame was distorted.[24] (See figure 7.)

[23] The system analyzes input from sensors monitoring wheel speed, lateral acceleration, steering angle, brake pressure, weight distribution, and yaw rate.

[24] The limo van driver kicked out the front windshield after the vehicle came to a stop.

Figure 7. Three-dimensional scan image showing damage to the limo van from the driver side.

In the passenger compartment, the left front (seat 3) captain's chair in row 1 was deformed on the outboard side and in contact with the intruding left sidewall. (Refer to figure 3 to view the seating diagram.) The right-side seat in row 1 (seat 4) was intact, and the mounting attachments for both row 1 seats were intact. The single forward-facing seat in row 2 (seat 5) was displaced inward by the intruding side panel, and the seat and mounting points sustained significant damage. The two forward-facing row 3 seats (seats 6 and 7) were heavily damaged and displaced. The three-position bench seat at the rear of the compartment was displaced upward and into the row 3 seats, with its cushion and backrest flattened. (See figure 8 for a photo of the interior.) In the cab, the driver and front passenger seats showed little damage.

Configuration. The limo van was manufactured as a Mercedes-Benz Sprinter 2500 170 EXT HT 3.0L turbo diesel cargo van. The original configuration had four doors: a driver door, a front passenger door, a sliding door on the passenger side, and double doors at the back. It had traction control, electronic brake assistance, antilock braking, and vehicle stability control.

In March 2012, the Sprinter van was modified by Midwest Automotive Designs Corporation (Midwest Automotive) to create a luxury seating compartment for eight passengers plus two bucket seats in the front cab.[25] The added seating included five captain's chairs and a three-position bench seat (containing an electrically operated sofa-bed). Midwest Automotive stated and/or provided test data showing that the equipment it added complied with all applicable *Federal Motor Vehicle Safety Standards* (FMVSSs).[26]

[25] Midwest Automotive is considered a "final stage manufacturer" but also an "alterer of pre-certified motor-vehicles." The work done was considered alteration because the original Sprinter van was delivered as a complete, roadworthy vehicle. Consequently, the limo van did not require a new vehicle identification number.

[26] The requirements included interior occupant protection (FMVSS 201), head restraints (FMVSS 202), glazing (FMVSS 205), seating systems (FMVSS 207), occupant crash protection (FMVSS 208), seat belts (FMVSS 209), seat belt anchorages (FMVSS 210), and side impact protection (FMVSS 214). Midwest Automotive self-certified for FMVSSs compliance.

Figure 8. Postaccident view of the interior of the limo van, looking back into the passenger seating area.

The external modifications by Midwest Automotive included installing side panels with three fixed windows on each side; the most forward of the windows on the passenger side was mounted in the sliding passenger door. The side windows in the passenger area were fixed and were not intended to be or labeled as emergency exits.

With respect to the vehicle interior, the basic configuration of the cab area was retained, but the modifications to the passenger area were extensive. The passenger seating compartment was fitted with two permanent plywood partitions; flat-screen televisions were mounted on both the front and back partitions. The front partition separated the cab from the passenger seating compartment, and the back partition separated the passenger compartment from an electronics bay and cargo area at the rear of the vehicle. The cargo area could be accessed only through the doors at the back of the limo van.

As originally delivered, the limo van had a gross vehicle weight rating (GVWR) of 8,550 pounds and a payload of 2,855 pounds.[27] The modifications by Midwest Automotive

[27] The GVWR is the value specified by the manufacturer as the loaded weight of the vehicle, including the vehicle's chassis, body, engine, engine fluids, fuel, accessories, driver, passengers, and cargo.

added vehicle weight and reduced the payload. Midwest Automotive could not provide a measured final vehicle weight at time of modification but estimated that the weight was about 6,910 pounds, based on the measured weight of more recent conversions of vehicles with similar configurations and capacities. The vehicle's postcrash measured weight was 6,950 pounds.

Classification. The limo van was operationally defined as a commercial motor vehicle according to Title 49 *Code of Federal Regulations* (*CFR*) 390.5, which states that the vehicle "is designed or used to transport more than 8 passengers (including the driver) for compensation and used in interstate commerce." The limo van had, as required, a US Department of Transportation (DOT) registration as a commercial vehicle under the Federal Motor Carrier Safety Administration (FMCSA). It was a DOT class 2 vehicle, in the category of vehicles with GVWRs of 6,001–10,000 pounds. The FMCSA also classifies vehicle types for safety resource guidance.[28] According to the National Highway Traffic Safety Administration (NHTSA), the limo van did not meet the design classification for "mini-bus," which is a vehicle designed to transport 16 or more people, but it did for "limousine" and "passenger van," which are vehicles designed to transport 9 to 15 people.[29]

Systems data. The limo van was equipped with an Audiovox Car Connection GPS-based fleet management system for route planning. The system reported the vehicle location and related parameters at intervals of about 5 minutes while the vehicle was running and once every hour while the ignition was off.

Garmin GPS data indicated that in the minute before impact, the limo van was in variable but slow traffic; about 30 seconds before impact, the limo van's speed was approximately 11 mph. At impact, it was traveling 3–4 mph. The last position reported by the GPS system had a heading of 30 degrees (the roadway has a heading of about 20 degrees). Reconstruction evidence indicated that, at impact, the limo van was angled about 10 degrees toward the right lane relative to the travel lane. (According to postcrash statements by the limo van driver, he was attempting a lane change to the right when the crash occurred.)

1.3.3 Other Vehicles Involved in the Crash

Buick Enclave. The Buick Enclave had damage to its right front fender and headlamp assembly. Damage at the rear was more substantial toward the passenger side and extended vertically from the bumper to the roof line. The rear hatch door was crushed inward, and the rear window was broken out.

Ford F-150 pickup truck. The Ford F-150 pickup truck sustained damage to the left rear corner, rear bumper, and tailgate.

Nissan Altima. The Nissan Altima had damage to its tail lamp assembly and fiberglass bumper cover.

---

[28] For additional information, see http://www.fmcsa.dot.gov/carrier-safety/carrier-safety-resources, accessed January 28, 2014.

[29] NHTSA considers this vehicle type as a "multipurpose vehicle."

Freightliner truck. The 2006 Freightliner 120 truck-tractor towing a 2001 Utility refrigerated trailer was damaged at the rear of the tractor cab on the left side. Damage extended rearward onto the trailer.

1.4 Drivers

This section presents information on the licensing, employment history, training, fitness, toxicology, driving history, and recent activity of the driver of the Walmart Transportation truck. It also provides relevant information about the limo van driver.

1.4.1 Walmart Transportation Truck Driver

The Walmart Transportation truck driver was a 35-year-old male. He held a Georgia class A commercial driver's license (CDL) with T and X endorsements and no restrictions, issued in April 2014 and expiring in December 2017.[30] When Walmart Transportation hired him on February 10, 2014, the driver held a Florida class A CDL with T and X endorsements and no restrictions.[31] As required by CDL regulation, the driver surrendered his Florida license when he obtained his Georgia license.[32] According to the driver's Walmart Transportation job application, he had a residence in Cutler Bay, Florida, from August 11, 2009, to September 20, 2013. His driver qualification file showed a Jonesboro, Georgia, residence address when he interviewed at the Walmart Transportation distribution center in Smyrna, Delaware, on December 6, 2013.

According to the driver's logbooks, it was his normal practice to use his vehicle's sleeper berth to sleep between adjacent shifts. According to another Walmart Transportation driver, who had served as the accident driver's driver-trainer, the accident driver also stayed at a Best Western hotel near the Smyrna distribution center.[33] Hotel records indicated that the accident driver had been registered at the hotel for all of his available off-duty days since the beginning of his employment with Walmart Transportation, with the exception of June 3–5, 2014.

Walmart Transportation management knew that the accident driver had a residence in Georgia and was aware of his living arrangements in Smyrna, Delaware. Walmart Transportation stated that such arrangements by its drivers were not unusual. Walmart Transportation hired drivers from several different states to work at the Smyrna distribution center but did not have any policy that addressed commuting distance from a driver's residence to the reporting terminal.[34]

[30] A T endorsement allows the driver to operate double/triple-trailers, and an X endorsement allows the driver to operate tank vehicles and to conduct placarded hazardous material hauling.

[31] The Florida license was issued in March 2010 and would have expired in December 2016.

[32] Per 49 *CFR* 383.1(b)(1).

[33] The Best Western gave a discount to Walmart Transportation drivers but that arrangement was not negotiated by Walmart Transportation.

[34] Investigators checked the home addresses for 119 Walmart Transportation drivers working from Smyrna; they found 14 drivers had home addresses not in Delaware or the surrounding states.

In his application for employment with Walmart Transportation, the accident driver listed two previous positions as a commercial driver, totaling approximately 3 years of driving experience.[35] By the date of the accident, he had about 4 months of experience as a driver for Walmart Transportation.

As part of his employment with Walmart Transportation, the driver completed 2 weeks of training in February 2014 on the following subjects: the collision avoidance system, the distracted driving policy, drug and alcohol awareness, the electronic logging device, and hours of service. He completed the required on-the-road training with a driver-trainer. When the June 7, 2014, crash occurred, the driver had recently completed a training review day after 90 days of employment.

According to his most recent DOT CDL medical examination, conducted in December 2013 as part of the Walmart Transportation hiring process, the driver's height was 69 inches and his weight was 209 pounds, corresponding to a body mass index (BMI) of 30.9. In the exam, the driver indicated "no" to all items in the health conditions list and did not indicate he was taking any medications, including over-the-counter medications.[36] The driver denied having sleep disorders or problems breathing. In the comments section, the medical examiner indicated that the driver took no medications, did not smoke, and had no past medical/surgical history. In his notes, the physician indicated a normal exam and that the driver was slightly overweight. The driver was qualified for 2 years from the December 2013 exam date.

According to Walmart Transportation, the accident driver had two drug tests on file. The first test was classified as a preemployment drug test conducted on December 6, 2013; it had a verification date of December 13, 2013, and showed a final disposition of "negative." The second test was classified as a postaccident drug test conducted on June 7, 2014; it had a verification date of June 10, 2014, and showed a final disposition of "negative."[37] A breathalyzer test conducted 7 hours 46 minutes after the crash gave a 0.0 result.

The driver's logbook, his cell phone records, the police crash report, and surveillance video were used to trace his activities. In the days before the accident, the driver had been at his home in Jonesboro, Georgia, rather than in the hotel where he typically stayed in Smyrna, Delaware. The driver told police he had a nap from 4:00 p.m. to 8:00 p.m. on Thursday evening, June 5. A review of the driver's cell phone records indicated that his window of sleep opportunity was slightly longer than 4 hours. He departed his residence in Jonesboro sometime between 8:30 p.m. and 10:30 p.m. and drove to the Walmart Transportation facility in Smyrna, arriving approximately 11:00 a.m. on Friday, June 6. The traveling distance of about 800 miles between Jonesboro and Smyrna indicates that the driver had little time available to stop, and no

[35] Walmart Transportation requires its driver applicants to have a minimum of 3 years of experience in over-the-road driving. Walmart Transportation hired the accident driver the second time he applied for a driving position; when he applied for the first time, in July 2012, he did not have 3 years of driving experience.

[36] A DOT physical exam for this driver performed in May 2013 by a physician in Orlando, Florida, indicated "no" to all items in the health conditions list and did not indicate he was taking any medications, including over-the-counter medications. That exam recorded his height as 71 inches and his weight as 216 pounds, which corresponds to a BMI of 30.1.

[37] The driver's sample was tested for marijuana, cocaine, amphetamines, opiates, 6-Monoacetylmorphine, PCP, and Ecstasy.

time to sleep. The driver then remained awake, working and driving 451 miles, until the crash occurred about 12:55 a.m. on Saturday, June 7. Including the drive from Georgia and the work trips completed once he reported to duty, the driver had driven about 1,250 miles and had been awake about 28.5 hours since his 4-hour nap.[38] After the crash, the driver made the following statement to an NJSP officer on scene: "I fell asleep" (NJSP 2014, p. 5).

On June 6 at 10:21 p.m., the Walmart Transportation regional operations center in Ohio sent a dispatch to the accident driver. That dispatch directed the driver to travel from Levittown, Pennsylvania, to Perth Amboy, New Jersey, a distance of about 50 miles (which would take about 55 minutes to drive) to pick up a backhaul load.[39] According to Walmart Transportation safety officials, the backhaul load at Perth Amboy did not have to be picked up until 7:30 a.m. on June 9, 2014. The accident driver had approximately 57 hours to fulfill this dispatch, allowing sufficient time for him to complete a 10-hour off-duty break before beginning the backhaul job. When the driver accepted the dispatch and began to drive to Perth Amboy, he had about 1 hour left before violating the 14-hour rule.

The truck was equipped with a Qualcomm electronic log for recording and monitoring driving and on-duty time. At the time of the crash, the driver had been on duty 13 hours 32 minutes of a 14-hour duty day. The accident driver would most likely have received audible alerts from the vehicle's onboard Qualcomm system at 12:22 a.m. and 12:52 a.m. (about 33 minutes and 3 minutes prior to the crash, respectively) as he approached the limit of the 14-hour hours-of-service (HOS) rule.[40]

During his employment with Walmart Transportation, the driver had three "performance tracking log" events reflecting safety manager involvement with the driver. Two events were for log violations—one for an 11-hour violation and one for a 14-hour violation—and a third event was associated with a preventable incident that damaged a truck.[41] As a result of the preventable incident, the driver lost his safety bonus for the first quarter of 2014.[42]

1.4.2 Limo Van Driver

The limo van driver was a 44-year-old male who was president and part owner of Atlantic Transportation. He was accompanied by a relief driver traveling as a passenger in the cab of the limo van. The driver held a Delaware class A CDL issued on May 19, 2014, which had an expiration date in May 2019. His CDL had Z (taxi cab and limousine), N (tank), and

[38] A driver who has been without sleep for more than 24 continuous hours is considered to be driving recklessly, in the same class as an intoxicated driver. (Per New Jersey Statutes section 2C:11-5).

[39] The term "backhaul" refers to the operational practice of not sending trucks back to the distribution center empty. After the truck arrives and unloads at the original destination point, Walmart Transportation provides full or partial load transport, typically for Walmart Transportation suppliers, to move goods, primarily back to Walmart Transportation distribution centers.

[40] Although the Qualcomm system most likely announced potential HOS violations to the driver, the system does not record notifications. The system only records when the driver violates the regulations.

[41] (a) The 11-hour rule states that a driver is permitted to drive for 11 hours after a 10-hour break. The 14-hour rule states that a driver cannot drive after 14 hours from the start of his or her day. (b) Walmart Transportation's performance tracking log form categorizes accidents and incidents based on the dollar value of damages.

[42] Driver performance metrics are discussed in section 1.5.1, subheading "Corporate safety policy."

P (passenger) endorsements and no restrictions.[43] During a postcrash interview, the limo van driver said he had previously held a CDL in Iowa and drove transfer trucks for approximately 10 years before he started limo van work in August 2004.

The limo van driver had an FMCSA medical certificate at the time of the accident with an issue date in December 2013 and an expiration date in July 2014.[44] The carrier conducted a postaccident drug test on June 7, 2014, the result of which was negative. The driver was cited in the postcrash roadside inspection report for failing to maintain a logbook.[45]

During a postcrash interview with NTSB investigators, the limo van driver stated that he had seen the Walmart truck earlier on the interstate. At that time, both vehicles were in the right lane, and the limo van driver stated that he saw the Walmart truck "wiggle." He said that the Walmart truck wiggled a second time and went "completely to the left." He said he passed the Walmart truck on the right after it went left.

1.5 Motor Carrier Operations

This section focuses primarily on the operations of motor carrier Walmart Transportation and the oversight of the accident truck and driver. Also included in this section is an overview of the two other commercial operators involved in the crash: Atlantic Transportation and 4-Way Transport.

1.5.1 Walmart Transportation LLC

Walmart Transportation LLC is registered as both a private property and for-hire carrier under motor carrier number 311233.[46] The carrier was issued a DOT number in 1974 and provided active operating authority in 1996.[47] The carrier transports general freight, beverages, and refrigerated foods for Walmart and Sam's Club stores nationally. The carrier is registered to transport hazardous materials. Per the carrier's FMCSA Motor Carrier Identification Report, Walmart Transportation has over 7,200 drivers and 6,200 truck-tractors companywide. The carrier's corporate office is in Bentonville, Arkansas.

Walmart Transportation operates a network of 42 regional distribution centers throughout the United States. The driver and vehicle involved in this crash originated from the Walmart

[43] Delaware motor vehicle regulations do not require a driver to have a CDL if the vehicle weighs less than 26,000 pounds, does not transport 16 or more people (including the driver), and does not transport hazardous materials.

[44] The relatively short duration of the medical certification was associated with a health concern for high blood pressure.

[45] The carrier produced the driver's 100-air-mile radius time record that recorded all work as on-duty, without distinguishing between on-duty/not driving and off-duty time. For June 7, 2014, the 100-air-mile radius time record showed a total of 12.5 hours of duty time for the accident trip. Because the driving trip was beyond the 100-air-mile radius, driving time should have been recorded using a regular logbook.

[46] Title 49 *CFR* 390.5 defines a private motor carrier as a person who provides transportation of property or passengers, by commercial motor vehicle, and is not for hire. The regulations define a for-hire motor carrier as a person engaged in the transportation of goods or passengers for compensation.

[47] The carrier's registration with the FMCSA predated the New Entrant Program.

Transportation distribution center in Smyrna, Delaware. At the time of the crash, that facility operated 92 truck-tractors (74 Freightliners and 18 Peterbilts) and about 450 semitrailers. The Smyrna distribution center had 117 commercial motor vehicle drivers, who were dispatched from a regional operations center in Ohio. The Smyrna distribution center has a delivery area covering Delaware, New Jersey, northern Virginia, the Eastern Shore area of Maryland and Virginia, and the city of Philadelphia, Pennsylvania.

Corporate safety policy. Walmart Transportation provides all its drivers with a *Walmart Driver Employee Handbook* that describes company policies, procedures, and philosophies. The handbook addresses a wide range of topics covering issues in the areas of vehicle maintenance and operation, driver behavior, driver fitness to work, authorized passengers, distracted driving, random drug and alcohol testing, log verification, driver expenses, and company benefits.

Walmart Transportation has programs designed to foster its safety culture. These programs include safety awareness, driver safety incentive pay, individual safe mileage awards, lights-on for safety, management road observations, million-mile safety awards and cookouts, driving safety awards, driving competitions, safety newsletters, distracted driver training, and recurrent annual training. The carrier also has a variety of safety slogans and safety posters located in driver lounges, break rooms, fuel stations, and facility entrances.

Fatigue management and obstructive sleep apnea testing. Walmart Transportation's annual defensive driving training discusses the requirement that drivers not operate a vehicle while ill or fatigued (49 *CFR* 392.3), and fatigue is a topic in the carrier's safety awareness program.[48] The *Walmart Driver Employee Handbook* instructs drivers to be physically and mentally ready for the road. Walmart Transportation officials indicated that they have a fitness to work policy that applies to all their employees, not just drivers. Walmart Transportation had no written policy specific to driving while fatigued.

Walmart Transportation initiated an obstructive sleep apnea (OSA) screening program for its drivers in October 2013.[49] At the time of the accident, Walmart Transportation estimated that 700 drivers had been evaluated for OSA. According to Walmart Transportation, it refers drivers with a preexisting OSA condition or those identified by the company doctor during an initial or a renewal DOT physical as potential OSA candidates to a medical clinic, which conducts the evaluation.[50] Walmart Transportation pays for the evaluation and associated supplies for its current drivers; if a prospective driver tests positive for OSA during the hiring process, he or she must pay all testing and monitoring costs to remain in the process. Walmart Transportation requires all drivers in the program to comply with the OSA policy, or they will not be

[48] Investigators reviewed the instruction given to Walmart Transportation drivers during company in-service training.

[49] According to the US National Library of Medicine, OSA is a sleep disorder that is marked by pauses in breathing of 10 seconds or more during sleep that causes unrestful sleep. OSA symptoms include loud or abnormal snoring, daytime sleepiness, irritability, and depression. (For more information, see http://www.ncbi.nlm.nih.gov/pubmedhealth/PMHT0024431, accessed June 30, 2015.)

[50] The FMCSA Medical Review Board has recommended that commercial drivers be screened for OSA if their BMI is above 30. In addition to being selected for OSA testing if they have a BMI of 30 or more, Walmart Transportation drivers may be identified for OSA testing based on having a neck size of 17 inches (15.5 inches for women drivers) or larger, having hypertension, or showing evidence of fatigue or other symptoms.

dispatched. According to carrier records, the Cranbury accident driver was screened for OSA but was not selected for further evaluation.

Driver hiring process. Walmart Transportation has a structured process for hiring drivers. Walmart Transportation headquarters safety specialists screen electronic applications to see if the applicant meets the minimum qualifications, listed below:

- Interstate class A CDL with hazmat endorsement (or willingness to obtain hazmat endorsement—including cleared background check—within 60 days of a conditional offer);
- 3 years of current over-the-road (OTR) tractor-trailer experience;
- Minimum of 50,000 miles OTR tractor-trailer experience in each of the last 3 years;
- Minimum of 250,000 miles OTR tractor-trailer experience;
- No preventable accidents while operating a commercial motor vehicle in the last 3 years;
- No preventable accidents while operating a commercial motor vehicle resulting in a fatality (lifetime);
- No preventable DOT-recordable accidents while operating a commercial motor vehicle in the last 10 years;[51]
- No more than one nonpreventable accident while operating a commercial motor vehicle in the last 3 years;
- No more than two moving violations while operating a personal or commercial motor vehicle in the last 3 years;
- No serious traffic violations while operating a commercial motor vehicle in the last 3 years; and
- No convictions for a driving while intoxicated (or similar impairment) offense or reckless driving with alcohol/drug involvement in the last 10 years.

According to Walmart Transportation, if the applicant meets these requirements, the recruiter will conduct a scheduled phone interview. If the applicant driver passes the phone interview, then the recruiter schedules a road test at the local distribution center. The road test evaluation includes an informal interview, and the applicant must successfully complete a pretrip inspection. Then, a preemployment drug test and DOT physical are performed at a Walmart Transportation-approved medical facility. Upon successful completion of the road test, preemployment drug test, and DOT physical, the driver will receive a job offer from the distribution center. According to Walmart Transportation, its driver turnover rate is 5 percent per

[51] Title 49 *CFR* 390.15(b) defines a DOT-reportable commercial vehicle accident as one involving a fatality or a bodily injury involving medical treatment away from the scene of the accident, or an accident in which one or more of the vehicles incurs disabling damage, requiring it to be towed from the scene.

year, which compares to an industry average of about 13–14 percent (based on a National Private Truck Council 2015 survey of members).

Driver training. When a new driver is hired, a 2-week training program begins. The first training day consists of learning about company benefits and pay. The second and third days consist of a defensive driving program conducted by the safety department. The first week also includes training on the HOS regulations and instruction concerning electronic logging devices.[52] The training materials include five slides on the topic of driver fatigue. The training is not pass/fail.

During the second week, the driver has OTR training with a designated driver-trainer. During this period, the new hire shares responsibilities with the driver-trainer. If the new driver successfully completes the week of OTR training, then he or she is released for dispatch. When the new driver has been employed for 90 days, he or she attends a mandatory training day to review company policies.

Walmart Transportation requires its drivers to take refresher training annually. Each local distribution center conducts training sessions several times a year. During January and February, Walmart Transportation conducts defensive driver training, which consists of 8–10 hours of classroom training. The carrier also conducts quarterly safety meetings. All company training and safety meetings are documented.

Driver compensation. Walmart Transportation drivers are paid biweekly and are compensated for both mileage and activity. Drivers receive safety incentive pay quarterly if they do not have any preventable accidents or incidents during the quarter.[53] Drivers are paid according to a formula that tracks five factors: mileage rate, activity pay, unscheduled time, scheduled time, and rest breaks. The mileage rate is multiplied by the miles driven per day. Activity pay covers such actions as arriving at a terminal, hooking up a load, making a scheduled stop, and unloading. Unscheduled time refers to events involving such variable factors as weather, traffic, and mechanical delays. Scheduled time refers to events such as company training sessions, meetings, and random drug tests.

For the accident driver, his miles driven accounted for less than 60 percent of his pay for the biweekly period containing the crash. The driver would have received more pay for taking an additional layover, rather than taking the last dispatch, and he could easily have done so, given that the dispatch assignment had an extended delivery window.

Vehicle maintenance. Walmart Transportation has a defined preventative maintenance program, which includes routine maintenance, for company vehicles (including leased vehicles).

[52] Electronic logging devices record the driver's hours of service as required by49 *CFR* Part 395. These systems are also referred to as electronic onboard recorders.

[53] To receive the incentive pay referred to as a "safety day," a driver must drive a minimum of 10,000 miles in the quarter, have no preventable vehicular accidents resulting in damage of $1,000.00 or greater, have no preventable vehicular incidents resulting in damage of $100.00–$999.99, and have no violations of the Walmart Transportation distracted driving policy.

Walmart Transportation compliance reviews. The carrier has had three compliance reviews (CR) with the FMCSA since obtaining its DOT number; all were rated “Satisfactory.”[54] As a result of this accident, the FMCSA conducted a postcrash examination of the accident driver’s logbook and qualification file and found no anomalies.

According to its Motor Carrier Management Information System (MCMIS) profile, Walmart Transportation had no Behavior Analysis and Safety Improvement Categories (BASICs) in alert status at the time of the crash. A postcrash review of the carrier profile showed no alerts in any BASICs in the past 24 months.[55] The BASICs for Walmart Transportation reflected the following statistics: Unsafe Driving (2.9 percent), HOS Compliance (0.5 percent), Driver Fitness (9 percent), Controlled Substances and Alcohol (0 percent), Vehicle Maintenance (4.8 percent), Hazardous Materials (18.6 percent), and Crash Indicator (5.7 percent).[56]

According to its MCMIS profile, Walmart Transportation had 2,784 driver roadside inspections, 1,615 vehicle inspections, and 909 hazardous materials inspections from June 9, 2013, to June 9, 2014. Its driver out-of-service (OOS) rate was 0.29 percent, its vehicle OOS rate was 3.41 percent, and its hazardous materials OOS rate was 0.69 percent. The comparable national OOS service rates for these factors were driver, 5.51 percent; vehicle, 20.72 percent; and hazardous materials, 4.5 percent. The Peterbilt tractor had one roadside inspection during the previous 365 days. That inspection took place on May 24, 2013. No violations were documented. The accident semitrailer had no documented roadside inspections.

The MCMIS profile also showed that, in 2013, Walmart Transportation had the following crash events: 5 fatal crashes, 73 injury crashes, and 360 tow-away crashes. The Walmart Transportation private fleet covered more than 667.4 million miles in 2013 (on this basis, Walmart Transportation averaged 1 fatal crash per 133.5 million miles, 1 injury crash per 9.1 million miles, and 1 tow-away crash per 1.9 million miles).

1.5.2 Atlantic Transportation Services LLC

Atlantic Transportation Services LLC is a for-hire passenger motor carrier that became a New Entrant carrier on September 15, 2005.[57] The carrier started operations under the name Bayside Limo in Dover, Delaware. After a corporate reorganization, the carrier changed its name to Atlantic Transportation Services LLC and moved its operations to Rehoboth Beach, Delaware.

[54] The CR dates were September 2, 1987; March 17, 1994; and July 8, 1994. A “non-rated” hazmat shipper review was conducted on September 9, 2004.

[55] The FMCSA uses data from roadside inspections, including all safety-based violations, state-reported crashes, and the Federal Motor Carrier Census, to quantify a carrier’s performance in seven BASICs. The seven BASICs are (1) Unsafe Driving, (2) HOS Compliance, (3) Driver Fitness, (4) Controlled Substances and Alcohol, (5) Vehicle Maintenance, (6) Hazardous Materials Compliance (if applicable), and (7) Crash Indicator. A carrier’s rating for each BASIC depends on its number of adverse safety events, the severity of its violations or crashes, and when the adverse safety events occurred (more recent events are weighted more heavily). Carriers are compared to a peer group of other carriers with similar numbers of inspections using a percentile rating of 0 to 100, with the 100 percentile indicating the worst performance.

[56] The FMCSA intervention threshold for Unsafe Driving, HOS Compliance, and Crash Indicator is 65 percent; for Driver Fitness, Controlled Substances/Alcohol, and Vehicle Maintenance, the threshold is 80 percent.

[57] The carrier’s DOT number is 1415859, and it has passenger operating authority under motor carrier number 537941.

The state of Delaware granted Atlantic Transportation a certificate of public convenience and necessity for limousine rights on June 19, 2013.

At the time of the accident, the company owned 14 vehicles and 2 trailers with GVWRs under 10,000 pounds. It employed 27 drivers (19 with CDLs). Its service area included Delaware, Pennsylvania, New Jersey, Maryland, and occasionally New York.

The carrier had a New Entrant safety audit on February 2, 2006, and completed the program on March 15, 2007. The carrier had a CR on August 8, 2008, and received a "Satisfactory" safety rating. The carrier had no other interventions from the FMCSA. At the time of the accident, the carrier had no alerts in its BASICs and values of zero in all BASICs during the 24 months prior to the accident. According to its MCMIS profile, the carrier had no roadside inspections in the past 24 months.

The driver did not provide a pretrip safety briefing or instructions to the limo van passengers before departing on the trip from Dover Downs, Delaware, on June 6, 2014; no such briefing was required by regulation. The carrier did not have a policy calling for the driver to notify passengers about mandatory seat belt use.

1.5.3 4-Way Transport LLC

The Freightliner tractor-trailer involved in the crash was operated by 4-Way Transport LLC. The carrier, headquartered in Philadelphia, Pennsylvania, was in the FMCSA New Entrant Program.[58] The carrier operated two tractors and two trailers and employed four drivers to haul fresh produce. The carrier serviced a five-state delivery area.[59] The vehicle involved in the accident was transporting fruits and vegetables (classified as exempted commodities) and was not subject to the requirements of operating authority regulations under 49 *CFR* 392.2.[60]

The driver of the Freightliner was conducting his first trip with the company when the crash occurred.[61] At the time of the accident, the driver held a Pennsylvania class A CDL that was issued in December 2013 and had an expiration date in December 2017. The driver also held a current medical certificate with an issue date in November 2013 and an expiration date in November 2015. The postaccident driver/vehicle inspection report cited the driver for a false logbook entry on June 4, 2014.

[58] The carrier applied for New Entrant status on May 3, 2013, and was issued DOT number 2402309.

[59] The five states were New Jersey, New York, Ohio, Massachusetts, and Pennsylvania.

[60] Per 49 *CFR* 392.2, every commercial motor vehicle must be operated in accordance with the laws, ordinances, and regulations of the jurisdiction in which it is being operated. Exempt commodities usually include unprocessed or unmanufactured goods, fruits and vegetables, and other items of low value. A listing of exempt and non-exempt commodities is in FMCSA Administrative Ruling 119.

[61] The trip began June 5, 2014.

1.6 Highway

1.6.1 Highway Description

I-95 traverses the eastern United States from Florida to Maine. In the crash area, I-95 is the New Jersey Turnpike, operated by the New Jersey Turnpike Authority (NJTA). The New Jersey Turnpike is the nation's busiest limited-access nonstop toll road. At the height of the construction season, as many as 500 lane closures a week may occur on the turnpike system in New Jersey. Originally 118 miles in length, the New Jersey Turnpike is today about 149 miles long, as a result of extensions added over the years.

Travel lane geometry. At the time of the crash, I-95 was being widened along a section of road between Interchanges 6 and 9, covering MPs 50–83.[62] The accident area was in a 12-mile-long construction segment for MPs 70.6–82.6.[63] Construction work for this segment began in 2009 and was completed in 2014. In this area, the turnpike consists of 12 lanes, 6 lanes in each direction, with each direction having 3 (inner) lanes for cars and 3 (outer) lanes for cars, trucks, and buses, separated by a guardrail barrier. The three inner lanes were closed to traffic due to construction. The crash occurred in the centermost of the outer three northbound lanes near MP 71.4, along a straight section of roadway.

Traffic volume and speed. The NJTA indicated that the northbound traffic volume on Saturday, June 7, 2014, near Interchange 8A was approximately 69,401 vehicles during this 24-hour period. Trucks and buses accounted for about 4.5 percent of the total traffic volume. Hourly volumes for the same day of the week and the same hour of the day (Saturday midnight until 1:00 a.m.) for northbound traffic at two sensor locations averaged 488 vehicles.[64] Average operating speeds for the same day of the week and same hour of the day were as follows:

- MP 46.86: lane 1 - 66 mph; lane 2 - 70 mph; lane 3 - 76 mph; and
- MP 84.87: lane 1 - 64 mph; lane 2 - 67 mph; lane 3 - 73 mph.[65]

To accommodate the road work, in 2012, the speed limit posted on the dynamic message signs (DMSs) had been reduced from 65 mph to 55 mph beginning at MP 49.[66] The speed limit was further reduced to 45 mph at MP 71.0 about midnight (1 hour before the accident time).

Existing signage on I-95. The 2009 edition of the *Manual on Uniform Traffic Control Devices* (MUTCD), published by the DOT Federal Highway Administration (FHWA), sets the national standard for traffic control devices on any street, highway, bikeway, and private road

[62] The turnpike had three lanes in each direction when this project began in 2009. It was being widened to two three-lane corridors in each direction. At the time of the crash, only one three-lane corridor northbound was open for traffic. Work in the area of the crash was under New Jersey State project no. T869.120.803, 2012.

[63] MP numbers increase in the northward direction.

[64] Traffic counts were taken for five Saturdays and averaged.

[65] (a) Lanes are numbered from the rightmost travel lane (lane 1) progressively to the left. There were three active travel lanes. The work zone was set up between the two data-recording stations. (b) Eight sets of traffic speeds were recorded, two northbound at two locations and two southbound at two locations. The 85th percentile speed for the eight sets ranged from 64 mph to 72 mph.

[66] In this report, "DMS" refers to dynamic message signs and variable message signs. Some DMSs are portable.

open to public travel.[67] The MUTCD classifies the information it contains as “Standards,” “Guidance,” “Options,” and “Support.” “Standards” are statements of required, mandatory practice. “Guidance” describes recommended but not mandatory practices, allowing for engineering judgment or an engineering study to factor into the traffic control plan. “Options” offer allowable modifications to “Standards” or “Guidance.” “Support” consists of informational statements.

New Jersey has adopted the 2009 MUTCD. Part 6 of the MUTCD addresses temporary traffic control and applied to the construction/work zone in this crash. The MUTCD defines four work zone areas: advance warning, transition, activity, and termination. Of particular relevance to this crash are the traffic control devices associated with advance warning areas. The advance warning area is the section of highway where road users are informed about activity and changing traffic conditions in the work area ahead.

Section 6C.04, “Advance Warning Area,” in the MUTCD provides “Guidance” on placement of advance warning signs before a temporary traffic control zone. The “Guidance” indicates that because drivers are conditioned to uninterrupted traffic flow on freeways and expressways, advance warning signs should be placed well ahead of the transition areas where the lane taper begins. It states, “The advance warning sign placement should extend on these facilities as far as 1/2 mile or more.” In the accident work zone, the NJTA required the advance warning area to be extended 2 miles before the beginning of the transition area.

On the northbound route before the work zone, the turnpike had two permanent overhead DMSs used by the New Jersey Traffic Management Center to communicate with traveling motorists. A DMS lowering the speed limit to 55 mph was located 22 miles prior to the crash location. The NJTA was unable to determine what message was displayed on the second overhead DMS, located at MP 62.7 (about 8 miles in advance of the work zone); department records indicated that NJTA did not have electronic connection with the sign from 6:59 p.m. on June 6, 2014, through 5:13 a.m. on June 7, 2014.

Figure 9 shows the traffic control devices used on the New Jersey Turnpike near Cranbury, New Jersey. On the night of the crash, the work zone was set up to close the center and right lanes so that construction workers could take down a large overhead sign at MP 74.1 northbound in the outer lanes. The transition area where the lane taper began was at MP 72.7. At the time of the crash, traffic had backed up 2.7 miles from where the construction work was being performed and more than 1.1 miles from the beginning of the transition area, where the lane closure began. The advance warning signage before the crash site consisted of (1) warning signs indicating “Right 2 Lanes Closed 2 MI” (0.9 mile before the crash site on both sides of the travel way), (2) regulatory signs indicating “Traffic Fines Doubled in Work Area” (0.8 mile before the crash site on both sides of the travel way), and (3) signs indicating “Speed Limit 45” (0.4 mile before the crash site on both sides of the travel way). The overhead DMS at MP 72.1, just north of the crash location, displayed “Roadwork Reduced Speed Ahead—45 MPH.”[68]

---

[67] The MUTCD is developed by the FHWA in conjunction with the National Committee on Uniform Traffic Control Devices and its many volunteers.

[68] The crash occurred at MP 71.4.

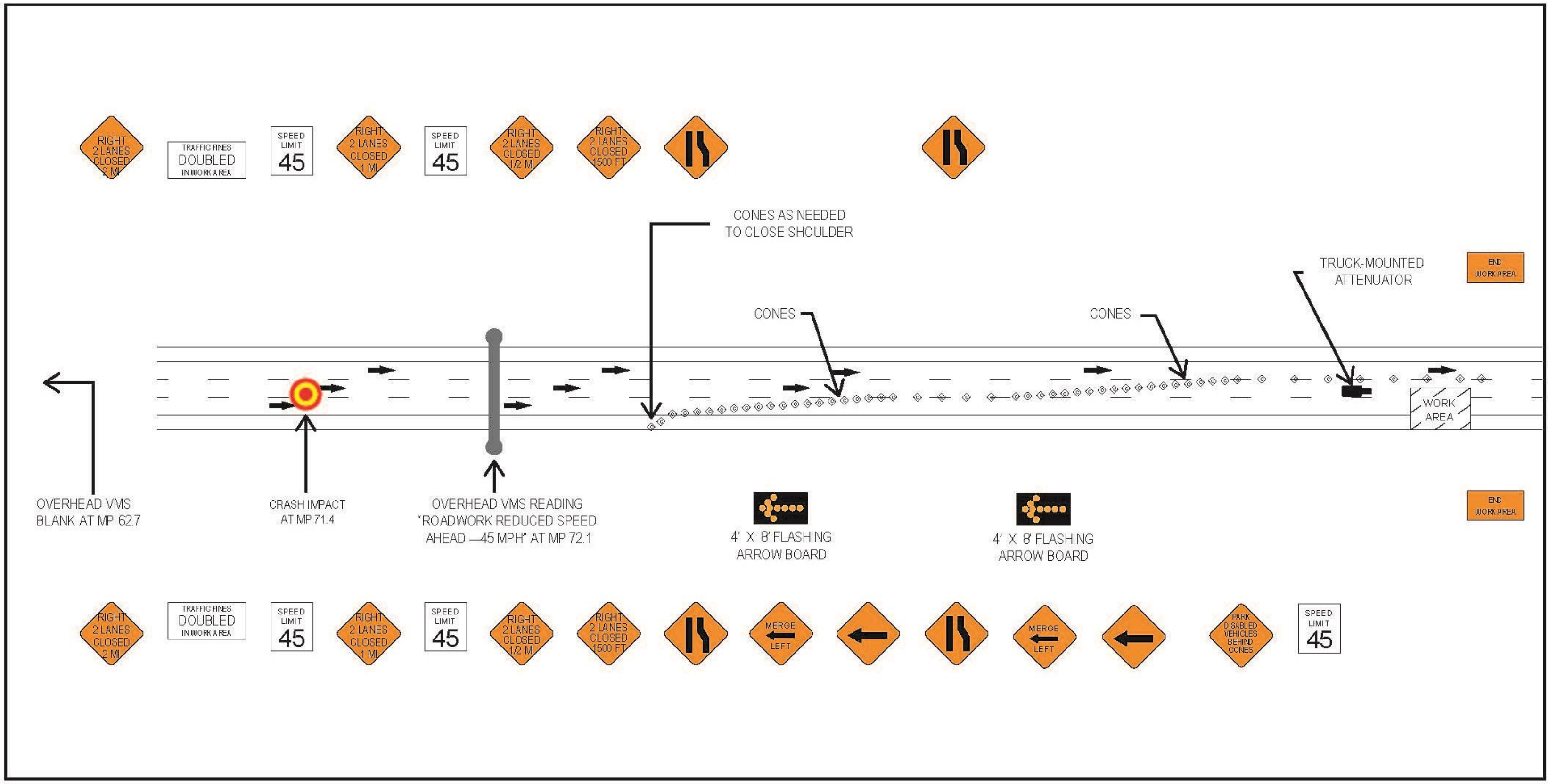


Figure 9. Traffic control devices used to close center and right lanes on night of crash. Signs are depicted to indicate the order of presentation on the left and right sides of the highway. Arrows on the roadway indicate the northbound direction of travel. (Figure is not to scale.)

The NJTA traffic protection standard drawing for "Multiple Right Lane Closing" is shown in appendix D. See appendix E for a sequential listing of the traffic control devices used in the work zone area.

1.6.2 Work Zone Procedures

The NJTA manager of operations indicated that on the day before the accident, contractors submitted a request for the center and right lanes to be closed to take down a large overhead sign at MP 74.1 northbound in the outer lanes. This submission revised an existing request for a lane closure. Initially, the lane taper was to begin about MP 72.9, but the distance was extended south to MP 72.5 to allow for the double taper arrangement.[69] The work zone included a 2-mile advance warning area beginning at MP 70.5.

At 11:34 p.m. on June 6, the DMS at MP 72.1 displayed a message that the right two lanes were being closed. In preparation for the closure, a marked NJSP car began to slow the traffic stream in the vicinity of MP 68 by traveling with the traffic with its emergency lights on and by veering to the left and right (occupying all the traffic lanes) as it progressed northbound. The contractor, Tetra Tech Inc., and a subcontractor, Griffin Sign Inc., began, with a seven-person crew, to place the cones and traffic control signs in accordance with the traffic control plan.[70]

1.6.3 Work Zone Oversight

The FHWA has developed a National Highway Work Zone Safety Program and a National Work Zone Safety Information Clearinghouse. The FHWA issued the *Work Zone Best Practices Guidebook* (third edition), publication no. FHWA-HOP-13-012, in August 2013. In addition, guidance on work zones has been developed through the National Cooperative Highway Research Program (NCHRP).[71]

The FHWA oversees federal-aid project work zones through guidance found in 23 *CFR* Part 630 Subpart J, "Traffic Safety in Highway and Street Work Zones." Subpart J was retitled "Work Zone Safety and Mobility" in October 2007 in response to federal rulemaking in 2004. The NJTA did not use federal-aid funds for this construction contract, but it used the policies and procedures that would have applied for the contract bidding and construction work.

[69] Page LC-T-9 of the "Lane Closures Document" indicated that, on Saturday nights at midnight, it was permissible to close two lanes at MP 72.5 on the northbound portion of the turnpike.

[70] The sequence of events was established based on interviews with the consulting engineering company's traffic control coordinator and the NJTA manager of operations, as well as review of the NJSP dashboard camera video.

[71] Such guidance is provided, for example, in (a) NCHRP Report 476: *Guidelines for Design and Operation of Nighttime Traffic Control for Highway Maintenance and Construction* (Bryden and Mace 2002); (b) NCHRP Report 500: *Guidance for Implementation of the* [American Association of State Highway and Transportation Officials] *AASHTO Strategic Highway Safety Plan, Volume 17: A Guide for Reducing Work Zone Collisions* (TRB 2005); and (c) *Best Practices in Work Zone Assessment, Data Collection, and Performance Evaluation* (Bourne and others 2010).

The NJTA *Design Manual*, *Traffic Control in Work Zone Manual*, and *Road Users Cost Manual*, as well as the contract specifications for this work project, were in accordance with the provisions of 23 *CFR* Part 630 Subpart J. These NJTA documents provide for advance planning, work zone impact analyses, training, and inspection of work zones. The NJTA *Road Users Cost Manual* contains the procedures for estimating traffic conditions based on traffic volumes and capacities. The NJTA "Road User Cost Worksheet" is used to calculate costs incurred by the contractor if traffic queuing delays the traveling public.

The NJSP Construction Incident Management Unit (CIMU) has inspection and oversight authority for all turnpike work zones. The NJSP assigns supplemental police patrols to work zone areas to support the primary CIMU trooper(s). The CIMU troopers and supplemental patrols oversee all construction activity on the turnpike, including lane closings, escorts, traffic slowdowns, enforcement, road closures, termination of lane closures, and investigation of industrial or construction accidents. They coordinate traffic control in cooperation with the NJTA operations department. The operations department also has traffic control supervisors on duty monitoring the work zones.

On the night of the crash, one CIMU sergeant was supervising and setting up the lane closure, and two supplemental units were patrolling work zones on the turnpike. The NJSP sergeant assigned to the work zone said that he supervised the installation of the work zone and traffic control devices and then drove through the zone periodically to inspect it—he estimated that he drove through it every 20 minutes when feasible.

1.6.4 Work Zone Safety Metrics

The NJTA provided 5 years of rear-end accident history for the Interchange 6 to 9 widening project. During the construction period between June 2009 and June 2014, an average of 638 rear-end accidents took place annually at MPs 50–83. For the 2 years preceding the project (2007–2008), an average of 403 such crashes took place per year.[72] The average number of fatalities varied little, with the preconstruction period averaging 1.5 fatalities per year compared to 1.6 fatalities per year during the years of construction. A review of NJSP reports indicated that seven of the eight fatal crashes in 2009–2014 involved a heavy truck.[73]

[72] For the period 2009–2014, there were 3,193 rear-end crashes; about half (1,660) involved injury, and there were 8 fatalities. For 2007–2008, the crashes totaled 806; of these, 287 involved injury, and there were 3 fatalities.

[73] The total of eight fatal crashes includes a disabled truck on the side of the road and the heavy truck in this investigation.

2 Analysis

The following safety issues were identified in this investigation:

- Enacting programs to address driver fatigue;
- Improving work zone safety, including reducing vehicle speeds;
- Assessing the limitations of, and means of enhancing, in-vehicle forward collision warning systems;
- Using the safety data available through critical event recording systems;
- Increasing passenger awareness of occupant restraint systems in passenger vehicles and ensuring that vehicle modifications do not reduce safety; and
- Creating an acceptable minimum standard of care to be provided by emergency medical responders.

Section 2.1 discusses the evidence for driver fatigue and how fatigue affected the Walmart Transportation truck driver's driving performance.

With respect to the work zone involved in this accident, the NJTA met the required standards for traffic control devices for such a construction zone, but this crash illustrates particular safety problems in the advance warning areas of work zones on high-speed highways. Traffic control practices that might have provided better warning of slowing traffic are discussed in section 2.2. Section 2.3 discusses how the excessive speed of the Walmart Transportation truck as it approached the work zone affected the outcome of the crash.

The Walmart Transportation truck was equipped with a collision warning system. The analysis in section 2.4 considers what enhancements could be made to such systems to improve their alerting capabilities and enable them to record more data for future system improvements. It also discusses how Walmart Transportation could have made better use of the information provided by its critical event reports to improve driver safety.

A limousine is a distinct type of vehicle that has a passenger seating environment unlike those of most passenger vehicles. Section 2.5 discusses limousine operations, including the use of seat belts and head restraints on such vehicles. Because the limo van involved in this crash was altered after original manufacture, the investigation considered two safety concerns resulting from the modifications. The altered vehicle had only a single exit door for the passenger compartment occupants and, because this exit was inoperable due to damage, rescue was delayed. The modifications also changed the vehicle's cargo capacity and, although that was not a factor in this crash, operators should have information about the effect of vehicle modifications on payload.

Finally, section 2.6 deals with the emergency response and discusses how the on-scene response could have been improved. In this case, the incident commander was delayed in accounting for the number of injured, which in turn, necessitated calling in additional ambulance resources. Poor coordination, lack of oversight, and different standards of care among emergency responders resulted in the injured being provided inconsistent levels of care.

The investigation examined numerous factors that ultimately were found to have played no role in the crash. The Walmart Transportation truck was subject to detailed postcrash inspections that revealed no preexisting mechanical defects or deficiencies in the vehicle's systems (steering, braking, suspension, and tires). The limo van, Buick Enclave, Ford F-150 pickup truck, Nissan Altima, and Freightliner combination unit were all either stopped or moving slowly in the queue of traffic that had formed in the work zone, and their mechanical conditions did not factor into the accident. The driver of the Walmart Transportation truck involved in this accident had a CDL with the correct endorsement for the vehicle he was operating. The results of postcrash testing for alcohol and illicit drug use by the Walmart Transportation truck driver were negative. There was no evidence of external distractions or of the use of a portable electronic device. Weather conditions at the time of the crash were clear and dry. The NTSB concludes that no mechanical conditions of the vehicles caused or contributed to the severity of the crash; alcohol, illicit drugs, or distractions did not appear to affect the Walmart Transportation truck driver; and weather and road conditions were not factors in the crash.

2.1 Driver Fatigue

The following considerations are relevant to determining the presence of driver fatigue: acute sleep loss and/or chronic partial sleep restriction; sleep quality and circadian factors, including time of day and dysrhythmia; time awake at the time of the crash; medical factors; and driving performance decrements.

2.1.1 Fatigue Assessment

The driver of the Walmart Transportation truck and his family declined to be interviewed; however, information about his activity was collected by the police and through electronic records. Based on the location and activity of the driver's cell phone and his work records, the investigation determined that the driver of the Walmart Transportation truck had sleep opportunity of only about 4 hours in the 33 hours preceding the crash and was experiencing acute sleep loss at the time of the crash. After driving approximately 12 hours in his personal vehicle from his Georgia residence to his place of work in Delaware, he had been on duty 13 hours 32 minutes of a 14-hour duty day and was experiencing the cumulative effects of driving in excess of 23 hours. He had also missed an entire sleep cycle. The crash occurred at 12:55 a.m., a time when individuals are biologically predisposed to sleep (Carskadon and Dement 2005). Moreover, following the crash, the driver told the NJSP that he fell asleep. The NTSB concludes that the driver of the Walmart Transportation truck was fatigued due to his failure to obtain sleep before reporting for duty, resulting in acute sleep loss and excessive time awake.

2.1.2 Driver Performance

A technical reconstruction of collision events and a review of electronic data revealed that traffic was slowed to less than 10 mph within the advance warning area of the active work zone on I-95. The driver of the Walmart Transportation truck was approaching the work zone traffic at a speed of 65 mph in the center of three lanes on a straight highway with an unobstructed line of sight. Vehicle tail lights were visible for more than 0.5 mile as the Walmart Transportation truck driver approached the slowed traffic. Additionally, the driver passed a pair of signs, one on each side of the roadway, indicating “Right 2 Lanes Closed 2 MI,” another pair of signs informing him of “Traffic Fines Doubled in Work Area,” and a pair of “Speed Limit 45” signs. He did not respond to the traffic in front of him that had been slowing for more than 0.25 mile to a speed of less than 10 mph. He did not respond to vehicle tail lights until he was within 200 feet of the limo van.[74]

When humans are impaired by fatigue, they are more likely to experience lapses in judgment, slowed reaction times, and reduced vigilance (Goel and others 2013, Lamond and Dawson 1999). Fatigue has been shown to affect a wide range of human performance, including vigilance and executive attention, psychomotor and cognitive speed, and working memory (Goel and others 2009). Lim and Dinges (2010) conducted a meta-analysis of 70 research articles to understand the effects of sleep deprivation on speed and accuracy measures in several cognitive categories. Effect sizes were largest for lapses of attention and reaction times, two behaviors that are critical for safe driving. In the 2014 NTSB public forum *Awake, Alert, Alive: Overcoming the Dangers of Drowsy Driving*, a panel discussed recent advances in in-vehicle drowsy driving detection. A NHTSA forum participant described a recently published study in which a real-time algorithm using vehicle-based data was able to predict lane departures 6 seconds before those lane departures occurred (Brown and others 2014). Therefore, based on the evidence of the crash investigation and supporting research, the NTSB concludes that due to his fatigued condition, the Walmart Transportation truck driver had a delayed response to slowed traffic in an active work zone.

2.1.3 Fatigue Management

The NTSB has a long history of making safety recommendations to address the problem of fatigue as it affects commercial drivers. In the course of 4 decades, the NTSB has made more than 50 recommendations in this area. Those recommendations have called for science-based HOS regulations, improved screening and treatment of sleep disorders, in-vehicle technologies to reduce fatigue-related crashes, and comprehensive fatigue management programs. Although some improvements have been made over the years, driver fatigue continues to pose a significant threat to public safety.

The Cranbury crash includes a situation that the NTSB has not previously addressed in the highway mode—a commercial driver working from a location significantly distant from his residence. Normally, the Walmart Transportation truck driver stayed in the vicinity of his work location while working. The driver’s coworker reported that the driver made arrangements at his own expense to stay at a hotel local to his workplace in Smyrna, Delaware; records show that he spent 11 nights in Smyrna in the 3 months preceding the crash. He also made regular use of his truck sleeper berth. The day before the Cranbury crash, however, the driver made an 800-mile overnight drive from his home in Georgia to his workplace in Delaware, which substantially

[74] Data recorded by on-vehicle systems show that in the last 2 seconds before impact, the truck driver applied his vehicle’s brakes and steered to the left, resulting in a relative impact angle of about 16 degrees and an impact speed of 47–53 mph.

contributed to his fatigue. This raises obvious questions about why this driver reported for duty not adequately rested, why he chose to conduct the backhaul assignment as an end-of-day task, and why he did not obtain adequate rest before continuing to accept dispatch assignments. Investigators were unable to interview the driver or his family to resolve these questions.

Walmart Transportation's hiring practices gave no special consideration to the hiring of drivers domiciled far from their assigned distribution terminal. Walmart Transportation told investigators that the carrier was aware that this driver was using a hotel as his local residence in Delaware and that such an arrangement was not uncommon. Its driver training program addressed fatigue, but Walmart Transportation did not have, nor was it required to have, a fatigue management program (FMP) that might have focused attention on the risks of driver off-duty activities.

An FMP offered through the employer uses a collection of policies, procedures, and information to address and reduce fatigue and its risks in the workplace. This commercial driver could have received information and education on fatigue and fatigue management through an FMP. The North American Fatigue Management Program (NAFMP) was developed by US and Canadian regulators, carriers, and researchers (NAFMP 2015).[75] It is an interactive, web-based training program designed to help commercial truck and bus companies increase awareness of the factors contributing to fatigue. The NAFMP was developed in part to address the fact that while HOS regulations can address work hours and required off-duty time, they cannot dictate lifestyle choices outside of the work environment—the specific situation relevant to this crash. The NAFMP is arranged in modules based on an individual's role in addressing fatigue factors—executives, safety managers, dispatchers, drivers, family members, and shippers/receivers. One module, driver family education, covers such important areas as long commutes, time awake, daytime sleeping and countermeasures, and establishing driver sleep as a family priority. The NTSB concludes that although Walmart Transportation addressed fatigue as part of its driver training program, it did not have a structured FMP in place that could have improved its ability to better monitor and educate its drivers about the risks of fatigue.

Drivers have both an individual and a professional responsibility to report for work rested and able to perform their duties as required by the *Federal Motor Carrier Safety Regulations*.[76] However, personal and social pressures push individuals to compromise rest requirements. In 2010, the NTSB investigated a truck-tractor semitrailer rear-end collision with passenger vehicles on Interstate 44 near Miami, Oklahoma, which also involved a fatigued truck driver encountering slowed traffic, in that case associated with a previous accident (NTSB 2010).[77] As a result of the Miami investigation, the NTSB made Safety Recommendation H-10-9 to the FMCSA, which called on the agency to

[75] See http://www.nafmp.com/en/, accessed January 27, 2015. Also see appendix F.

[76] Per 49 *CFR* 392.3, "No driver shall operate a commercial motor vehicle, and a motor carrier shall not require or permit a driver to operate a commercial motor vehicle, while the driver's ability or alertness is so impaired, or so likely to become impaired, through fatigue, illness, or any other cause, as to make it unsafe for him/her to begin or continue to operate the commercial motor vehicle."

[77] The NTSB has investigated many crashes in recent years that resulted from commercial driver fatigue (NTSB 2007, 2008a–c, 2009a–c, 2010, 2012a–b, and 2013).

H-10-9

> Require all motor carriers to adopt a fatigue management program based on the North American Fatigue Management Program guidelines for the management of fatigue in a motor carrier operating environment.

The FMCSA responded to the recommendation by citing progress made in the development of the NAFMP but stated that it "believes that non-regulatory alternatives should be explored fully prior to any effort to mandate such programs." On May 13, 2014, the NTSB responded to the FMCSA and expressed disappointment with the FMCSA's decision not to require implementation of this recommendation by all motor carriers. Our response letter stated, "We are concerned that a voluntary adoption policy with no monitoring of such a policy's results will fail to adequately address the problem of fatigued drivers and will continue to result in catastrophic crashes." The recommendation is classified "Open—Unacceptable Response." The NTSB concludes that had the FMCSA required motor carriers to adopt an FMP as recommended by the NTSB in 2010, it seems likely, based on other instances of the carrier's compliance with federal motor carrier safety requirements, that Walmart Transportation would have implemented a program to better monitor and educate its drivers about the risks of fatigue. Therefore, because the FMCSA has not yet required carriers to adopt FMPs, the NTSB reiterates Safety Recommendation H-10-9 to the FMCSA.

It is not necessary for carriers to wait until FMPs are required to implement them, and some large carriers have already done so. The NTSB recommends that Walmart Transportation develop and implement an FMP based on the NAFMP guidelines. Such a program would improve the carrier's management of driver fatigue risk and serve as an example of an industry member fulfilling the intent of Safety Recommendation H-10-9.

The Cranbury accident driver must have been aware that he was fatigued, given his complete lack of sleep before going on duty. Onboard monitoring systems can inform management of many unsafe driver behaviors, such as a fatigued driver's inability to maintain lane-keeping. When such systems are in place and management uses them as a safety tool, drivers are less likely to operate fatigued, and carriers can identify those that do.

In 2012, in a report concerning a 2011 motorcoach run-off-the-road and collision with a vertical highway signpost on Interstate 95 in New York City, which killed 15 and seriously injured 17 (NTSB 2012a), the NTSB issued recommendations on driver fatigue and onboard monitoring systems. Safety Recommendation H-12-13 from that report called on the FMCSA to take the following action:

H-12-13

> Develop and disseminate guidance for motor carriers on how to most effectively use currently available onboard monitoring systems and develop a plan to periodically update the guidance.

The FMCSA responded to the recommendation with a description of efforts to develop and evaluate an onboard monitoring system that allows for direct measurement of a set of driving characteristics that are indicators of unsafe driving behavior. The agency conducted a pilot test using a low-cost onboard driver behavior monitoring system and conducted a large field operational test of commercial motor vehicle drivers that involved 18 months of testing and as much as 32 million miles of naturalistic driving data. The test used a prototype system that integrated forward collision warning, electronic onboard recording, driver behavior monitoring, and inattentive/drowsy/aggressive driver detection. Data collection concluded in 2014. The FMCSA also engaged the National Surface Transportation Safety Center for Excellence to develop guidance for motor carriers on how to most effectively use currently available onboard monitoring systems. The FMCSA has conducted research in support of policy and rulemaking activities regarding onboard monitoring systems. The NTSB has classified Safety Recommendation H-12-13 "Open—Acceptable Response." The NTSB concludes that the research the FMCSA has been conducting to evaluate integrated onboard systems, including fatigue-monitoring technologies, should be finalized. The NTSB reiterates Safety Recommendation H-12-13 to the FMCSA.

2.2 Work Zone Safety

The nation's interstate system is aging and requires an increasing number of maintenance and construction work zones to rebuild, repair, and maintain the roadway network. Highway work zones present motorists with unusual and unexpected conditions that can increase driver errors. NCHRP research summarizing work zone crash risks showed that, for 18 cited studies, crash risks typically increased 20–30 percent in work zones (Ullman and others 2008, pp. 4–5). Because of the increased crash risk associated with work zones, they have received special consideration by the NTSB as well as the FHWA and state departments of transportation.

In 1992, the NTSB issued a safety study titled *Highway Work Zone Safety* (NTSB 1992).[78] The report identified work zone safety concerns and issued recommendations to the FHWA pertaining to commercial vehicles traveling through work zones (including Safety Recommendation H-92-45).[79] In a report of an investigation conducted while the safety study was in progress, the NTSB issued Safety Recommendations H-91-19 and -28 concerning speed compliance and traffic control (NTSB 1991).[80]

In 1995, the FHWA developed its National Highway Work Zone Safety Program (*Federal Register* 1995) and subsequently amended its regulations governing work zones in September 2004 with a final rule (*Federal Register* 2004, FHWA 2006). The rule required that, by October 2007, state departments of transportation implement transportation management plans (TMPs) for the systematic consideration and management of work zone impacts on all federal-aid highway projects. A TMP lays out the work zone management strategies (including a traffic control plan) that will be used for a road project.

[78] The study was initiated in 1988, and it involved investigations of more than 40 accidents.

[79] Safety Recommendation H-92-45 read as follows: "Determine if a combination of efforts, such as speed reductions coupled with onsite enforcement and positive barriers, may be needed at work zones when commercial vehicles are a relatively large percentage of the average daily traffic." It was "Closed—Acceptable Action."

[80] The subject accident occurred in Sutton, West Virginia, on July 26, 1990. Safety Recommendation H-91-19 to the West Virginia Department of Transportation read as follows: "Require the use of oversized signs to encourage compliance with reduced speed limits in work zones." Safety Recommendation H-91-28 to the FHWA read as follows: "Encourage the use of work zone safety devices and procedures, such as 'rumble strips,' that alert the various senses." Both recommendations were "Closed—Acceptable Alternate Action."

To conform to the new regulation, New Jersey developed its *Traffic Mitigation Guidelines for Work Zone Safety and Mobility* (NJDOT 2007). Based on its review of the associated requirements and the work zone near the Cranbury crash, the NTSB concludes that with respect to the work zone where the crash took place, the NJTA followed the guidance in 23 *CFR* Part 630 Subpart J, and the NJTA's temporary traffic control zone and the lane closure process it used were in accordance with MUTCD "Standards" and NJTA policy.

2.2.1 Work Zone Traffic Queues

In general, work zone traffic queues develop when demand exceeds capacity; they subside when demand falls below the queue's discharge capacity. Once traffic has slowed or stopped, the differential speed of approaching traffic creates a stop-and-go movement that eventually affects the length of the queue. Engineering estimates vary, but a mile-long queue can develop in minutes (Maze, Schrock, and Kamyab 2000; Kujirai and Matano 1998; Hellinga 2001).

Ideally, traffic should not come to a near stop within the advance warning area of a work zone.[81] In the moments preceding this crash, however, slowed traffic had backed up 2.7 miles from where the construction work was being performed and more than 1.1 miles into the advance warning area designed to inform drivers of changing traffic conditions.

Work zones present an elevated crash risk to heavy trucks, and truck involvement is over-represented in fatal work zone crashes. NHTSA Fatality Analysis Reporting System (FARS) data have shown that trucks are involved in 11.2 percent of all fatal crashes, but they were involved in 23.6 percent of fatal work zone crashes in 2012 (FMCSA 2014). FARS data also showed that large truck fatal crashes in work zones are more likely to involve multiple vehicles; about 32.6 percent of large truck fatal crashes in work zones involved three or more vehicles; this compares to 16.9 percent of large truck fatal crashes in general involving three or more vehicles.

Running into the rear of a slowing or stopped vehicle is the most common type of work zone crash; for heavy trucks, 56 percent of fatal work zone crashes were rear-end crashes. Given that a loaded 80,000-pound tractor-trailer requires almost 50 percent more stopping distance than a passenger vehicle, it is clear that work zone queues present elevated risk to heavy trucks.

A Texas Transportation Institute research project considered the problem of traffic flowing at normal speed encountering unexpected slow or stopped traffic (Wiles and others 2003). The research identified the following techniques for providing advance warning of stopped traffic: DMSs, some of which are trailer-mounted and/or portable; variable speed signs; larger static signs (text and symbol); queue-activated roadside beacons; incident response vehicles; tracking the end of queue; and enforcement vehicles with special driving methods. Research focusing on heavy truck characteristics has suggested that more MUTCD "Guidance" is needed to ensure work zone safety for such vehicles, as expressed in the following statement:

[81] MUTCD Section 6C.04 states that "drivers are conditioned to uninterrupted flow," and there is an option to "eliminate advance warning when the road work activity is sufficiently removed from the road users' path so that it does not interfere with normal flow."

"Special traffic control strategies need to be developed to guide trucks passing the work zones" (Li and Bai 2008).

2.2.2 MUTCD "Guidance"

This crash illustrates a weakness in current best practices for managing highway work zones/lane closures; specifically, the current MUTCD "Guidance" does not adequately consider the dynamic nature of the queue that may develop and does not contain sufficient provisions to warn all drivers that they are approaching congested traffic queues. A body of research work, most of which has been funded by the FHWA, addresses work zone safety and the role of advanced technology in supplementing the minimum requirements for work zone traffic control devices. In 2005, the Transportation Research Board (TRB) released NCHRP Report 500: *Guidance for Implementation of the AASHTO Strategic Highway Safety Plan, Volume 17: A Guide for Reducing Work Zone Collisions*. The report provided strategies to improve work zone safety through better traffic control, including the implementation of intelligent transportation system (ITS) tools (TRB 2005). ITS tools and technology—such as traffic monitoring, real-time communication of travel times, and length of backup—have been effective in reducing vehicle speeds in congested flow conditions (FHWA 2004). DMSs can be used to convey work zone speed limit information and to advise drivers of slower downstream speeds and travel times.[82] The FHWA has supported the development of, and research on the use of, ITS systems in work zones, including recently publishing an ITS implementation guide for work zones (Ullman, Schroeder, and Gopalakrishna 2014).

MUTCD section 6G04, "Modifications to Fulfill Special Needs," provides "Guidance" on devices that may be added to supplement those used in typical applications. It states, "When conditions are more complex, typical applications should be modified by … incorporating appropriate devices and practices from the following list:"[83]

Additional Devices

1. Signs
2. Arrow panels
3. More channelizing devices at closer spacing
4. Temporary raised pavement markers
5. High-level warning devices
6. Portable DMSs
7. Temporary traffic control signals

[82] The Texas Department of Transportation is using traffic control devices equipped with sensors to detect the formation of queues and warn drivers of slowed/stopped traffic ahead. When the sensors identify queues, messages are posted to portable changeable message signs to alert drivers. Temporary portable rumble strips are also being used in some locations as part of the end-of-queue warning.

[83] Applications not relevant to the New Jersey Turnpike (such as pedestrian and bicycle accommodations) are not listed here.

8. Temporary traffic barriers
9. Crash cushions
10. Screens
11. Rumble strips
12. More delineation

Upgrading of Devices

1. A full complement of standard pavement markings
2. Brighter and/or wider pavement markings
3. Larger and/or brighter signs
4. Channelizing devices with greater conspicuity
5. Temporary traffic control barriers instead of channelizing devices

Increased distances

1. Longer advance warning areas
2. Longer tapers

Lighting

1. Temporary roadway lighting
2. Steady-burn lights used with channelizing devices
3. Flashing lights for isolated hazards
4. Illuminated signs
5. Flood lights

Research is available to advise traffic safety engineers on what MUTCD section 6G04 refers to as "complex" traffic conditions. Traffic safety engineers must use traffic control devices as effectively as possible to communicate the hazards of highway work zones, and those hazards stem primarily from unexpected conditions. Traffic control plans for work zones on interstates and freeways should prioritize devices designed to alert drivers and control speed, particularly in the advance warning area where higher-speed traffic can encounter slower-moving traffic queues. The risks these slower-moving queues present to heavy trucks should be considered by traffic engineers and the associated traffic management plans. The NTSB concludes that engineering decisions concerning traffic control devices would benefit from additional MUTCD "Guidance" on (1) traffic conditions that call for supplemental devices in addition to the MUTCD "Standard," (2) the length of advance warning areas and the use of rumble strips in these areas, (3) traffic control devices particular to speed control, and (4) other proactive measures to monitor and warn motorists of traffic backing up within the work zone. Accordingly, the NTSB recommends that the FHWA amend the MUTCD "Guidance" for work zone projects on freeways and expressways to advise traffic engineers on the use of supplemental traffic control strategies and devices to mitigate crash events involving heavy commercial vehicles.

2.3 Vehicle Speed

The Walmart Transportation truck driver traveled 0.9 mile past the first work zone sign and more than 0.4 mile past the 45-mph speed limit sign without slowing his speed from 65 mph. The truck was traveling at 65 mph until it reached a closing distance of approximately 200 feet before impact. To assess the role of speed in the crash, reconstruction analysis considered the vehicle braking performance from an initial velocity of 45 mph, which was the posted speed in the work zone area. Reconstruction analysis applied the same data and methodology used to calculate the onset of braking but adjusted the truck's initial speed to 45 mph. Based on the results of this analysis, the NTSB concludes that had the Walmart Transportation truck been traveling at the posted work zone speed of 45 mph, the vehicle could have been stopped before impact, if the brakes had been applied at the same point.

The risk of speed change problems along the New Jersey Turnpike construction project should have been well known to the NJTA. Rear-end crashes along the 33-mile-long section averaged over 650 per year during the years of the Interchange 6 to 9 widening project and represented a more than 50 percent increase over the rear-end crash counts in the 2 years preceding the construction project.

As a result of its investigation of a 2011 motorcoach crash in New York City, the NTSB issued a pair of safety recommendations that called on NHTSA to develop speed countermeasure technology for heavy vehicles (NTSB 2012a). They read as follows:

> <u>H-12-20</u>
>
> Develop performance standards for advanced speed-limiting technology, such as variable speed limiters and intelligent speed adaptation devices, for heavy vehicles, including trucks, buses, and motorcoaches.
>
> <u>H-12-21</u>
>
> After establishing performance standards for advanced speed-limiting technology for heavy commercial vehicles, require that all newly manufactured heavy vehicles be equipped with such devices.

In response to those recommendations, NHTSA acknowledged that it had received a 2006 petition to initiate rulemaking to amend the FMVSSs to require vehicle manufacturers to limit the speed of heavy trucks. In 2007, NHTSA and the FMCSA jointly responded to that petition with a request for comments notice in the *Federal Register*. In 2011, NHTSA announced that it anticipated publishing a notice of proposed rulemaking on this issue by the end of 2012; to date, it has not done so. Both recommendations are in "Open—Acceptable Response" status.

Intelligent speed adaptation technology may provide a needed countermeasure to excessive vehicle speed, particularly in work zones, where restricted speeds are unexpected. Therefore, the NTSB reiterates Safety Recommendations H-12-20 and -21 to NHTSA.

2.4 In-Vehicle Warning Systems

This Walmart Transportation truck was equipped with an in-vehicle collision warning system that provided download data for analysis. This section discusses this and other in-vehicle safety systems that wirelessly communicated critical information about vehicle operation.

2.4.1 Bendix Wingman Active Cruise with Braking System

Walmart Transportation had equipped the accident truck with a Bendix Wingman ACB system, the name of which reflects its cruise control functionality.[84] The active braking feature is available only when cruise control is in use. However, even when cruise control and automatic braking are not active, the Wingman ACB system is capable of providing three types of collision alerts to the driver: following distance, stationary object, and impact.

Following distance alerts are provided when an established distance between the equipped vehicle and a tracked vehicle ahead is decreasing—the duration of such an alert tone can range from a fraction of a second to continuous. Stationary object alerts are delivered up to 3.0 seconds in advance of sizable stationary objects. Impact alerts warn the driver via text and a loud continuous tone to take immediate evasive action to avoid a potential collision, if a threat is within 500 feet.[85]

Because the Walmart Transportation truck's cruise control was off, no radar data were recorded. The data that were available from the Wingman ACB system indicated that there were no active diagnostic trouble codes and that the system was functional and available prior to the impact and the loss of radar sensor communication.[86] The NTSB concludes that the Wingman ACB system on the Walmart Transportation truck was capable of issuing an alert to the driver just prior to the crash.

The Wingman ACB system recorded data based on an event triggered by loss of communication between the radar sensor and the primary control module at the time of the crash. Five seconds of pretrigger data were recorded at 0.5-second intervals. Data from the Wingman ACB system recorded the audible alert status as "off" for all system status snapshots taken at 0.5-second intervals preceding the collision. No radar data were recorded because the cruise control was off. The NTSB concludes that, based on the data recorded by the Wingman ACB system, the system did not provide a precrash alert, although the possibility that it issued an alert that occurred between the 0.5-second data-sampling intervals cannot be ruled out.

[84] Meritor WABCO Vehicle Control Systems also makes collision avoidance systems for commercial vehicles. In 2014, Detroit Diesel Corporation introduced Detroit Assurance, a safety system suite that includes a base bumper-mounted radar system that features collision mitigation, through active braking assist, and adaptive cruise control. (Detroit Diesel Corporation is an affiliate of Daimler Trucks North America LLC.) The manufacturer Mobileye offers warning systems only, which do not provide brake interventions on commercial vehicles.

[85] Impact alert criteria are based on the vehicle closure rate; warnings depend on both the speed at which each vehicle is traveling and the speed differential.

[86] The Bendix Wingman ACB radar sensor module was mounted on the front bumper of the truck-tractor; it was damaged in the crash. Data were from the driver interface unit located in the truck cab.

The speed differential of approximately 60 mph between the Walmart Transportation truck and the limo van may have affected the ability of the Wingman ACB system to provide following distance data processing and alerts. The Wingman ACB system may not have identified the slowing limo van, which was moving at a slight angle to the trajectory of the truck, as a stationary object. To better understand the timing implications of a stationary object alert, investigators conducted a simulation analysis of the crash.[87] The simulation included the hypothetical crash scenario of what would have happened if the driver had received a stationary object alert 3.0 seconds prior to collision.[88] Given the closing speed between the Walmart Transportation truck and the limo van, average driver reaction time, and brake system actuation, the warning would not have prevented the collision.

The Wingman ACB system's limited capability to store data is a constraint, to both Bendix's ability to analyze and enhance system performance and accident investigators' ability to reconstruct accident events accurately. Without forward radar sensor data, and having no record of alerts, we are left with an incomplete record of system performance. The NTSB concludes that collision warning and avoidance systems capable of storing and retrieving vehicle and system performance information would aid in the evaluation and improvement of such systems, as well as facilitate a better understanding of crashes. The NTSB recommends that the manufacturers of collision warning and avoidance systems for commercial motor vehicles—Bendix, Detroit Diesel Corporation, and Meritor WABCO Vehicle Control Systems—include, in all collision warning and avoidance systems for use on truck-tractors, single-unit trucks, and motorcoaches, the capability to store and retrieve data pertaining to object detection, driver audible/visual alerts, and interventions by the system for a period and at a data rate adequate to support accident investigation and reconstruction.

2.4.2 Collision Avoidance System Recommendations

The NTSB has a long history of advocating for standards, rulemaking, and industry adoption of collision avoidance systems. The NTSB first addressed collision warning technology as a major safety issue during our investigation of a 1995 multivehicle collision in Menifee, Arkansas, in which a commercial vehicle entered dense fog, slowed from 65 mph to 35–40 mph, and was then struck from behind. Subsequent collisions occurred as vehicles drove into the wreckage. The accident, which involved eight loaded truck-tractor semitrailers, resulted in five fatalities (NTSB 1995).

In a special investigation report released in 2001, the NTSB investigated nine rear-end accidents that killed 20 people and injured 181 (NTSB 2001). In the report, the NTSB explored both vehicle- and infrastructure-based technologies for preventing rear-end collisions and discussed the challenges of implementation, consumer acceptance, public perception, and training associated with the deployment of such systems. As a result of the 2001 special investigation report and the investigation of a 2005 accident involving the rollover of a

[87] The simulation was conducted using PC-Crash software (see http://pc-crash.com, accessed June 30, 2015). The simulation used survey measurements, vehicle trajectories, final rest positions, measurements and weights of vehicles, and electronic data to calculate a collision speed.

[88] The 3.0-second timing parameter used in the simulation was based on the Wingman ACB system's alert timeframe.

combination unit that came to rest blocking both lanes of a dark interstate near Osseo, Wisconsin (NTSB 2008c), the NTSB issued the following safety recommendations concerning commercial vehicle safety systems to NHTSA:

> H-01-6
>
> Complete rulemaking on adaptive cruise control and collision warning system performance standards for new commercial vehicles. At a minimum, these standards should address obstacle detection distance, timing of alerts, and human factors guidelines, such as the mode and type of warning.
>
> H-01-7
>
> After promulgating performance standards for collision warning systems for commercial vehicles, require that all new commercial vehicles be equipped with a collision warning system.
>
> H-08-15
>
> Determine whether equipping commercial vehicles with collision warning systems with active braking and electronic stability control systems will reduce commercial vehicle accidents. If these technologies are determined to be effective in reducing accidents, require their use on commercial vehicles.

The NTSB recently published a special investigation report on *The Use of Forward Collision Avoidance Systems to Prevent and Mitigate Rear-End Crashes*; the report changed the status of these three recommendations (NTSB 2015a). It classified Safety Recommendations H-01-7 and H-08-15 “Closed—Unacceptable Action.” It classified Safety Recommendation H-01-6 “Closed—Unacceptable Action/Superseded” and superseded it with the following new safety recommendation to NHTSA:

> H-15-5
>
> Complete, as soon as possible, the development and application of performance standards and protocols for the assessment of forward collision avoidance systems in commercial vehicles.

The NTSB recognizes that NHTSA has not yet had time to formulate a response to this new recommendation, but the high-velocity impact of the Walmart Transportation truck encountering slowed traffic in a work zone queue highlighted the need for collision avoidance systems on heavy trucks with performance parameters different from those for lighter vehicles. Therefore, the NTSB reiterates Safety Recommendation H-15-5 to NHTSA because it is relevant to the circumstances of the Cranbury crash.

2.4.3 Critical Event Reporting

Walmart Transportation equipped the accident truck with an Omnitracs telematics system capable of generating CERs and producing wireless communications of such events. Two types of vehicle events generate CERs: “hard-braking” and “stability control” events. When the vehicle experiences either of these types of events, the system generates a CER and sends an e-mail to the local Walmart Transportation safety manager. A record of the event is placed in the driver's file. During his employment with Walmart Transportation, the accident driver had an average of three CERs per month.

The Walmart Transportation safety officer at the Smyrna, Delaware, distribution center told investigators that he uses CER alerts concerning hard-braking and stability control to instruct and train the carrier's drivers. But Walmart Transportation did not have procedures in place to analyze the CER data for causes or trends, nor to make use of the full set of these safety incident data. Analyses of such near-miss data could reveal patterns related to factors such as duration of driving time, time of day, day of week, day in work week cycle, driving team, supervisor, route characteristics (congestion or topography), and driver experience. Maintaining a record of driver explanations for events could also offer insights useful to the carrier.[89] A detailed analysis of CERs could be used to better understand event precursors (for example, hard-braking for unexpected pedestrian actions versus hard-braking for a traffic signal change), thereby revealing different levels of safety risk.

Many trucking companies use predictive modeling of safety data as a fleet management tool. Omnitracs has a business unit, FleetRisk Advisors, that conducts data assessment and risk modeling. The NTSB concludes that analysis of CER data would enable Walmart Transportation to better understand driving behavior factors in aggregate terms as well as to study individual driver-level performance. The NTSB recommends that Walmart Transportation incorporate into its corporate safety program a method for conducting ongoing analysis of aggregated CER data on hard-braking and stability control events.

2.5 Limousine Operations

2.5.1 Pretrip Briefings and Occupant Restraint Use

The seat belt laws in Delaware and New Jersey required the limo van occupants to use seat belts; however, of the seven occupants of the limo van operated by Atlantic Transportation, only one was belted.[90] The seating configuration in limousines is intended to create a relaxed social setting with seats facing each other to facilitate conversation. In such a setting, passengers may easily overlook the use of restraints if not prompted by the operator.

The absence of serious injuries sustained by the occupants of the front seats of the limo van was due to the lower impact forces at the front (as opposed to the rear) of the limo van, the lack of intrusion in this area, the relatively confined space that reduced occupant motion and secondary impacts, and the deployment of airbags. The serious injuries to the passengers seated in the passenger compartment of the limo van were caused by their uncontrolled movement within the relatively open compartment. Use of available occupant protection system elements,

[89] Walmart Transportation had its drivers write explanations for some CERs that went into their driver folders, but this process was not followed for all alerts.

[90] In Delaware, the violation is a primary offense; in New Jersey, it is a primary offense for the front seat occupants and a secondary offense for back seat occupants over the age of 18.

such as seat belts and properly adjusted head restraints (which provide support for an occupant's head and neck), limits such uncontrolled movement. An effective head restraint is designed to be adjustable to different-size occupants to mitigate sudden head movements during a rear-end collision. Performance of the head restraint depends on its position; it should extend to the top of the head and be as close as possible to the center of the back of the head. Without this restraint during a rear-end crash, the unsupported head causes neck injuries. The Insurance Institute for Highway Safety reports that neck injuries account for 25 percent of the cost of claims.[91] The NTSB concludes that the serious injuries sustained by the passengers seated in the passenger compartment of the limo van were caused by flailing and secondary impacts with the interior or other occupants, or intrusion/contact with the vehicle sidewall and roadway, which resulted, in part, from the passengers' failure to use available seat belts and properly adjusted head restraints.

In addition to the Cranbury crash, the NTSB investigated three crashes of passenger-carrying operations in 2014 that involved unbelted passengers: a 15-seat van crash in which only one front seat passenger was belted, a 32-seat medium-size bus crash in which numerous seat belts were found stowed between seat cushions, and a 56-seat motorcoach crash in which only one passenger was belted (NTSB 2015c, NTSB 2015d, and NTSB 2015b).[92]

The motorcoach crash occurred in Orland, California, on April 10, 2014 (NTSB 2015b). As a result of that investigation, the NTSB recently made the following recommendation to the FMCSA:

> <u>H-15-14</u>
>
> Require all passenger motor carrier operators to (1) provide passengers with pretrip safety information that includes, at a minimum, a demonstration of the location of all exits, explains how to operate the exits in an emergency, and emphasizes the importance of wearing seat belts, if available; and (2) also place printed instructions in readily accessible locations for each passenger to help reinforce exit operation and seat belt usage.

The limo van driver in the Cranbury crash was not required to provide a pretrip safety briefing to his vehicle's passengers, and no pretrip briefing or other information was given to encourage seat belt use by the limo occupants. Atlantic Transportation did not have, nor was it required to have, established policies for making pretrip safety briefings concerning emergency exits and seat belt use to its passengers. Therefore, the NTSB reiterates Safety Recommendation H-15-14 to the FMCSA.

Atlantic Transportation operators did not provide any passenger notice on using seat belts or properly adjusted head restraints. As has been stated, however, Delaware and New Jersey law

[91] See http://www.iihs.org/iihs/topics/t/neck-injury/topicoverview, accessed July 26, 2015.

[92] Passenger counts refer to vehicle design capacity. The numbers of involved vehicle occupants, including drivers, were 12, 16, and 46, respectively.

required that the passengers in the limo van wear seat belts.[93] Limousine operators, in general, may be unaware of the laws in many states that make drivers responsible for restraint use by their passengers. The NTSB concludes that the guidance provided to limousine operators concerning passenger seat belt use and properly adjusted head restraints is inadequate.

The National Limousine Association (NLA) is a non-profit organization representing the luxury chauffeured ground transportation industry. Its members include limousine owners, operators, suppliers, and manufacturers, as well as regional and state limousine associations. Atlantic Transportation has been an NLA member since 2006.

Because the vehicles used in the limousine industry vary widely, from light passenger vehicles to heavy buses, there is no consistent safety practice for addressing the issue of passengers' use of safety equipment. Therefore, the NTSB recommends that the NLA develop and distribute guidelines to its member operators urging them, during pretrip safety briefings, to (1) direct passengers to use seat belts where required by law and strongly encourage passengers to use seat belts where not required by law, and (2) encourage passengers to use properly adjusted head restraints.

2.5.2 Vehicle Exits and Effect on Emergency Egress

Federal standards do not establish requirements for emergency exits or means of evacuation for vehicles other than a "bus." The limo van did not meet the FMVSS definition of a bus and so was not required to provide emergency exits. However, some safety authorities recognize that passenger vehicles like the limo van should have emergency exits. For example, under European standards, a commercial vehicle designed to transport more than nine people (such as the limo van) falls into a category with requirements for emergency exits covered by United Nations Economic Commission for Europe Regulation 107.

In March 2012, Midwest Automotive altered the vehicle to provide a luxury seating compartment for eight passengers. Alterations to the passenger compartment included two permanent dividers: a front privacy partition separating the cab from the passenger seating compartment, and a rear partition separating the passenger compartment from an electronics bay and cargo area. Only one side door remained to access the passenger compartment. The NTSB reviewed the FMVSSs and found that Midwest Automotive addressed all applicable FMVSSs on a self-certification basis. The NTSB found no issues concerning compliance with the FMVSSs, either as the vehicle was originally manufactured or after its alteration.

However, the lack of an emergency exit caused problems that delayed the emergency response. Because the vehicle overturned onto its left (driver) side, the sliding door on the passenger side was facing upward, which would have made it difficult for injured occupants and

[93] The New Jersey seat belt law (NJS 39:3-76.2f) requires the driver, front seat passengers, and children under 18 years old to wear seat belts. Noncompliance is a primary offense. The driver is responsible for proper restraint use by all vehicle occupants under age 18. Per a secondary law, all back seat occupants 18 years and older are required to buckle up. Such unbelted back seat passengers can be issued a summons if the vehicle in which they are riding is stopped for another violation. The Delaware seat belt law requires that all vehicle occupants, including those in the back seat, wear seat belts at all times. Noncompliance is a primary offense and the citation is issued to the vehicle driver.

rescue personnel to use it for evacuation. Moreover, due to vehicle damage, this door was not functional following the crash. One of the passenger windows was broken out by a bystander and used for entering the van, but it could not be used for passenger evacuation due to its small size and the fact that the passengers were injured. Bystanders and the occupants of the limo van's cab attempted to access the passenger compartment through the front partition. Rescue personnel first attempted to access the passenger compartment by removing the limo van's rear doors. When access to this compartment from the back proved not possible, responders opened an access point via the cab's front partition. Although a clear effect on medical outcomes could not be established, access to the injured passengers was delayed as a result of the vehicle's interior modifications. The NTSB concludes that the modified limo van, with permanent barriers at the front and back of the passenger compartment and only one side door, failed to provide adequate means of emergency evacuation or rescue of injured victims. The NTSB recommends that NHTSA require that modifications to limo van vehicles (1) retain a full-sized exit on at least one side of the vehicle's passenger compartment, and (2) have at least one other exit located on the front, back, or roof of the passenger compartment.

2.5.3 Vehicle Weight

The limo van had a GVWR of 8,550 pounds. The company that modified the vehicle, Midwest Automotive, could not provide investigators a vehicle weight as measured at the time of modification. The company provided a weight estimate of 6,910 pounds.[94]

Subtracting the estimated weight for the altered vehicle (6,910 pounds) from the GVWR (8,550 pounds) left only 1,640 pounds to account for the weight of all vehicle occupants and cargo. Midwest Automotive stated in its compliance paperwork that its vehicles are configured to allow for 150 pounds per occupant (1,500 pounds), plus a baggage allowance of 140 pounds for a fully loaded vehicle.[95] If, with all of the seating positions occupied, the average weight of the vehicle's occupants exceeds 150 pounds, the limo van could be overloaded. Given the increasing average weight of individuals in the United States, it is unlikely that limo van occupants would weigh, on average, only 150 pounds each.[96]

An article published in a trade magazine in February 2014 highlighted safe operation of limousines by stating that operators are ultimately responsible for the overall load weight of their vehicles (Romjue 2014). The Royal Society for the Prevention of Accidents in the United

[94] This estimate corresponded reasonably well with the postcrash measured weight of the limo van, which was 6,950 pounds.

[95] Title 49 *CFR* Part 567 "Certification," defines GVWR as "Gross Vehicle Weight Rating or GVWR followed by the appropriate value in pounds, which shall not be less than the sum of the unloaded vehicle weight, rated cargo load, and 150 pounds times the number of the vehicle's designated seating positions…."

[96] The Federal Aviation Administration (FAA) advisory circular on Aircraft Weight and Balance Control uses average weight calculations of 190 pounds per person for summer and 195 pounds per person for winter (FAA 2005); and according to the Centers for Disease Control and Prevention, more than one-third of Americans are obese. (See http://www.cdc.gov/obesity/data/facts.html, accessed May 27, 2015.)

Kingdom has posted a factsheet on its website with recommended procedures to ensure proper loading of minibuses.[97]

At the time of the crash, the accident limo van was very near its GVWR capacity, using a reasonable approximation of 190 pounds for each of the 7 (adult) occupants, and it would have been loaded beyond capacity if it had been carrying 10 adults. On this basis, the NTSB concludes that although the loaded limo van did not exceed its capacity at the time of the crash, and vehicle weight was not a factor in the crash, had all of its available seats been occupied, the limo van could have exceeded its capacity by several hundred pounds.

Vehicle conversions may affect vehicle capacities and impose operational constraints. Payload variations affect a vehicle's center of gravity and handling characteristics, which can compromise the vehicle's stability. The vehicle's suspension system and tire performance, in particular, can be negatively affected by an overweight condition. The NTSB recommends that the NLA request that its vehicle-altering and final-stage manufacturing members post the total passenger and luggage weight limit on any vehicle they alter.

2.6 EMS Standards

A sequence of on-scene missteps indicated a lack of coordination during the emergency response and a failure to meet basic care standards for injured persons. Rescue operations began immediately, but medical care was delayed because responders had difficulty accessing the victims. Responders attempted to enter the limo van through the rear doors, which did not connect to the passenger area, and more time was needed to remove obstructions to gain access via the front partition. The limo van driver, who received only minor injuries and tried to help in extricating the injured passengers, said he told emergency responders that removing the back doors would not provide access to the passenger compartment, but rescue efforts through that route persisted until the inner wall was revealed. Because of problems accessing the passenger compartment, it took responders more than 30 minutes to extricate the injured limo van occupants (the first two were removed from the van at 1:38 a.m. and 1:39 a.m.). The four seriously injured occupants of the limo van did not reach the emergency department until well over an hour after the crash, although the hospital was only 16 miles away.[98]

There was also evidence of poor communication on the scene. Mercer County Dispatch initially dispatched three BLS ambulances but recalled one because initial reports from the scene did not indicate the presence of seriously injured victims. The fire/rescue operations focused on the victims who remained trapped in the limo van and did not recognize that there was another seriously injured victim on scene who had self-extricated. Information about the number and injury severity of victims was not updated expeditiously. Although the limo van driver and bystanders told the first-arriving firefighters that the passenger compartment contained five occupants and that some were too injured to self-extricate, no additional ambulances were

---

[97] For additional information, see http://www.rospa.com/road-safety/advice/drivers/bus-coach-minibus-drivers/minibuses-loading-safety/, accessed May 6, 2015.

[98] The EMS dispatch call was recorded at 1:04 a.m.; hospital arrivals for these vehicle occupants were at 2:20 a.m., 2:25 a.m., 2:35 a.m., and 2:35 a.m.

requested until ALS paramedics arrived.[99] Then, two additional ambulances were dispatched.[100] Partly as a result, there was confusion about whether to transport some of the first-assessed injured passengers immediately or to hold the ambulances for the more seriously injured. This confusion resulted in one of the injured being first placed in and then removed from an ambulance. The incident commander failed to establish a triage or medical point of contact and failed to recognize that insufficient BLS resources had been dispatched.

One injured passenger, from seat 4, arrived at the helicopter landing zone at 1:55 a.m. Care was delayed at the landing zone for about 10 minutes while flight paramedics assessed and stabilized this injured passenger; these tasks should have been performed before he was removed from the scene. The passenger was then transported by air, and he arrived at the emergency department at 2:25 a.m. Another injured passenger, from seat 3, was loaded into an ambulance at 1:53 a.m. and transported directly to the hospital, arriving at 2:20 a.m. ALS records indicate this injured person was found on scene in the care of members of a first aid squad but did not have appropriate interventions, such as a cervical collar or backboard.[101] For the transport of another injured passenger, from seat 6, time was lost due to uncoordinated medivac service. One BLS ambulance brought that injured passenger to the landing zone, incurred a delay of about 20 minutes because no medivac was available, and then transported him to the hospital by ground ambulance.

Routine prehospital emergency care procedures require patients with serious traumatic injuries to be immobilized to protect them from further injury. While there are some criteria to define situations in which minimally injured individuals would not need immobilization, none of the seriously injured passengers from the limo van met those criteria. The fact that, during the response to this crash, emergency medical personnel moved injured individuals who were not appropriately immobilized is evidence either of a training problem or of a lack of oversight to ensure adherence to standards. The New Jersey Turnpike receives federal funding that both supports and imposes requirements on its operation. Travelers from many different states, including New Jersey, have a reasonable expectation that an appropriate standard of care would guide EMS operations serving the turnpike.

New Jersey does not require fully volunteer first aid squads or their constituent volunteers to be certified or to submit to state-level standards or oversight. As such, it is not possible to ensure equipment, staffing, or care standards. The NTSB concludes that miscommunication and a lack of oversight on scene resulted in failure to obtain appropriate medical resources in a timely fashion, indicating that better integrated oversight and mutual agency training could help prepare emergency responders to avoid common problems. The NTSB recommends that the New Jersey Department of Health–Office of Emergency Medical Services and the New Jersey State First Aid Council, work together to establish, with the

[99] Notes from the fire chief on scene indicated that, upon arrival at the crash site, he thought only three victims were trapped.

[100] Monroe Township BLS ambulance 501 was dispatched at 1:39:26 a.m., and East Windsor Rescue Squad District 2 BLS ambulance 508 was dispatched at 1:43:32 a.m. Both ambulances had arrived on scene by 1:47:16 a.m. EMS records confirm that an injured person was assessed and stabilized 30 minutes before a BLS transport was available.

[101] There was ample time to have dealt with stabilizing this injured passenger; he was not loaded into an ambulance until an hour following the crash.

involvement of county EMS coordinators, local municipalities, and EMS agencies, minimum training and practice standards for all organizations that provide EMS on the New Jersey Turnpike.

2.7 Postcrash Walmart Transportation Safety Actions

In a postcrash submission Walmart Transportation provided to the NTSB, the motor carrier reported that it had taken measures to avoid similar accidents in the future by implementing new policies, including a driver commute policy. Walmart Transportation stated that it has implemented a plan to counsel drivers domiciled more than 250 miles from their assigned dispatch terminal. For those situations, a work commute plan is to be signed by the driver, discussed with the safety manager, and placed in the employee's file. According to the carrier, 6 months after the release of the June 2015 policy, Walmart Transportation drivers will be required to live within 250 miles of their assigned terminal, and newly hired drivers are to meet that requirement. The carrier reported that it is also considering a policy that would require drivers who live between 150 and 250 miles of their assigned terminals to enter into a work commute plan.

3 Conclusions

3.1 Findings

1. No mechanical conditions of the vehicles caused or contributed to the severity of the crash; alcohol, illicit drugs, or distractions did not appear to affect the Walmart Transportation LLC truck driver; and weather and road conditions were not factors in the crash.

2. The driver of the Walmart Transportation LLC truck was fatigued due to his failure to obtain sleep before reporting for duty, resulting in acute sleep loss and excessive time awake.

3. Due to his fatigued condition, the Walmart Transportation LLC truck driver had a delayed response to slowed traffic in an active work zone.

4. Although Walmart Transportation LLC addressed fatigue as part of its driver training program, it did not have a structured fatigue management program in place that could have improved its ability to better monitor and educate its drivers about the risks of fatigue.

5. Had the Federal Motor Carrier Safety Administration required motor carriers to adopt a fatigue management program as recommended by the National Transportation Safety Board in 2010, it seems likely, based on other instances of the carrier's compliance with federal motor carrier safety requirements, that Walmart Transportation LLC would have implemented a program to better monitor and educate its drivers about the risks of fatigue.

6. The research the Federal Motor Carrier Safety Administration has been conducting to evaluate integrated onboard systems, including fatigue-monitoring technologies, should be finalized.

7. With respect to the work zone where the crash took place, the New Jersey Turnpike Authority (NJTA) followed the guidance in 23 *Code of Federal Regulations* Part 630 Subpart J, and the NJTA's temporary traffic control zone and the lane closure process it used were in accordance with *Manual on Uniform Traffic Control Devices* "Standards" and NJTA policy.

8. Engineering decisions concerning traffic control devices would benefit from additional *Manual on Uniform Traffic Control Devices* (MUTCD) "Guidance" on (1) traffic conditions that call for supplemental devices in addition to the MUTCD "Standard," (2) the length of advance warning areas and the use of rumble strips in these areas, (3) traffic control devices particular to speed control, and (4) other proactive measures to monitor and warn motorists of traffic backing up within the work zone.

9. Had the Walmart Transportation LLC truck been traveling at the posted work zone speed of 45 mph, the vehicle could have been stopped before impact, if the brakes had been applied at the same point.

10. The Wingman Active Cruise with Braking system on the Walmart Transportation LLC truck was capable of issuing an alert to the driver just prior to the crash.

11. Based on the data recorded by the Wingman Active Cruise with Braking system, the system did not provide a precrash alert, although the possibility that it issued an alert that occurred between the 0.5-second data-sampling intervals cannot be ruled out.

12. Collision warning and avoidance systems capable of storing and retrieving vehicle and system performance information would aid in the evaluation and improvement of such systems, as well as facilitate a better understanding of crashes.

13. Analysis of critical event report data would enable Walmart Transportation LLC to better understand driving behavior factors in aggregate terms as well as to study individual driver-level performance.

14. The serious injuries sustained by the passengers seated in the passenger compartment of the limo van were caused by flailing and secondary impacts with the interior or other occupants, or intrusion/contact with the vehicle sidewall and roadway, which resulted, in part, from the passengers' failure to use available seat belts and properly adjusted head restraints.

15. The guidance provided to limousine operators concerning passenger seat belt use and properly adjusted head restraints is inadequate.

16. The modified limo van, with permanent barriers at the front and back of the passenger compartment and only one side door, failed to provide adequate means of emergency evacuation or rescue of injured victims.

17. Although the loaded limo van did not exceed its capacity at the time of the crash, and vehicle weight was not a factor in the crash, had all of its available seats been occupied, the limo van could have exceeded its capacity by several hundred pounds.

18. Miscommunication and a lack of oversight on scene resulted in failure to obtain appropriate medical resources in a timely fashion, indicating that better integrated oversight and mutual agency training could help prepare emergency responders to avoid common problems.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the Cranbury, New Jersey, crash was the Walmart Transportation LLC truck driver's fatigue, due to his failure to obtain sleep before reporting for duty, which resulted in his delayed reaction to slowing and stopped traffic ahead in an active work zone and his operation of the truck at a speed in excess of the posted limit. Contributing to the severity of the injuries was the fact that the passengers seated in the passenger compartment of the limo van were not using available seat belts and properly adjusted head restraints.

4 Recommendations

4.1 New Recommendations

As a result of its investigation, the NTSB makes the following new safety recommendations:

To the Federal Highway Administration:

Amend the *Manual on Uniform Traffic Control Devices* "Guidance" for work zone projects on freeways and expressways to advise traffic engineers on the use of supplemental traffic control strategies and devices to mitigate crash events involving heavy commercial vehicles. (H-15-16)

To the National Highway Traffic Safety Administration:

Require that modifications to limo van vehicles (1) retain a full-sized exit on at least one side of the vehicle's passenger compartment, and (2) have at least one other exit located on the front, back, or roof of the passenger compartment. (H-15-17)

To the New Jersey Department of Health–Office of Emergency Medical Services:

Work with the New Jersey State First Aid Council to establish, with the involvement of county emergency medical services (EMS) coordinators, local municipalities, and EMS agencies, minimum training and practice standards for all organizations that provide EMS on the New Jersey Turnpike. (H-15-18)

To the New Jersey State First Aid Council:

Work with the New Jersey Department of Health–Office of Emergency Medical Services to establish, with the involvement of county emergency medical services (EMS) coordinators, local municipalities, and EMS agencies, minimum training and practice standards for all organizations that provide EMS on the New Jersey Turnpike. (H-15-19)

To the National Limousine Association:

Develop and distribute guidelines to your member operators urging them, during pretrip safety briefings, to (1) direct passengers to use seat belts where required by law and strongly encourage passengers to use seat belts where not required by law, and (2) encourage passengers to use properly adjusted head restraints. (H-15-20)

Request that your vehicle-altering and final-stage manufacturing members post the total passenger and luggage weight limit on any vehicle they alter. (H-15-21)

To Walmart Transportation LLC:

Develop and implement a fatigue management program based on the North American Fatigue Management Program guidelines. (H-15-22)

Incorporate into your corporate safety program a method for conducting ongoing analysis of aggregated critical event report data on hard-braking and stability control events. (H-15-23)

To Bendix Commercial Vehicle Systems LLC, Detroit Diesel Corporation, and Meritor WABCO Vehicle Control Systems:

Include, in all collision warning and avoidance systems for use on truck-tractors, single-unit trucks, and motorcoaches, the capability to store and retrieve data pertaining to object detection, driver audible/visual alerts, and interventions by the system for a period and at a data rate adequate to support accident investigation and reconstruction. (H-15-24)

4.2 Reiterated Recommendations

As a result of its investigation, the NTSB reiterates the following safety recommendations:

To the Federal Motor Carrier Safety Administration:

H-10-9

Require all motor carriers to adopt a fatigue management program based on the North American Fatigue Management Program guidelines for the management of fatigue in a motor carrier operating environment.

H-12-13

Develop and disseminate guidance for motor carriers on how to most effectively use currently available onboard monitoring systems and develop a plan to periodically update the guidance.

H-15-14

Require all passenger motor carrier operators to (1) provide passengers with pretrip safety information that includes, at a minimum, a demonstration of the location of all exits, explains how to operate the exits in an emergency, and emphasizes the importance of wearing seat belts, if available; and (2) also place printed instructions in readily accessible locations for each passenger to help reinforce exit operation and seat belt usage.

To the National Highway Traffic Safety Administration:

H-12-20

Develop performance standards for advanced speed-limiting technology, such as variable speed limiters and intelligent speed adaptation devices, for heavy vehicles, including trucks, buses, and motorcoaches.

H-12-21

After establishing performance standards for advanced speed-limiting technology for heavy commercial vehicles, require that all newly manufactured heavy vehicles be equipped with such devices.

H-15-5

Complete, as soon as possible, the development and application of performance standards and protocols for the assessment of forward collision avoidance systems in commercial vehicles.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

CHRISTOPHER A. HART
Chairman

ROBERT L. SUMWALT
Member

T. BELLA DINH-ZARR
Vice Chairman

EARL F. WEENER
Member

Adopted: August 11, 2015

Member Weener filed the following statement.

Board Member Statement

Member Earl F. Weener filed the following concurring statement on August 18, 2015.

Notation 8717 – Member Weener's Statement: Concurring

The underlying investigation of this unfortunate accident was comprehensive and sound and I concur with the report, including the findings as amended at the Board Meeting, and the probable cause. However, I am concerned that we are not giving enough attention to the human factors issues associated with the improving technology, fitness for duty and personal responsibility, and prevention versus survivability. This incident involves issues with fatigue, limitations of technology, vehicle modifications, and emergency response, all of which require personal accountability and appropriate oversight to overcome.

Every year, motor vehicle crashes claim more than 30,000 lives, injure tens of thousands more, and cost billions of dollars in damages. In 2012 alone, more than 1.7 million rear-end crashes occurred on our nation's highways, resulting in more than 1,700 fatalities and 500,000 injured people. Many of these accidents could have been mitigated, or possibly even prevented, with the use of technology. However, slow and insufficient action on the part of the National Highway Traffic Safety Administration (NHTSA) to develop performance standards for these technologies and require them in passenger and commercial vehicles, has contributed to the ongoing and unacceptable frequency of rear-end crashes.[1]

Highway crashes are largely preventable and predictable; they are human-made problems amenable to rational analysis and countermeasures.[2] More than 30 years ago, William Haddon, Jr., described road transportation as an ill-designed "man-machine" system needing comprehensive systemic treatment.[3] The Haddon Matrix illustrates the interaction of three factors – human, vehicle, and environment – during three phases of a crash event: pre-crash, crash, and post-crash (Figure 1). Each cell of his matrix allows opportunities for intervention to reduce highway crash injury. In this accident, factors that could populate the Haddon Matrix include, in the pre-crash phase, fatigue (impairment), speed management, and highway work zone. The crash phase could include fatigue, seat belts and head restraints, and vehicle modifications. Lastly, the post-crash phase illustrates the lack of first responder training and certification, difficulty extracting victims, design/modification of the limo, and emergency transportation coordination.

1 NTSB Safety Recommendations H-01-007—*Closed—Unacceptable Action*, H-08-15—*Closed Unacceptable Action*.

2 World report of road traffic injury prevention, edited by Margie Peden [et al.]. ISBN 92 4 149131 5. © World Health Organization 2004.

3 Haddon, Jr., W., The Changing Approach to the epidemiology, prevention, and amelioration of trauma: the transition to approaches etiologically rather than descriptively bases. American Journal of Public Health, 1968, 58:1431-1438.

The Haddon Matrix				
		FACTORS		
PHASE		HUMAN	VEHICLES AND EQUIPMENT	ENVIRONMENT
Pre-crash	Crash Prevention	Information Attitudes Impairment Police enforcement	Roadworthiness Lighting Braking Speed management	Road design and layout Speed limits pedestrian facilities
Crash	Injury prevention during the crash	Use of restraints Impairment	Occupant restraints Other safety devices crash-protective design	Crash-protective roadside objects
Post-crash	Life sustaining	First-aid skill Access to medics	Ease of access Fire risk	Rescue facilities Congestion

Figure 1.

The National Transportation Safety Board (NTSB) has for nearly two decades encouraged technological countermeasures to rear-end collisions and has previously issued 12 safety recommendations pertaining to this issue. The accident report adds one new recommendation and reiterates three previously issued. As clearly articulated in this year's Special Investigation Report – *The Use of Forward Collision Avoidance Systems to Prevent and Mitigate Rear-End Crashes*, forward collision avoidance systems will likely prevent or at least mitigate rear-end collisions.[4]

This is the first accident in which we have had the opportunity to investigate a striking vehicle that was equipped with a forward collision avoidance system. In this case, the installed technology was the Bendix Wingman Active Cruise with braking system (ACB). However, this system only provided autonomous braking when in cruise control mode. The driver was impaired due to fatigue, admitting on scene that he fell asleep, and he was not driving with the cruise control on; therefore, automatic braking did not apply to prevent or mitigate the rear-end crash. Further, no radar data were recorded because the cruise control was off; all other system status snapshots were recorded at only 0.5-second intervals preceding the collision which limited data analysis.[5] More important though is the fact that the device delivers a stationary object alert up to 3.0 seconds in advance of sizable stationary objects, and impact alerts warn the driver via text and a loud continuous tone to take immediate evasive action to avoid a potential collision, if a threat is within 500 feet. Research has estimated driver reaction time to be 2.3 seconds (some accident reconstruction specialists use 1.5 seconds).[6] An alert of only 3.0 seconds would likely not prevent an accident without autonomous braking, particularly if the driver is experiencing an episode of micro-sleep or is experiencing extreme fatigue while driving 65 mph.

Commercial truck drivers are expected to be professional drivers, and Title 49 *Code of Federal Regulations* Part 392 prohibits operation of a commercial motor vehicle while the driver's ability or alertness is so impaired by fatigue, illness, or any other cause, that it is unsafe to operate the

[4] Special Investigation Report: *The Use of Forward Collision Avoidance Systems to Prevent and Mitigate Rear-End Crashes, May 19, 2015*, NTSB/SIR-15-01 (Washington, DC: National Transportation Safety Board, 2015).

[5] Bendix has now developed three generations of this technology, with this being the first.

[6] McGee, Daniel V., et al. Driver Reaction Time in Crash Avoidance Research: Validation of Driver Simulator Study on a test track, 2000 (IEA2000_ABS51.pdf), http://copradar.com/redligth/factors/index.html (accessed August 13, 2015.

vehicle.[7] Fatigue has been found to be a factor in 30% of fatal crashes involving heavy commercial vehicles. The risk of being involved in a highway crash doubles after 11 hours of driving and is 10 times greater at night than during the day. Scientific research has shown that fatigue is affected by several factors, including duration and quality of sleep, shiftwork and work schedules, circadian rhythms, and time of day and that it can impair information processing and reaction time.[8,9] In this case, the regulation was not a deterrent to driving while fatigued. Additionally, it is unrealistic to expect a regulation to govern personal time off. However, a professional truck driver has an implied expectation of personal responsibility and an expectation to report for duty properly rested.

The Federal Motor Carrier Safety Administration (FMCSA) has reported that driver impairment, including by fatigue, was the fourth most commonly cited factor in fatal truck crashes in 2012.[10]

I submit that we, along with NHTSA and the FMCSA, need to focus more attention on the human factors challenges. Technology and enhanced safety devices should be explored, and fatigue management and personal accountability amongst highway drivers with special emphasis on environmental conditions such as work zones; needs to be advocated throughout the government, industry, organized labor, industry associations, and the driving community.

Chairman Hart and Member Sumwalt joined in this statement.

[7] 35 FR 7800, May 21, 1970, as amended at 60 FR 38746, dated July 28, 1995.

[8] Safety Report: *Efforts in 1990's to Address Operator Fatigue* NTSB/SR-99-01 (Washington, DC: National Transportation Safety Board, 1999).

[9] Roehrs, T.; Beare, D.; Zorick, F., Roth, T. 1994. *Sleepiness and Ethanol Effects on Simulated Driving*.

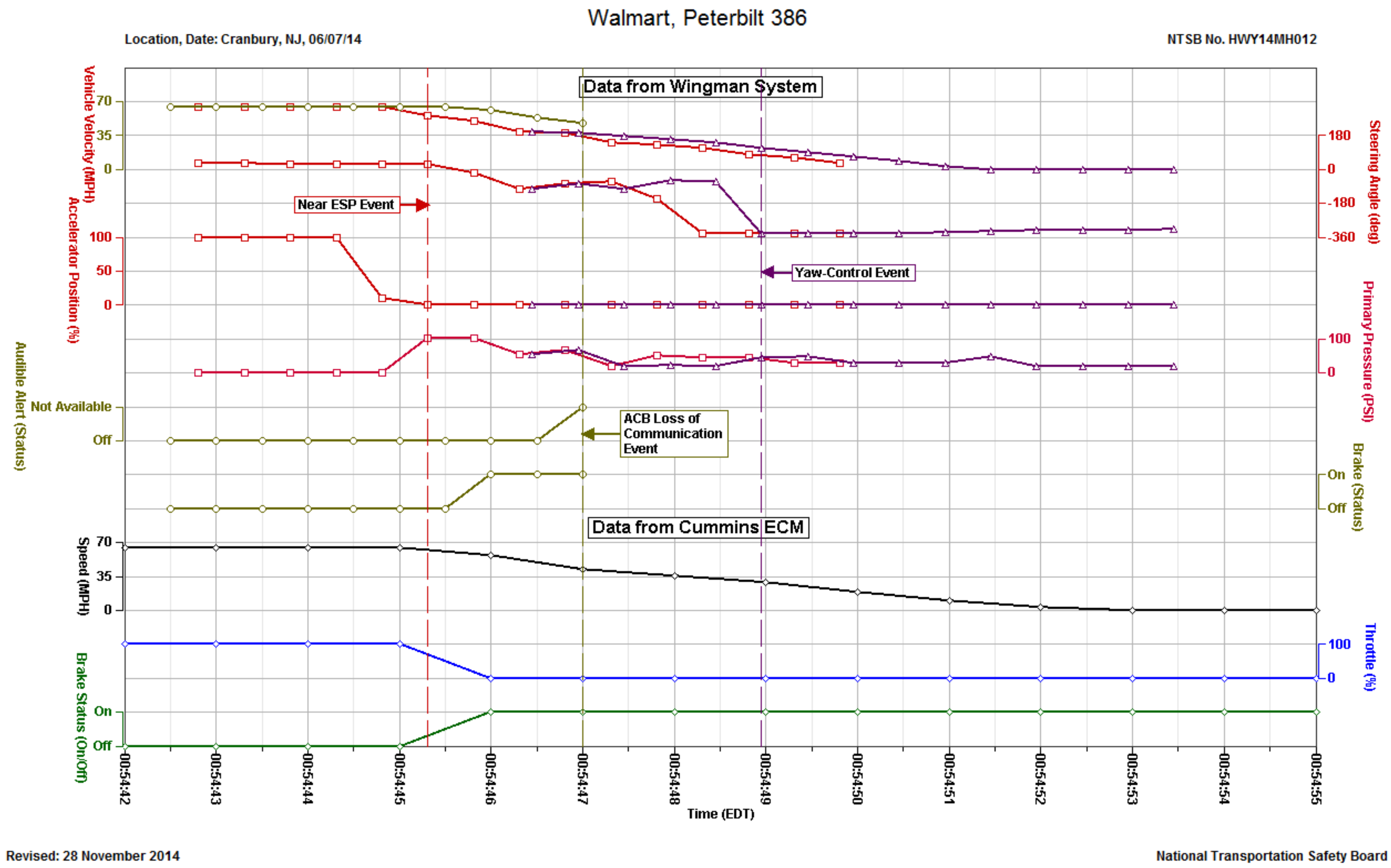
[10] FMCSA, *Large Truck and Bus Crash Facts 2012*, June 2014.

Appendix A. Investigation

The National Transportation Safety Board (NTSB) received notification of this crash on Saturday, June 7, 2014, and launched investigators to address motor carrier, survival, human, vehicle, and highway factors. The NTSB team included staff from the Office of Research and Engineering.

The Federal Motor Carrier Safety Administration, Federal Highway Administration, National Highway Traffic Safety Administration, New Jersey State Police, New Jersey Turnpike Authority, Middlesex County Prosecutor's Office (Homicide/Fatal Crash unit), Walmart Transportation LLC, and Bendix Commercial Vehicle Systems LLC were parties to the investigation.

Appendix B. Walmart Transportation Truck ESP and ECM Data

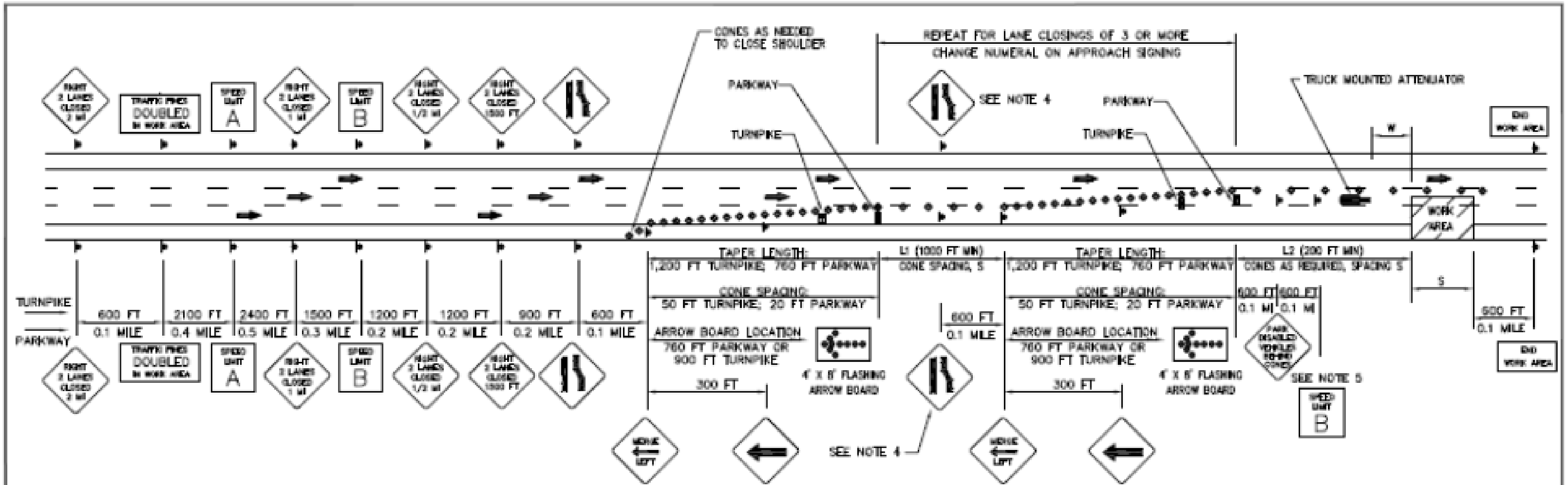


Appendix C. Collision-Related Data Parameters for the Walmart Transportation Truck, Limo Van, Buick Enclave, and Ford F-150 Pickup Truck

Vehicle	Data Source	Event Trigger	Data Parameter Used	Data Recording
Walmart Transportation truck	Cummins ECM	Hard braking	• Vehicle speed • Brake status (on/off) • Percent throttle • Cruise control	60 seconds before and 15 seconds following the trigger event at 1-second intervals
	Bendix Active Cruise Control and Electronic Stability Program (ESP)	• Communication loss with radar sensor • Activation of rear electronic stability program • Yaw-control brake intervention event	• Vehicle speed • Steering angle	• 5 seconds before trigger event • 2.5 seconds before and 5 seconds following the trigger event at 1/2-second intervals
	Omnitracs fleet management system	"Critical event" - Hard braking *(Customer has flexibility to define what actions constitute a trigger or critical event.*)	• Speed • Time: GPS-based	~5 minutes before and 2 minutes following trigger event at 1-second intervals
Limo van	Audiovox fleet management device	GPS position recorded at specified intervals and at changes in ignition status	• Position • Average speed • Time	• Geographic coordinates • Average speed between coordinates • GPS clock time • 24 hours of data
	Garmin nuvi 2555LMT portable GPS	GPS position based on time interval or changes to vehicle speed or heading	• Position • Average speed • Time	• Geographic coordinates • Average speed between coordinates • GPS clock time

Vehicle	Data Source	Event Trigger	Data Parameter Used	Data Recording
Buick Enclave	Airbag control module (sensing and diagnostic module)	Airbag algorithm activation (algorithm enable [AE])	• Speed • Brake status • Supplemental restraint system deployment timing • Impact orientation	2.5 seconds pre-AE in 1/2-second intervals – data reported is asynchronous
Ford F-150 pickup truck	Airbag control module (restraint control module)	Airbag algorithm activation (AE)	• Speed • Brake status • Supplemental restraint system deployment timing	5 seconds pre-AE in 1/2-second intervals – data reported is asynchronous

Appendix D. New Jersey Turnpike Authority Traffic Protection Standard



CONE SPACING, S (FT)

ROADWAY	S
PARKWAY	80
TURNPIKE	75

TMA SPACING, W (FT)

WORK ZONE SPEED LIMIT	W
45	100
35	75

PARKWAY SPEED LIMIT SIGNING

MILEPOST	SPEED LIMIT SIGN A	SPEED LIMIT SIGN B
0–7.6	N/A	N/A
7.6–12	45	45
12–63	N/A	N/A
63–80	55	45
80–100	45	45
100–124	55	45
124–165	45	45
165–172	55	45

* – SEE NOTE 1

TURNPIKE SPEED LIMIT SIGNING

MILEPOST	SPEED LIMIT SIGN A	SPEED LIMIT SIGN B
0–52	N/A	N/A
PHMTE*	45	45
52–97	45	45
97–105	45	45
105E–117E	45	45
105W–113W	45	45
113W–117W	N/A	N/A
117–122	45	45
NBHCE	N/A	N/A

* – SEE NOTE 6

NOTES:

1. THIS DETAIL NOT APPLICABLE TO THE EXPRESS ROADWAY OF THE GARDEN STATE PARKWAY FROM MILEPOST 104 TO MILEPOST 118.
2. "L2" DEPENDS ON THE TAPER POINT LOCATION BUT SHALL BE A MINIMUM OF 200 FEET.
3. A LANE CLOSING WILL BE REQUIRED WHEN THE SHOULDER IS LESS THAN 10 FEET WIDE OR WHEN EQUIPMENT IS OPERATED LESS THAN 3 FEET FROM THE TRAVELED LANE. HOWEVER, STABILIZING ATTACHMENTS SUCH AS OUTRIGGERS MAY EXTEND TO THE SHOULDER LINE WITHOUT NECESSITATING THE CLOSING OF THE ADJACENT LANE.
4. WHEN THE DISTANCE "L1" IS ONE-HALF MILE OR MORE, A W9-3(L OR R) SIGN SHOULD BE USED A MINIMUM OF 500 FEET IN ADVANCE OF THE W4-2(L OR R) SIGN SHOWN AND SHOULD BE PLACED ON BOTH SIDES OF THE ROADWAY.
5. A SIGN "PARK DISABLED VEHICLES BEHIND CONES" SHALL BE INSTALLED WHERE SHOWN FOR CLOSINGS OF ONE-HALF MILE OR MORE. SHOULD THE LENGTH OF THE WORK ZONE PERMIT, A SPEED LIMIT SIGN WITH VALUE "B" SHALL BE INSTALLED DOWNSTREAM FROM THE "PARK DISABLED VEHICLES BEHIND CONES" SIGN. THIS SPEED LIMIT SIGN SHALL REPEAT EVERY ONE-HALF MILE SHOULD THE LENGTH OF THE WORK ZONE PERMIT. ADDITIONAL "PARK DISABLED VEHICLES BEHIND CONES" SIGN(S) MAY BE INSTALLED SHOULD THE LENGTH OF THE WORK ZONE PERMIT, BUT AT A MINIMUM 500 FEET FROM ANY OTHER TEMPORARY TRAFFIC CONTROL SIGN.
6. FOR THE WESTBOUND PEARL HARBOR MEMORIAL TURNPIKE EXTENSION (PHMTE) BETWEEN MILEPOSTS P3.7 AND P1.0, A=45 AND B=45. FOR WORK AREAS ELSEWHERE ON THE PHMTE, THE VALUES SHOWN APPLY.

LEGEND:

- TEMPORARY TRAFFIC CONTROL SIGN
- ARROW BOARD
- CONE
- DIRECTION OF TRAVEL

No.	DATE	REVISION
1	6/11	REVISED DRAWING

NEW JERSEY TURNPIKE AUTHORITY
TRAFFIC PROTECTION STANDARD DRAWING

MULTIPLE RIGHT LANE CLOSING

OPERATIONS DEPARTMENT
WOODBRIDGE, NEW JERSEY
Drawing By: EDD
Checked By: KJM

SCALE: NONE
DATE: 10/2009

TP 3

Appendix E. Sequence of Traffic Control Devices Used in the Work Zone Area

1. **MP 70.5**: warning began (2 miles before the beginning taper of lane closure) with two standard warning signs, one on each side of the roadway, indicating "Right 2 Lanes Closed 2 MI"
2. **Approximately MP 70.6** (600 feet past the warning signs noted in #1): a set of black and white regulatory signs was posted indicating that traffic fines were doubled in the work area
3. **MP 71.0** (100 feet after sign referenced in #2): black and white speed limit signs indicating a limit of 45 mph were posted on both sides of the road
4. **MP 71.5** (1/2 mile past the first speed limit sign): a second set of warning signs indicating "Right 2 Lanes Closed 1 MI" was posted
5. **MP 71.8**: second set of black and white 45-mph speed limit signs was posted on both sides of the road
6. **MP 72**: another set of warning signs was posted on both sides of the road indicating "Right 2 Lanes Closed 1/2 MI"
7. **MP 72.2**: another set of warning signs indicating "Right 2 Lanes Closed 1500 FT" was posted
8. **MP 72.4**: a set of lane ending warning signs was placed on both sides of the road
9. **MP 72.5**: "Merge Left" warning sign was posted on the right roadside; in addition, the 1,200-foot-long taper began with 50-foot spacings
10. **Approximately MP 72.7** (900 feet into the first taper): a 4-foot by 8-foot flashing arrow board was erected, warning drivers to move left out of the right-hand lane
11. **Approximately MP 72.8** (at the end of the first taper): cones were placed over a 1,000-foot-long area before the next taper began, which closed off the center lane; cone spacing was 75 feet in the tangent area; this taper was preceded by a lane ending sign, a merge left sign, and a flashing arrow board; the second taper also had 50-foot cone spacing over a 1,200-foot length
12. **Approximately MP 72.9** (At the end of the second taper): a warning sign advising motorists to park disabled vehicles behind cones; this warning sign was followed by another 45-mph speed limit sign
13. **Between the end of the taper and the actual work area**: cones were spaced at 75-foot intervals
14. **MP 74.1**: the work area was preceded by two crash attenuator trucks positioned in each lane approximately 200 feet before the work crew

Appendix F. North American Fatigue Management Program

The North American Fatigue Management Program (NAFMP) was developed by American and Canadian regulators, carriers, insurers, and researchers. The NAFMP is a voluntary, fully interactive, web-based educational and training program developed to provide truck and bus commercial vehicle drivers, as well as carriers, an awareness of the factors contributing to fatigue and its effect on performance. (For additional information, see http://www.nafmp.com/en/about-nafmp/faqs.html.) The NAFMP was developed specifically to address the fact that while hours-of-service regulations can address work hours and required off-duty time, they cannot dictate lifestyle choices outside of the work environment—the specific situation discovered in the Cranbury, New Jersey, crash.

The NAFMP is arranged into modules; depending on a person's role (driver, safety manager, family, and so forth), specific modules would apply to that person. The suggested modules for some specific roles are listed in table F–1.

Table F–1. Suggested NAFMP modules by role.

Module	Executives	Safety Managers	Dispatchers	Drivers	Family	Shippers/ Receivers
Introduction and Overview	X	X	X			
Safety Culture and Management Practices	X					
Driver Education		X	X	X		
Driver Family Education		X			X	
Train-the-Trainer for Driver Education and Family Forum		X				
Shippers and Receivers						X
Motor Carrier Sleep Disorders Management	X	X	X			
Driver Sleep Disorders Management				X		
Driver Scheduling and Tools			X			
Fatigue Mentoring and Management Technologies	X					

References

Bendix (Bendix Commercial Vehicle Systems LLC). 2010. *Bendix Wingman ACB Active Cruise Control with Braking Operator's Manual*. Elyria, OH: Bendix. (A PDF of the manual is available at http://www.bendix.com/en/products/acb/wingmanacb/acb_1.jsp?q=operator's manual acb, accessed June 30, 2015.)

Bourne, J., C. Eng, G. Ullman, D. Gomez, B. Zimmerman, T. Scriba, R. Lipps, D. Markow, K.C. Matthews, D. Holstein, and R. Stargell. 2010. Scan 08-04, *Best Practices in Work Zone Assessment, Data Collection, and Performance Evaluation*. Work described in this document was conducted as part of NCHRP Project 20-68A, the US Domestic Scan program.

Brown, T., J. Lee, C. Schwarz, D. Fiorentino, and A. McDonald. 2014. *Assessing the Feasibility of Vehicle-Based Sensors to Detect Drowsy Driving*. Report No. DOT HS 811 886. Washington, DC: National Highway Traffic Safety Administration.

Bryden, J., and D. Mace. 2002. NCHRP Report 476: *Guidelines for Design and Operation of Nighttime Traffic Control for Highway Maintenance and Construction*. Washington, DC: Transportation Research Board.

Carskadon, M., and W. Dement. 2005. "Normal Human Sleep: An Overview." In M. Kryger, T. Roth, and W. Dement (eds.). *Principles and Practice of Sleep Medicine*. 4th Edition. Philadelphia, PA: Elsevier-Sanders.

FAA (Federal Aviation Administration). 2005. *Advisory Circular—Aircraft Weight and Balance Control*. AC 120-27E. Washington, DC: FAA.

Federal Register. 2004. Vol. 69, no. 174 (September 9), "Work Zone Safety and Mobility."

____. 1995. Vol. 60. no. 205 (October 24), "Notices Regarding the National Highway Work Zone Safety Program."

FHWA (Federal Highway Administration). 2006. *Work Zone Impacts Assessment: An Approach to Assess and Manage Work Zone Safety and Mobility Impacts of Road Projects*, FHWA-HOP-05-068. Washington, DC: FHWA. (For additional information, see http://ops.fhwa.dot.gov/wz/resources/final_rule/wzi_guide/wzi_guide.pdf, accessed August 7, 2015.)

____. 2004. *Intelligent Transportation Systems in Work Zones. 2004. A Case Study: Work Zone Traffic and Incident Management System*, FHWA-OP-04-072. Washington, DC: FHWA. (See http://ops.fhwa.dot.gov/wz/technologies/albuquerque/its_albuquerque.pdf, accessed August 7, 2015.)

FMCSA (Federal Motor Carrier Safety Administration). 2014. *Analysis Brief: Work Zone Fatal Crashes Involving Large Trucks, 2012*. Washington, DC: FMCSA.

Goel, N., M. Basner, H. Rao, and D.F. Dinges. 2013. "Circadian Rhythms, Sleep Deprivation, and Human Performance," *Process in Molecular Biology and Translational Science* 119: 155–190.

Goel, N., H. Rao, J.S. Durmer, and D.F. Dinges. 2009. "Neurocognitive Consequences of Sleep Deprivation," *Seminars in Neurology* 29: 320–339.

Hellinga, B. 2001. "Automated Freeway Queue Warning Systems: Optimizing Performance." Presentation at the INFORMS International Conference, Cluster: Dynamic Optimization, Maui, Hawaii.

Kujirai, S. and M. Matano. 1998. "Introduction of Congestion Tail Display System into Metropolitan Expressway," *OMRON Technics* 38(2), serial 126.

Lamond, N. and D. Dawson. 1999. "Quantifying the Performance Impairment Associated with Fatigue" *Journal of Sleep Research* 8: 255–262.

Li, Y. and Y. Bai. 2008. "Comparison of Characteristics Between Fatal and Injury Accidents in the Highway Construction Zones," *Safety Science* 46(4): 646–660.

Lim, J. and D.F. Dinges. 2010. "A Meta-Analysis of the Impact of Short-Term Sleep Deprivation on Cognitive Variables," *Psychological Bulletin* 136(3): 375–389.

Maze, T., S.D. Schrock, and A. Kamyab. 2000. "Capacity of Freeway Work Zone Lane Closures," P*roceedings, Mid-Continent Transportation Symposium 2000*. Ames, IA: Iowa State University Center for Transportation Research and Education.

NAFMP (North American Fatigue Management Program). 2015. NAFMP website. (http://www.nafmp.com/en/, accessed August 7, 2015.)

NJDOT (New Jersey Department of Transportation). 2007. *Traffic Mitigation Guidelines for Work Zone Safety and Mobility*, "Appendix A: Policy & Procedure 815." Trenton, NJ: NJDOT.

NJSP (New Jersey State Police). 2014. Report number D010-2014-00731A.

NTSB (National Transportation Safety Board). 2015a. *The Use of Forward Collision Avoidance Systems to Prevent and Mitigate Rear-End Crashes*. NTSB/SIR-15/01. Washington, DC: NTSB.

____. 2015b. *Truck-Tractor Double Trailer Median Crossover Collision With Motorcoach and Postcrash Fire on Interstate 5, Orland, California, April 10, 2014.* NTSB/HAR-15/01. Washington, DC: NTSB.

____. 2015c. Lake City, Florida, February 21, 2014, crash investigation. NTSB accident HWY14FH007.

____. 2015d. Davis, Oklahoma, September 26, 2014, crash investigation. NTSB accident HWY14MH014.

____. 2013. *School Bus and Truck Collision at Intersection Near Chesterfield, New Jersey, February 16, 2012*. NTSB/HAR-13/01. Washington, DC: NTSB.

____. 2012a. *Motorcoach Run-Off-the-Road and Collision With Vertical Highway Signpost, Interstate 95 Southbound, New York City, New York, March 12, 2011*. NTSB/HAR-12/01. Washington, DC: NTSB.

____. 2012b. *Motorcoach Roadway Departure and Overturn on Interstate 95 Near Doswell, Virginia, May 31, 2011*. NTSB/HAR-12/02. Washington, DC: NTSB.

____. 2010. *Truck-Tractor Semitrailer Rear-End Collision Into Passenger Vehicles on Interstate 44, Near Miami, Oklahoma, June 26, 2009*. NTSB/HAR-10/02. Washington, DC: NTSB.

____. 2009a. *Motorcoach Rollover on US Highway 59 Near Victoria, Texas, January 2, 2008*. NTSB/HAR-09/03/SUM. Washington, DC: NTSB.

____. 2009b. *Motorcoach Run-Off-the-Bridge and Rollover, Sherman, Texas, August 8, 2008*. NTSB/HAR-09/02. Washington, DC: NTSB.

____. 2009c. *Motorcoach Run-Off-the-Road and Rollover, US Route 163, Mexican Hat, Utah, January 6, 2008*. NTSB/HAR-09/01. Washington, DC: NTSB.

____. 2008a. *Rear-End Chain-Reaction Collision State Route 121, Near Lake Butler, Florida, January 25, 2006*. NTSB/HAB-08/05. Washington, DC: NTSB.

____. 2008b. *Motorcoach Run-Off-the-Road and Rollover, Interstate 55, Near Turrell, Arkansas, October 9, 2004*. NTSB/HAB-08/04. Washington, DC: NTSB.

____. 2008c. *Truck-Tractor Semitrailer Rollover and Motorcoach Collision With Overturned Truck, Interstate Highway 94, Near Osseo, Wisconsin, October 16, 2005*. NTSB/HAR-08/02. Washington, DC: NTSB.

____. 2007. *Rear-End Chain Reaction Collision, Interstate 94 East, Chelsea, Michigan, July 16, 2004*. NTSB/HAB-07/01. Washington, DC: NTSB.

____. 2001. *Vehicle- and Infrastructure-Based Technology for the Prevention of Rear-End Collisions*. NTSB/SIR-01/01. Washington, DC: NTSB.

____. 1995. *Multiple Vehicle Collision With Fire During Fog Near Milepost 118 on Interstate 40, Menifee, Arkansas, January 9, 1995*. NTSB/HAR-95/03. Washington, DC: NTSB.

____. 1992. *Highway Work Zone Safety*, NTSB/SS-92-02. Washington, DC: NTSB.

____. 1991. *Multiple Vehicle Collision and Fire in a Work Zone on Interstate Highway 79 Near Sutton, West Virginia, July 26, 1990*. NTSB/HAR-91/01. Washington, DC: NTSB.

Romjue, Martin. 2014. "Know Your Limits before Putting on Vehicle Pounds," *Limousine, Charter & Tour*, February 2014. Skokie, IL: Limousine, Charter & Tour. (http://www.lctmag.com/regulations/article/43089/know-your-limits-before-putting-on-vehicle-pounds, accessed April 7, 2015.)

TRB. (Transportation Research Board). 2005. NCHRP Report 500: *Guidance for Implementation of the AASHTO Strategic Highway Safety Plan, Volume 17: A Guide for Reducing Work Zone Collisions*. Washington, DC: TRB.

Ullman, G., M. Finley, J. Bryden, R. Srinivasan, and F. Council. 2008. NCHRP Report: 627: *Traffic Safety Evaluation of Nighttime and Daytime Work Zones*. Washington, DC: TRB.

Ullman, G., J. Schroeder, and D. Gopalakrishna. 2014. *Use of Technology and Data for Effective Work Zone Management: Work Zone ITS Implementation Guide*, FHWA-HOP-14-008. Washington, DC: FHWA.

Wiles, P., S. Conner, C. Walters, and E. Pultorak. 2003. *Advance Warning of Stopped Traffic on Freeways: Current Practices and Field Studies of Queue Propagation Speeds*, Research Report 0-4413-1. College Station, TX: Texas Transportation Institute.