Pedestrian Safety

Special Investigation Report

NTSB/SIR-18/03
PB2018-101632

National
Transportation
Safety Board

NTSB/SIR-18/03
PB2018-101632
Notation 58357
Adopted September 25, 2018

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Washington, D.C. 20594

National Transportation Safety Board. 2018. *Pedestrian Safety*. Special Investigation Report NTSB/SIR-18/03. Washington, DC.

Abstract: In this special investigation report, the National Transportation Safety Board (NTSB) examines pedestrian safety in the United States and recommends actions to help prevent pedestrian injuries and fatalities. The investigation, which began in 2016 with a public forum on pedestrian safety, was supported by an inquiry into the causes of 15 crashes in which vehicles fatally injured pedestrians on public highways—representing only a fraction of the nearly 6,000 pedestrians killed on US roads in 2016. The report reviews the past 10 years of data on highway deaths; describes previous NTSB investigations related to pedestrian safety, including the 15 fatal pedestrian crashes as well as studies of the effects of speed and alcohol on highway crashes; summarizes the issues raised during the public forum; and makes 11 recommendations for improving pedestrian safety. The report considers vehicle-based countermeasures, such as improved headlights, vehicle designs that reduce injuries to pedestrians, and collision avoidance systems. It also reviews infrastructure designs that make streets safer for pedestrians. The report emphasizes that better data are needed—especially on pedestrian activity (exposure data) and on the types and outcomes of crashes involving pedestrians—to improve federal, state, and local decision-making related to pedestrian safety. As a result of its special investigation, the NTSB made safety recommendations to the National Highway Traffic Safety Administration, the Federal Highway Administration, and the Centers for Disease Control and Prevention.

The NTSB is an independent federal agency dedicated to promoting aviation, railroad, highway, marine, and pipeline safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, "accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties . . . and are not conducted for the purpose of determining the rights or liabilities of any person." 49 *Code of Federal Regulations* section 831.4. Assignment of fault or legal liability is not relevant to the NTSB's statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report. 9 *United States Code* section 1154(b).

For more detailed background information on this report, visit the NTSB investigations webpage and search for NTSB accident number DCA15SS005. Recent publications are available in their entirety at the NTSB website. Other information about available publications can also 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.**

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
BAC	blood alcohol concentration
CRSS	Crash Reporting Sampling System
CODES	Crash Outcome Data Evaluation System
FARS	Fatality Analysis Reporting System
FAST	Fixing America's Surface Transportation (Act)
FMVSS	Federal Motor Vehicle Safety Standard
GES	General Estimates System
GTR	global technical regulation
HSIP	Highway Safety Improvement Program
LED	light-emitting diode
NASS	National Automotive Sampling System
NCAP	New Car Assessment Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
STEP	Safe Transportation for Every Pedestrian
STRADA	Swedish Traffic Accident Data Acquisition
SUV	sport utility vehicle

Executive Summary

In May 2016, the National Transportation Safety Board (NTSB) hosted a forum intended to begin a public conversation about pedestrian safety. After the forum, the NTSB began investigating a series of 15 fatal crashes in which vehicles on public highways killed pedestrians. In 2016, during the project design phase, the set of 15 investigative cases represented the average number of pedestrian fatalities every day. By the time the project was complete, the average had increased to 16 a day.

This special investigation report discusses the public forum and previous NTSB investigations related to pedestrian safety, including the 15 fatal pedestrian crashes, and makes recommendations to improve pedestrian safety. Special investigation reports combine the work of a similar set of cases to address a particular safety issue. This report and the related public forum represent the NTSB's first full consideration of pedestrian safety since the 1970s.

The report uses an organizing framework of vehicle-based changes, infrastructure improvements, and data needs for improving pedestrian safety. Given that the poor visibility of people walking in and around moving vehicles is a serious problem, the report considers improvements to vehicle lighting systems that are being developed but are not yet in place. The report also considers other vehicle safety systems that can improve pedestrian safety and recognizes the needs of local transportation planning work to improve pedestrian safety. Several recommendations target data needs to better guide the implementation of countermeasures and to gauge the effectiveness of programmatic efforts. The report focuses on issues common to all pedestrians without separating out subgroups of risk or specific countermeasures for only certain types of events. The report makes recommendations to the National Highway Traffic Safety Administration, the Federal Highway Administration, and the Centers for Disease Control and Prevention.

1 Introduction

The number of pedestrians killed on our roadways exhibited a decreasing trend for 35 years, but beginning in 2010, the number of fatalities began increasing.[1] In 2016, according to data in the US Department of Transportation Fatality Analysis Reporting System (FARS), a total of 5,987 pedestrians died in collisions with highway vehicles in the United States—on average, more than 16 per day.[2] Preliminary estimates from the states for the number of fatalities in 2017 remain essentially unchanged, at 5,984 pedestrian fatalities (Retting 2018). An accurate number of all pedestrian crashes, not just fatal crashes, is difficult to determine.[3] As estimated by the Centers for Disease Control and Prevention, however, annual traffic-related injuries to pedestrians on US public roads (number of crashes) had risen to 129,000 by 2015.[4]

Not only has the number of pedestrian crashes increased, but as reported by the Insurance Institute for Highway Safety, pedestrian crashes have also become deadlier—deaths per 100 crashes increased by 29 percent from 2010 to 2015 (Hu and Cicchino 2018). The following section summarizes selected characteristics of the FARS data for the period 2007–2016. Additional data and observations are found in a supplemental data report titled *Fatal and Nonfatal Crashes Involving Pedestrians*, available in the National Transportation Safety Board (NTSB) online public docket for this investigation.[5]

1.1 Ten-Year Trends

The proportion of pedestrian deaths compared with all highway deaths rose over the past decade, from 1 in 9 in 2007 to 1 in 6 in 2016. Over the same 10-year period, the number (as opposed to the proportion) of pedestrian fatalities increased by 27 percent. In contrast to the increase in pedestrian fatalities, overall highway fatalities have decreased by 12 percent over the past 10 years. Using data from FARS, figure 1 graphs pedestrian fatalities against all highway fatalities between 2007 and 2016.[6] The total US population, number of highway fatalities, and number and rate of pedestrian highway fatalities for the same 10-year period are tabulated in table 1.

[1] The number of annual deaths was lowest in 2009, at 4,109.

[2] By definition, a pedestrian fatality in FARS occurs on a public road. Therefore, 5,987 is an undercount that does not include people killed by road vehicles in parking lots, private ways, or at work sites.

[3] Stutts and Hunter (1999) found that 12 percent of pedestrians injured in crashes were struck in nonroadway locations, such as parking lots. The number of nonfatal pedestrian crashes is not reliably documented by police crash reports because many do not involve vehicle damage.

[4] See the Centers for Disease Control and Prevention webpage on motor vehicle safety/pedestrian safety (https://www.cdc.gov/motorvehiclesafety/pedestrian_safety/index.html).

[5] See the NTSB docket. The NTSB identification number for the special investigation report on pedestrian safety is DCA15SS005.

[6] Data for 2016 are preliminary and are expected to be finalized in late 2018.

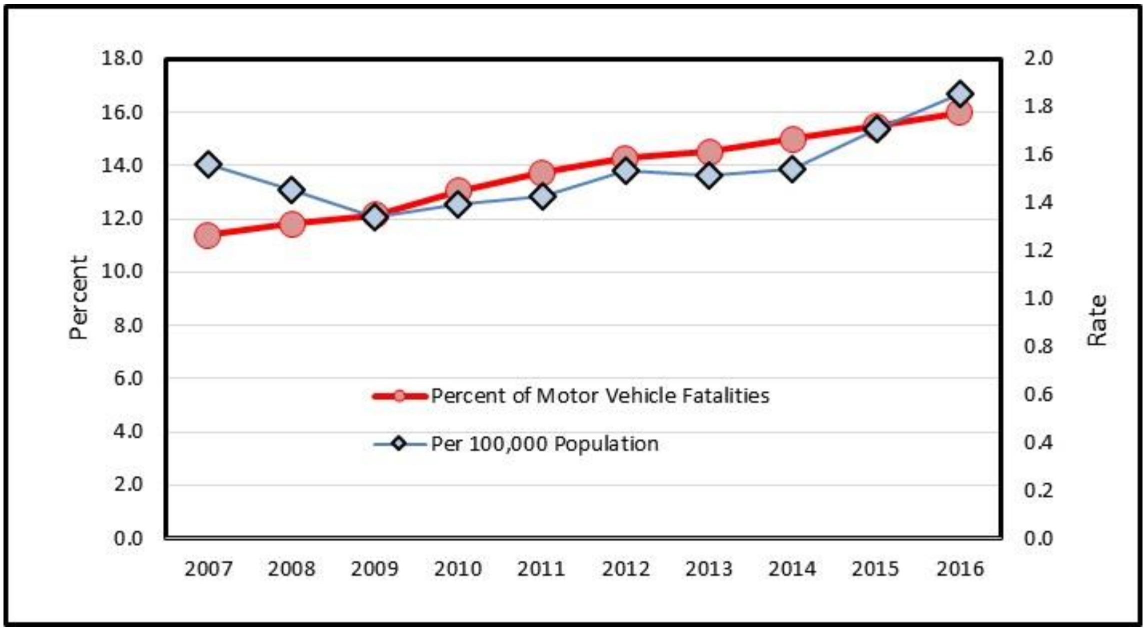

Figure 1. Pedestrian deaths as percent of all motor vehicle fatalities and as rate per 100,000 population (2007–2016).

Table 1. Pedestrian fatalities compared with total motor vehicle fatalities and population (2007–2016).

Year	Population	Total Motor Vehicle Fatalities	Pedestrian Fatalities			
			Total	Percent of Motor Vehicle Fatalities	Per 100,000 Population	Change vs. Previous Year (%)
2007	301,621,157	41,259	4,699	11.4	1.6	-2.0
2008	304,059,724	37,423	4,414	11.8	1.5	-6.1
2009	307,006,550	33,883	4,109	12.1	1.3	-6.9
2010	308,745,538	32,999	4,302	13.0	1.4	+4.7
2011	311,591,917	32,479	4,457	13.7	1.4	+3.6
2012	313,914,040	33,782	4,818	14.3	1.5	+8.1
2013	316,128,839	32,894	4,779	14.5	1.5	-0.8
2014	318,857,056	32,744	4,910	15.0	1.5	+2.7
2015	321,418,820	35,485	5,495	15.5	1.7	+11.9
2016	323,127,513	37,461	5,987	16.0	1.9	+9.0

Most fatal pedestrian crashes (90 percent) involve a single vehicle. In 2016, 84 percent of pedestrians in highway crashes were fatally injured by passenger vehicles, 6 percent by large trucks, and the remaining 10 percent by buses, motorcycles, or vehicle types that were not recorded. Figure 2 shows the age distribution for both fatally injured pedestrians and drivers involved in those crashes. Slightly more pedestrians 50 to 60 years of age were involved in fatal crashes than those in other age groups. Drivers in their twenties and thirties showed an increased involvement in fatal pedestrian crashes.

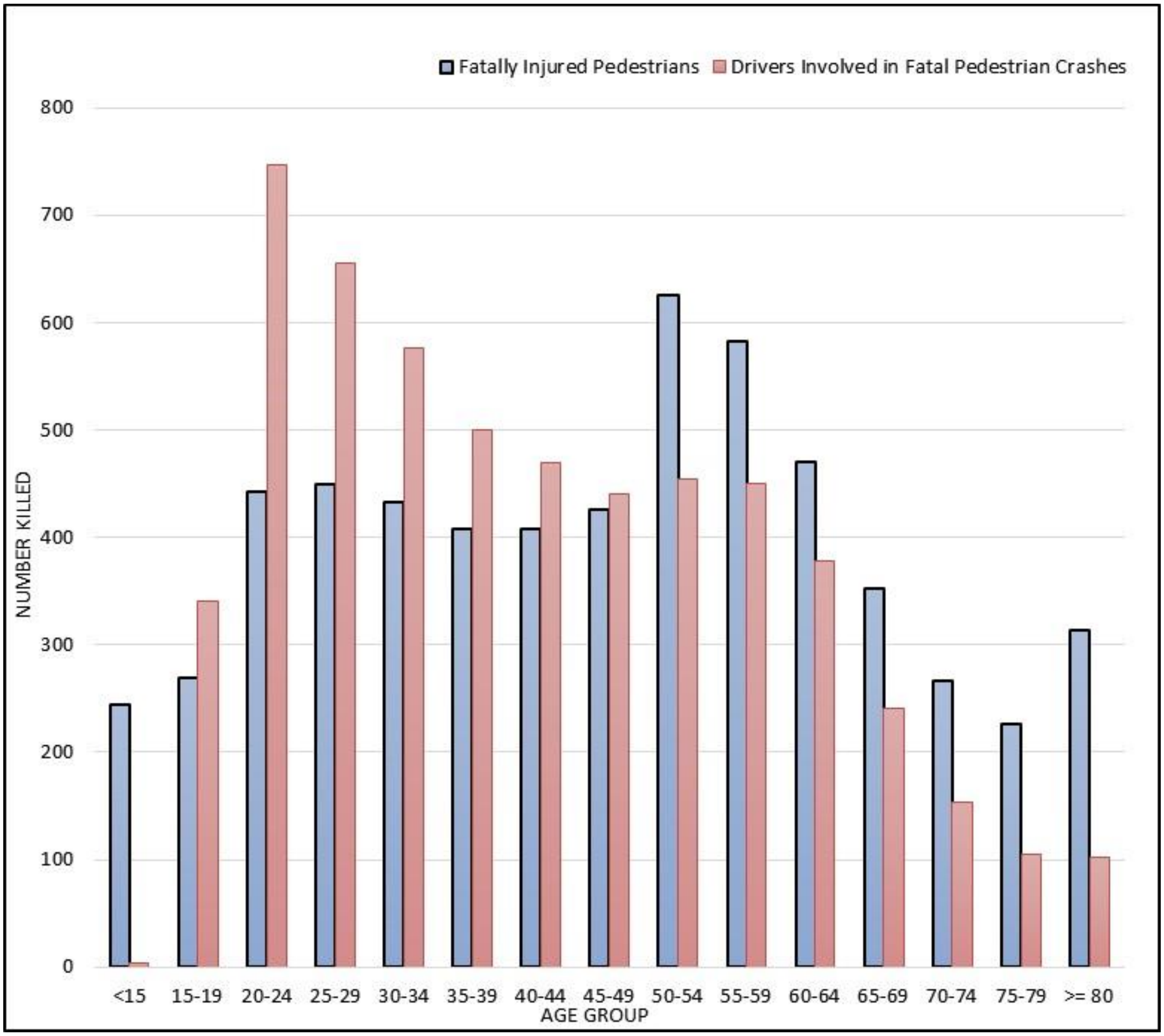

Figure 2. Age distribution of pedestrians and drivers in fatal pedestrian crashes (2016).

As with the overall US population, the average age of fatally injured pedestrians has increased in the last decade, from 45 years old in 2007 to 47 years old in 2016. The number of male pedestrian fatalities was more than twice that of females (77 percent male, 23 percent female).

In 2016, about 48 percent of all highway crashes occurred in dark conditions (NHTSA 2018). For pedestrians, the percentage of nighttime fatalities was substantially higher, with nearly three-quarters occurring in the dark. As shown in table 2, the trend for pedestrian fatalities occurring in dark conditions has been increasing, from 68 percent in 2007 to nearly 75 percent in 2016.

Table 2. Pedestrian fatalities by lighting condition (2007–2016).

Year	Total Fatalities	Fatalities by Lighting Condition					
		Daylight		Dusk	Dawn	Dark	
		Number	% of Total			Number	% of Total
2007	4,699	1,322	28.1	98	69	3,179	67.7
2008	4,414	1,145	25.9	101	88	3,059	69.3
2009	4,109	1,079	26.3	87	75	2,846	69.3
2010	4,299	1,092	25.4	80	81	3,030	70.5
2011	4,457	1,068	23.9	103	59	3,204	71.9
2012	4,818	1,168	24.2	101	76	3,452	71.6
2013	4,779	1,166	24.4	102	79	3,405	71.2
2014	4,910	1,191	24.3	97	88	3,510	71.5
2015	5,495	1,245	22.7	104	84	4,041	73.5
2016	5,987	1,290	21.5	124	81	4,453	74.4

Most pedestrian fatalities occur in urban environments, as shown in table 3, which gives details of the types of roads where pedestrians were fatally injured over the 10-year history.[7] Principal arterial roads (roads that carry the highest volume of traffic, traveling at the highest speeds) account for the highest number of fatalities. FARS data indicate that 18 percent of fatal pedestrian crashes occur at intersections, 72 percent at nonintersections, and 10 percent at other locations (such as roadsides or shoulders, sidewalks, and median crossing islands). Unclassified roads by year are usually 1 percent of total fatalities but can run as high as 5 percent.

Table 4 summarizes the extent to which alcohol is involved in fatal pedestrian crashes, considering both pedestrians and drivers. Readers are cautioned that a comparison of 2016 with earlier years may be affected by incomplete data.[8] Between 2007 and 2016, an average of 68 percent of fatally injured pedestrians had available data from tests of blood alcohol concentration (BAC). Of those pedestrians, 38 percent had a BAC of 0.05 or more.[9] Of the 26 percent of drivers with available BAC data, 17 percent showed a BAC of 0.05 or more.

[7] An *urbanized area* is defined as an area with 50,000 persons that, at a minimum, encompasses the land area delineated as the urbanized area by the US Census Bureau. Rural areas are defined as not urban.

[8] Data for 2016 are preliminary. Typically, after preliminary data are finalized, alcohol and drug results are higher because of completed tests.

[9] Table 4 uses a BAC measure of 0.05 grams per deciliter. Drivers with a BAC of 0.05 are 1.38 times more likely to be in a crash than are sober drivers (Compton and others 2002).

Table 3. Pedestrian fatalities by type of road (2007–2016).

Year	Total Fatalties	Urban Roads		Rural Roads	
		Number	Percent	Number	Percent
2007	4,699	3,442	73.2	1,257	26.8
2008	4,414	3,184	72.1	1,230	27.9
2009	4,109	2,947	71.7	1,162	28.3
2010	4,302	3,129	72.7	1,173	27.3
2011	4,457	3,269	73.3	1,188	26.7
2012	4,818	3,541	73.5	1,277	26.5
2013	4,779	3,502	73.3	1,277	26.7
2014	4,910	3,806	77.5	1,104	22.5
2015	5,495	4,056	73.8	1,439	26.2
2016	5,987	4,317	72.1	1,670	27.9

Table 4. Numbers and percentages of pedestrians and drivers tested for alcohol after fatal pedestrian crashes, with BAC results (2007–2016).

Year	Fatally Injured Pedestrians					Drivers in Fatal Pedestrian Crashes				
		Tested		BAC=0.05+			Tested		BAC=0.05+	
	Total	Number	% of Total	Number	% of Number Tested	Total	Number	% of Total	Number	% of Number Tested
2007	4,699	3,174	67.5	1,294	40.8	5,037	1,205	23.9	245	20.3
2008	4,414	3,069	69.5	1,305	42.5	4,735	1,242	26.2	247	19.9
2009	4,109	2,917	71.0	1,167	40.0	4,413	1,190	27.0	202	17.0
2010	4,302	3,044	70.8	1,190	39.1	4,690	1,415	30.2	243	17.2
2011	4,457	3,148	70.6	1,281	40.7	4,790	1,502	31.4	255	17.0
2012	4,818	3,307	68.6	1,329	40.2	5,180	1,495	28.9	246	16.5
2013	4,779	3,300	69.1	1,284	38.9	5,205	1,361	26.1	244	17.9
2014	4,910	3,391	69.1	1,275	37.6	5,302	1,330	25.1	206	15.5
2015	5,495	3,785	68.9	1,424	37.6	5,903	1,513	25.6	210	13.9
2016	5,987	3,350	56.0	1,287	38.4	6,392	1,376	21.5	210	15.3

BAC results are not from a representative sample due to differences in the likelihood of testing for the two groups. A significantly higher percentage of fatally injured pedestrians is tested for alcohol than are drivers involved in crashes with pedestrians. Drivers who survive a fatal pedestrian crash may be tested if police have probable cause to suspect impairment.

Data Trend Summary

National highway numbers tell us that to improve highway safety, the nation must prioritize pedestrian safety. The US Department of Transportation has embraced Vision Zero, a safety campaign that started in Sweden and has been adopted across Europe.[10] Many large, urban areas in the United States have joined the Vision Zero movement.[11] Vision Zero's goal is to eliminate traffic fatalities and injuries. The issue of pedestrian safety and the broader category of vulnerable road users must be considered if this country is to move toward Vision Zero's goal of no highway deaths.[12]

[10] Other international programs, such as one from Australia called the "Safe System Assessment Framework," are similar. See the Austroads website for a description of the Safe System approach (https:/austroads.com.au/latest-news/safe-system-assessment-framework).

[11] Vision Zero cities increased from 26 in March 2017 to 35 in January 2018. Of the 34 largest US cities (by population), 14 are in the Vision Zero network. See the network website for a map of Vision Zero cities (https://visionzeronetwork.org/resources/vision-zero-cities/).

[12] *Vulnerable road users* include road users most at risk in traffic, such as pedestrians, pedal cyclists, motorcyclists, persons with disabilities, children, and older people.

2 NTSB Work Related to Pedestrian Safety

2.1 Safety Reports

Shortly after its inception, the NTSB completed a special study that assessed the efforts of the US Department of Transportation to further pedestrian safety (NTSB 1971).[13] The report reviewed the magnitude of the problem of pedestrian safety and the characteristics of pedestrian fatalities. The salient, summarizing fact was that, in metropolitan areas, more than half of all highway fatalities were pedestrians (pedestrian fatalities at that time totaled 9,800—18 percent of annual highway deaths).[14] The NTSB recommended that the Department of Transportation seek funding to support both pedestrian safety research and state programs, in proportion to the number of pedestrian fatalities among all highway fatalities.

Recent NTSB highway safety reports have dealt with topics related to pedestrian safety. In 2013, the NTSB released a special report (*Reaching Zero*) on ways to reduce alcohol-impaired driving (NTSB 2013b). Alcohol impairment for both drivers and pedestrians is a substantial highway safety problem. Alcohol-impaired driving is associated with about one-third of US highway fatalities. The prevalence of intoxicated drivers is higher at night, when the visibility of people walking on or along roads is problematic, making it difficult for drivers to see and recognize them. The *Reaching Zero* report cited a Federal Bureau of Investigation estimate of annual driving-while-intoxicated arrests; an updated estimate for 2015 was 1,087,171 arrests.[15]

Moreover, only 1 out of 80 impaired driving trips is estimated to result in the driver's arrest (Ferguson 2012). Adding to the problem of intoxicated drivers, the Insurance Institute for Highway Safety found that about a third of fatal pedestrian crashes involve pedestrians walking under the influence of alcohol (IIHS 2017).[16] The NTSB's *Reaching Zero* report called for comprehensive actions to address alcohol-impaired driving, including stronger laws, improved enforcement strategies, innovative adjudication programs (such as driving-while-intoxicated courts), and accelerated development of new in-vehicle alcohol detection technologies. The report recognized the need for states to identify specific, measurable goals for reducing impaired driving fatalities and injuries, and to regularly evaluate the effectiveness of implemented countermeasures. The report made 10 new recommendations, reiterated 9 recommendations, and reviewed the status of the more than 100 alcohol-related recommendations issued over the NTSB's history.

[13] The study was completed on May 12, 1971, by the NTSB Surface Transportation Office. The NTSB later reorganized into separate modal offices, one of which was the Office of Highway Safety.

[14] In a report completed in response to the Highway Safety Act of 1973 (Public Law 93-87), the National Highway Traffic Safety Administration (NHTSA) found that two-thirds of fatalities and 85 percent of crashes occurred in urban settings (NHTSA 1975, 4).

[15] The Federal Bureau of Investigation publishes online crime statistics (*Crime in the United States*) from its uniform crime reporting program by year. Data for persons arrested in 2015 can be found on the bureau's Crime in the US website (https://ucr.fbi.gov/crime-in-the-u.s/2015/crime-in-the-u.s.-2015).

[16] Similar levels of impairment were found in earlier research by the Insurance Institute for Highway Safety: fatally injured pedestrians ages 16 and older with BACs of 0.08 or higher accounted for 39 percent of the group in 1992 and 37 percent in 2011.

In 2017, the NTSB released a safety study on reducing car crashes related to speeding (NTSB 2017). The study considered five safety issues pertaining to the application of proven and emerging measures to counter speeding: (1) lowering speed limits, (2) using data-driven approaches for speed enforcement, (3) employing automated speed enforcement, (4) applying intelligent speed adaptation (using an onboard system such as the global positioning system to determine the speed limit, then warning drivers when they exceed the limit), and (5) exercising national leadership. The study made 19 safety recommendations: to the US Department of Transportation, the National Highway Traffic Safety Administration (NHTSA), the Federal Highway Administration, the 50 states, and three highway safety associations. The two recommendations most relevant to pedestrian safety were H-17-27 and -28, issued to the Federal Highway Administration. Both recommended revising the *Manual on Uniform Traffic Control Devices*—in the case of Recommendation H-17-28, to strengthen protection for vulnerable road users.

The relationship between speed and crashes is complex and is affected by factors such as road type, driver age, alcohol impairment, and roadway characteristics (curvature, grade, width, adjacent land use, etc.). In contrast, the relationship between speed and the severity of injuries is consistent and direct—higher crash speeds result in injuries that are more severe. The effect of speed is especially critical for pedestrians involved in motor vehicle crashes because pedestrians lack protection. The average risk of a pedestrian being severely injured in a motor vehicle crash is 10 percent at an impact speed of 16 mph (figure 3).[17] The risk increases to 25 percent at a vehicle speed of 23 mph, 50 percent at 31 mph, 75 percent at 39 mph, and 90 percent at 46 mph (Tefft 2011).

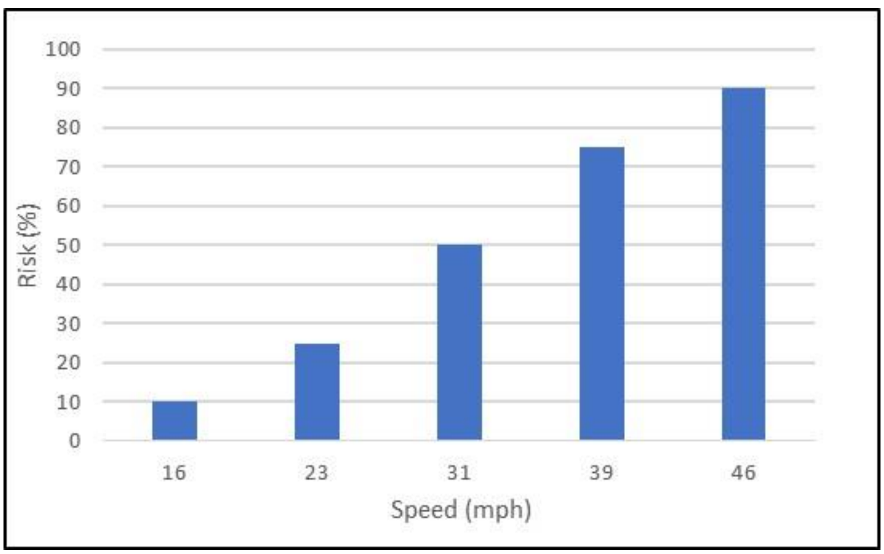

Figure 3. Effect of motor vehicle speed on pedestrian risk of severe crash injury.

[17] One of two coding systems is usually applied to injury severity. The medically preferred system, the Abbreviated Injury Scale developed by the Association for the Advancement of Automotive Medicine, uses a six-point scale, 1 = minor to 6= maximal. As described in section 4.3.3, police officers use a five-point scale referred to as KABCO (killed, incapacitating, nonincapacitating, possible injury, and no injury).

2.2 Major Investigations

2.2.1 Past

Between 1997 and 2004, the NTSB investigated three major motor vehicle crashes in which pedestrians were injured or killed:

- Crash at a bus stop outside Cosmopolis, Washington, on November 26, 1996 (NTSB 1997).
- Crash at a transit bus facility in Normandy, Missouri, on June 11, 1997 (NTSB 1998).
- Crash at a farmers' market in Santa Monica, California, on July 16, 2003 (NTSB 2004).

In the crash near Cosmopolis, Washington, a utility truck fatally injured a 10-year-old student who had just exited a transit bus.[18] In the course of its investigation, the NTSB determined that the safety of children traveling to and from school on transit buses is not equivalent to that of children who ride school buses, due to a lack of adequate safety procedures and equipment (such as the red flashing lights that require other vehicles to stop when a school bus is loading or unloading schoolchildren).

The crash in Normandy, Missouri, involved a transit bus, operated by a driver-trainee, that collided with seven pedestrians on a bus platform, killing four of them.[19] The NTSB determined that the probable cause of the crash was the trainee's misapplication of the accelerator, resulting in the bus's overriding the curb and traveling onto the occupied pedestrian platform. The NTSB concluded that the absence of an effective separation between the transit facility roadway and the pedestrian platform contributed to the deaths and injuries.

In the crash in Santa Monica, California, a car struck another car, then continued through an intersection and a farmers' market, killing 10 pedestrians and injuring 63.[20] No one in either car was injured. The NTSB determined that the probable cause of the crash was the driver's failure to maintain control of his vehicle due to his unintended acceleration. The NTSB determined that the lack of a barrier system to protect pedestrians in the area from errant vehicles contributed to the severity of the crash.

[18] In Recommendations H-97-26 through -30, the NTSB (1997) asked NHTSA, the National Association of State Directors of Pupil Transportation Services, the American Public Transit Association, and the Community Transportation Association of America to collect data on school children riding transit buses.

[19] In a set of companion recommendations to five organizations, the NTSB (1998) asked for positive pedestrian protection in transit facility designs (H-98-1 to the Federal Highway Administration, "Closed—Acceptable Alternative Action"; H-98-2 to the Federal Transit Administration, "Closed—Acceptable Action"; H-98-3 to the American Association of State Highway Transportation Officials, "Closed—Unacceptable Action"; H-98-4 and -5 to the American Public Transit Association, "Closed—Acceptable Action"; H-98-6 and -7 to the Community Transportation Association of America, "Closed—Unacceptable Action, No Response Received."

[20] Recommendations in NTSB (2004) called for the Federal Highway Administration to provide guidance on the use of barriers (H-04-25) and for NHTSA to develop standards for event data recorders in light-duty vehicles (H-04-26). Recommendations H-04-27 and -28 addressed barrier use by the city of Santa Monica.

In 2009, the NTSB issued a special investigation report on pedal misapplication that looked at five cases involving heavy vehicles (NTSB 2009). The five events resulted in 2 driver fatalities, no pedestrian fatalities, and a total of 71 injuries. The report reiterated to the Community Transportation Association of America a recommendation (H-98-6) to create a physical separation between the roadway and the area where pedestrians board buses.

2.2.2 Current

In 2018, the NTSB began investigating a pedestrian fatality that occurred at night in Tempe, Arizona, when a test vehicle operating as a self-driving system in computer-control mode struck a pedestrian pushing her bicycle across a four-lane urban road. The NTSB has released a preliminary report about the investigation; the investigative work had not been completed at the time of this writing.[21]

2.3 Investigation of 15 Fatal Pedestrian Crashes

In 2016, the NTSB began investigating a series of 15 highway crashes in which vehicles fatally injured pedestrians (NTSB 2018a, 2018b, 2018c, 2018d, 2018e, 2018f, 2018g, 2018h, 2018i, 2018j, 2018k, 2018l, 2018m, 2018n, and 2018o). The crashes occurred between April 24 and November 3, 2016. Three of the crashes were in northern Virginia, three in Maryland, three in New York City, two in Washington, DC, and one each in Maine, Connecticut, Wisconsin, and Minnesota (figure 4).

Table 5 lists details of the crashes, such as where and when they occurred, the type of vehicle involved, whether crosswalks were present, the vehicle's speed, and whether the driver was turning. The table also gives details about the drivers and pedestrians involved in the crashes, including evidence of alcohol or other drug use.

The investigation revealed a number of salient facts about the 15 fatal pedestrian crashes, as summarized in the following categories:

- **Vehicle:** all crashes involved single vehicles; 4 vehicles were passenger cars, 8 were sport utility vehicles (SUVs), small trucks, or minivans, and 3 were buses.
- **Lighting:** 6 crashes occurred at night, 6 during daylight, and 3 at twilight.
- **Alcohol use:** 13 pedestrians were tested for alcohol; 6 tested positive. Of the 7 drivers tested for alcohol, 2 tested positive.
- **Illicit drug use:** 13 pedestrians were tested for illicit drug use; 1 tested positive. Of the 7 drivers tested for illicit drugs, 2 tested positive.[22]

[21] See the NTSB website (https://www.ntsb.gov/investigations/AccidentReports/Pages/HWY18MH010-prelim.aspx).

[22] One driver tested positive for both alcohol and illicit drugs.

- **Cell phone use by pedestrian:** cell phones were reported as not used in 7 of 15 cases (based on witness accounts or lack of on-scene evidence); in 7 of the 15 cases, police made no report of cell phone use, and in 1 case, a cell phone was reported as in use.
- **Cell phone use by driver:** for 11 of 15 cases, police reported that a cell phone was not used, in 3 of the 15 cases police made no report of cell phone use, and in 1 case, a cell phone was reported in use for directions, not texting or talking (based on a driver interview, not on retrieved data for text or call activity).
- **Gender of pedestrian:** 11 were male, 4 were female.
- **Gender of driver:** 9 were male, 6 were female.
- **Speeding:** of the 15 involved vehicles, 3 were reported as exceeding the speed limit (based on a driver interview); 3 of the vehicles' engine data recorders were downloaded, but only 2 produced data; crash reconstructions were available for 10 cases but did not calculate vehicle speed.

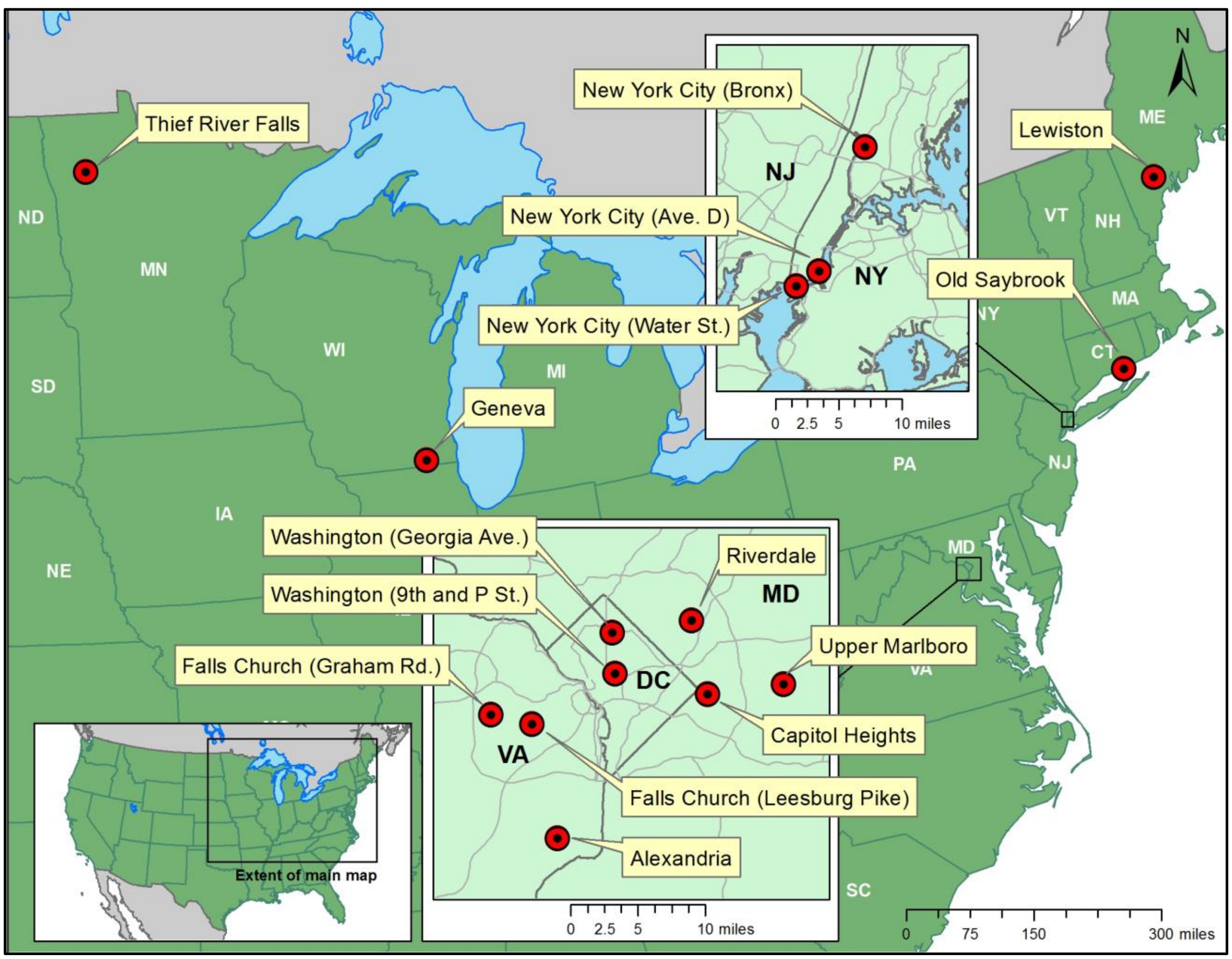

Figure 4. Map showing locations of 15 fatal pedestrian–vehicle collisions investigated by NTSB.

Table 5. Details of investigations of 15 fatal pedestrian crashes.

Crash Location	Date (Weekday)	Time	Inter-section	Cross-walk	Turn	Vehicle Type	Speed (mph)		Pedestrian				Driver			
							Travel	Limit	Age	Sex	BAC	Drug	Age	Sex	BAC	Drug
Riverdale MD	April 24 (Sun)	9:16 pm	Y	N	N	Sedan	33	35	55	M	0.3	N	50	F	N/T	N/T
Falls Church VA (Leesburg Pike)	May 18 (Wed)	3:40 pm	Y	Y	Y (left)	SUV	20	30	71	M	0	N	51	M	N/T	N/T
Falls Church VA (Graham Road)	June 4 (Sat)	10:18 pm	N	Y	N	Pickup	30–35	35	53	M	0.216	Y	46	M	N/T	N/T
Upper Marlboro MD	June 24 (Fri)	12:30 pm	Y	Y	Y (left)	SUV	20	35	76	M	0	N	69	M	N/T	N/T
Capitol Heights MD	July 20 (Wed)	4:19 pm	N	Y	N	Sedan	55–58	30	18	M	0	N	19	F	N/T	N/T
Old Saybrook CT	Aug 16 (Tue)	8:00 pm	N	N	N	SUV	30–40	35	89	M	0	N	73	M	0	N
Town of Geneva WI	Aug 16 (Tue)	11:25 pm	N	N	N	SUV	55	55	54	F	0.232	N	44	M	0	Y
Washington DC (9th & P)	Aug 18 (Thu)	3:00 am	Y	N	N	Sedan	30	25	44	M	0.1	N	31	F	0.14	Y
Alexandria VA	Aug 30 (Tue)	6:17 am	N	N	N	SUV	45	45	56	M	0.16	N	69	F	N/T	N/T
Washington DC (Georgia Ave)	Oct 2 (Sun)	3:05 am	N	N	N	Sedan	N/A	25	23	M	0.2	N	21	M	0.06	N
New York NY (Ave D)	Oct 4 (Tue)	9:50 am	Y	Y	Y (left)	Transit bus	12	25	73	F	0	N	57	M	0	N
Thief River Falls MN	Oct 6 (Thu)	7:00 am	N	N	N	Minivan	38–49	60	7	M	N/T	N/T	69	F	N/T	N/T
New York NY (Bronx)	Oct 14 (Fri)	12:25 pm	Y	Y	Y (right)	School bus	9	25	43	F	0	N	47	M	0	N
New York NY (Water St)	Oct 21 (Fri)	5:30 pm	Y	Y	N	Transit bus	10	25	58	F	0	N	63	M	N/T	N
Lewiston ME	Nov 3 (Thu)	7:10 am	Y	Y	N	Pickup	33–37	25	13	M	N/T	N/T	54	F	0	N/T

NOTE: BAC = blood alcohol concentration. Y = yes, N = no. N/T = not tested. SUV = sport utility vehicle. M = male, F = female. N/A = not available.

Pedestrian crashes typically involve one vehicle and one pedestrian. As a result, the physical evidence associated with such a crash may be limited and tends to be quickly removed from the scene. For purposes of this project, the NTSB modified its process for issuing notifications of crashes and launching investigative teams. In conjunction with the pedestrian safety forum held in the spring of 2016 (described in section 3, below), NTSB staff contacted local law enforcement agencies in the District of Columbia, Virginia, and Maryland to set up a direct notification process for fatal pedestrian crashes. As the pedestrian safety project proceeded, agencies in other states participated and helped identify more crashes for the investigation.

For the 15 fatal pedestrian crashes, investigators from the NTSB Office of Highway Safety documented the crash scenes, completed data collection forms, interviewed witnesses, and worked with local law enforcement officials. Information collected by the investigators included documentation of the crash site using computational photography and digital processing that could confirm postcrash measurements of the extent of vehicle damage.

The 15 crashes investigated for this report do not constitute a representative sample of pedestrian crashes. But the NTSB made an effort to select cases that covered the range of pedestrian crash characteristics. A summary of each investigation is found in appendix A. The data collection form that investigators used is reproduced in appendix B. The investigative evidence can be accessed from the NTSB public docket; see appendix A for instructions. In addition, the NTSB webpage (www.ntsb.gov/pedestrian) allows interested readers to explore the investigative data in the context of maps and graphs.

3 Public Forum on Pedestrian Safety

The NTSB hosted a public forum on May 10, 2016, to discuss pedestrian safety. The forum was chaired by then-Vice Chairman Dinh-Zarr and supported by staff from the NTSB offices of Highway Safety and Research and Engineering. The forum was organized around four panels, each of which addressed a different aspect of pedestrian safety. Presenters discussed the merits and drawbacks of safety data, policy, countermeasures, and technology, as well as the challenges associated with speeding, impaired driving, impaired walking, and distractions. Panel descriptions, panelist biographies, and the agenda topics covered in the forum can be found on the NTSB website.[23] Appendix C gives a list of panel participants.

3.1 Panel 1: Understanding Pedestrian Safety

The first panel looked at statistical trends and the underlying effects of the safety risks people face when walking across or along public roads. Inherent in the discussion was that people walk as a means of transportation. But what became obvious during the discussion is that our transportation data systems are inadequate to assess where we walk and what risks we face on different routes. We know that the number of pedestrian fatalities has increased over the past decade. But how many walking trips underlie the annual fatalities and injuries? How many people walk to work, the grocery store, or the park, and how is that number affected by demographic trends? How does urban pedestrian traffic differ from rural walking? What is a pedestrian transportation measure that parallels vehicle miles traveled?

The panel discussed the Transportation Research Board's project, National Cooperative Highway Research Program (NCHRP) Project 07-19, "Methods and Techniques for Collecting Pedestrian and Bicycle Volume Data," which recognized that better exposure data are needed.[24] That project's work led to the *Guidebook on Pedestrian and Bicycle Volume Data Collection* (TRB 2014). The techniques described in the guidebook called for technology applications and data mining that seemed best applied to local, site-specific projects.

Our overall understanding of pedestrian safety relies on the FARS census of fatal events and the Crash Reporting Sampling System (CRSS), which uses data from police reports.[25] Our knowledge is incomplete because the investigative records may themselves be limited, and because injury-only events are not necessarily covered in police records. The Federal Highway Administration's National Household Travel Survey, which has a section called "person travel,"

[23] For more information, see the news release about the pedestrian safety forum on the NTSB website (https://www.ntsb.gov/news/events/Pages/2016_pedestrian_FRM.aspx).

[24] *Exposure* is a measure of the number of potential opportunities for a crash to occur.

[25] CRSS, which replaced the National Automotive Sampling System/General Estimates System (NASS/GES), is a sample of police-reported crashes involving all types of motor vehicles, pedestrians, and cyclists, ranging from property-damage-only crashes to those that result in fatalities. CRSS is used to estimate the overall crash picture; for a description of CRSS, see the website of NHTSA's National Center for Statistics and Analysis (https://www.nhtsa.gov/national-center-statistics-and-analysis-ncsa/crash-report-sampling-system-crss).

is one source of information about pedestrian traffic. The survey is done by phone and offers little insight into pedestrians' route choices or risk behaviors, although it indicates broad trends.[26] For example, it tells us that, over time, fewer children walk to school. Almost half of children in kindergarten through grade eight walked to school in 1969; by 2009, that proportion had dropped to 13 percent. The survey does not have the scope or resolution needed to guide countermeasures for improving pedestrian safety, however. The panel therefore discussed the efforts of the American Association of State Highway and Transportation Officials (AASHTO) to quantify the exposure of pedestrians and better understand a pedestrian's risk of being struck by a moving vehicle.

3.2 Panel 2: Planning Safer Streets for Pedestrians

In past decades, public road projects have been prioritized based on the degree to which they reduced traffic congestion. In that approach, automobile through-put metrics of delay (delay minutes) are used to measure the level of service (convenience associated with reduced congestion). Panel 2 looked at changes needed to balance pedestrian safety interests with car travel. The panel discussed how policies guide the way our roads are planned, funded, designed, and built. Participants drew from federal, state, and local (urban) perspectives and considered examples of the innovative approaches communities are using to promote pedestrian safety. The panel discussed the passage of a long-term highway funding bill, the Fixing America's Surface Transportation (FAST) Act, and the policy of "complete streets," meaning streets that are designed and operated to accommodate all users of a roadway.[27] The FAST Act replaced the previous legislation (which allowed states to use funds for highway safety improvement on any projects that met their safety-improvement goals) with a block grant program that encompassed small-scale transportation projects, such as those for pedestrians.

The discussion also covered US Department of Transportation initiatives to promote infrastructure improvements, integrate design solutions, and promote "road diets" (reducing the number or width of lanes) to curtail speeding.[28] The panel recognized that local communities want public roads to be safe for use by all people, including children, the elderly, non-English-speaking residents, and people with disabilities. To create safe walking environments, the discussion returned to the needs of local transportation planners to craft data-driven, individualized, site-specific solutions for their communities.

[26] The Federal Highway Administration is launching an initiative to transform the National Household Travel Survey into a more-robust annual data-gathering effort, covering data on "daily travel," "long distance travel," and "origin destination." See the website of the Transportation Pooled Fund Program for details about the proposed effort (http://www.pooledfund.org/Details/Solicitation/1466).

[27] The FAST Act, Public Law 114-94, was enacted on December 4, 2015.

[28] Decreasing the number of travel lanes or the width of a road (also called lane reduction or road rechannelization) is a technique in transportation planning that can lower vehicle speeds and reduce collisions.

3.3 Panel 3: Enhancing Pedestrian Safety Through Design and Countermeasures

The third panel discussed highway engineering and design processes that can identify context-sensitive traffic control improvements. Central to the discussion was identifying the data necessary for effective site-specific safety plans for pedestrians. Injury prevention has been organized around the “three Es”—engineering, education, and enforcement—now augmented by encouragement and evaluation. The panel discussed infrastructure design improvements for pedestrian safety that have resulted from engineering approaches. The Federal Highway Administration has identified 20 proven countermeasures for improving safety, 6 of which directly affect pedestrian safety: leading pedestrian intervals (giving pedestrians a few seconds’ head start over vehicles at an intersection), medians and pedestrian crossing islands, pedestrian hybrid beacons (traffic control devices that remain dark until a pedestrian activates a beacon that directs drivers to stop), road diets for slowing traffic, walkways, and road safety audits. The panel discussed highway project costs and funding constraints experienced by both state and local jurisdictions. States use processes identified by the federal Highway Safety Improvement Program (described in section 4.3.3) to evaluate the use of pedestrian safety countermeasures. The panel also discussed the limitations of comparing design improvements for safety across different communities.

3.4 Panel 4: Improving Pedestrian Safety Through Vehicle Technology

The last decades have witnessed advances in vehicle-based technologies designed to improve safety, mitigate injury, and prevent crashes. Panel 4 discussed vehicle-based systems specific to pedestrian safety. The overwhelming safety factor for a vehicle striking a pedestrian remains the physics of differential mass (the weight and size of a pedestrian compared with that of a vehicle), plus the lack of protection afforded pedestrians. Consequently, of primary importance is mitigating speed or avoiding impact. The panel considered collision warning systems, collision avoidance systems, and automatic braking.

Some vehicle technologies, such as adaptive headlights that adjust their brightness depending on oncoming traffic, can help drivers see a pedestrian sooner, allowing them to apply the brakes earlier and possibly avoid the pedestrian. Other vehicle systems focus on slowing impact speeds or preventing impacts by using automated pedestrian detection systems that can identify potential conflicts (the presence of a pedestrian) and respond by automatically engaging the brakes. In addition to speed, the physical design of vehicles can ameliorate injuries to pedestrians from an impact—for example, by making bumpers softer or installing air bags on the hood. The panel discussed a range of designs and technologies and acknowledged ongoing work to evaluate those systems. One realization of the panel was the slow implementation of vehicle-based solutions. Because the average age of cars in the United States is 11.5 years, technology replacement can be slow.

4 Recommendations for Improved Pedestrian Safety

This section presents recommendations for improving pedestrian safety. The discussion begins with a consideration of vehicle-based designs (section 4.1) that can improve pedestrian safety—vehicle lighting systems, protective physical designs, and automated crash avoidance systems. Such systems would benefit from performance-based standards for manufacturers that were harmonized with other countries' requirements. Performance standards for safety systems would also promote a new car buyer's understanding of, and expectations about, vehicle safety systems. The discussion considers ongoing research into vehicle-based standards by NHTSA.

The second recommendation area, infrastructure planning (section 4.2), considers the development of environmental and infrastructure design projects that will improve pedestrian safety. It recognizes that walking networks are integrated into our vehicle-centric road system and that design changes are necessary to reduce the safety risk to pedestrians. According to the Federal Highway Administration's *Strategic Agenda for Pedestrian and Bicycle Transportation*, "The work involved to develop and use data is particularly challenging for those working in the nonmotorized transportation arena because of inconsistencies and gaps in the national, state, regional, and local agencies" (FHWA 2016a).[29] Recognizing that design solutions are site-specific, the discussion looks at the planning necessary to prioritize pedestrian safety projects. The goal is to develop pedestrian safety action plans that are data-driven and context-dependent, and to implement the plans as efficient, acceptable community projects.

Section 4.3 addresses safety data needs related to pedestrian travel. It discusses data systems for different purposes: exposure data, crash and injury event records, and system performance data. Information systems exist in each area, but changes in transportation networks and advances in information technology call for transportation planners to continuously consider improvements to the systems, particularly for measures of nonmotorized travel (for example, the number of people who walk rather than using another mode of travel).

4.1 Vehicle-Based Safety Countermeasures

One of the most important factors in a motorist's ability to detect pedestrians is visibility. A pedestrian's risk of a fatal injury is four times greater at night than in the daytime. Of the 15 fatal pedestrian crashes the NTSB investigated for this study, 6 occurred at night and 3 occurred during the twilight transition between day and night. Almost all involved some aspect of the driver not seeing the pedestrian. Drivers avoid hitting pedestrians when they are paying attention and have the time to see and avoid a person in the roadway. The first safety issue (section 4.1.1) addresses improved vehicle headlights as a practical and direct way to help drivers see and avoid pedestrians.

[29] *Nonmotorized transportation* includes walking, bicycling, using small-wheeled devices such as skates, and moving about by wheelchair.

The basic design of cars affects pedestrian injury, particularly in the sensitive range of speeds between 25 and 35 mph—a range common to most urban streets with high pedestrian use and that accounted for 12 of the 15 fatal pedestrian crashes the NTSB investigated (refer to table 5, section 2.3). Vehicle profiles that incorporate injury-mitigating designs have been adopted by other countries and are reflected in their safety programs for new vehicles. Section 4.1.2 discusses vehicle designs that should be incorporated by manufacturers and offered as safety systems to individual buyers of new cars, as well as to fleet operators.

Recent developments in automated systems have led to vehicle-based technologies designed to prevent crashes. Section 4.1.3 considers technology that identifies imminent conflicts between a vehicle and a pedestrian and responds by warning the driver or engaging automatic braking. The discussion closes with a recognition of NHTSA's new requirements for battery-operated (hence quiet) hybrid and electric vehicles to emit a sound that will warn pedestrians of their presence. The requirements will improve pedestrian safety; no further recommendation is proposed in that area.

4.1.1 Vehicle Headlight Performance

Crash data show that more pedestrian fatalities occur at night. In 2016, a total of 4,453 pedestrians were killed during the hours of darkness, compared with 1,290 in daylight. The NTSB investigations also show that crashes are more likely in darkness, with 9 of the 15 occurring outside daylight hours.[30] The general effects of darkness are brought into specific focus by the crash in Lewiston, Maine, which killed a 13-year-old student who was on his way to school, crossing the road in a crosswalk before daylight, at 7:10 a.m. in November 2016.

Research using 11 years of FARS data analyzed the distribution of fatal crashes across annual daylight saving time transitions and estimated the safety risk to pedestrians to be at least four times higher in darkness than in light (Sullivan and Flannagan 2001). The annual number of fatal pedestrian crashes in darkness is sufficiently large to suggest that lighting countermeasures have the potential to prevent a substantial number of pedestrian fatalities. The most feasible approach to improving lighting is to improve headlights on cars so drivers can better see and avoid pedestrians.

Because vehicle lighting is an important safety system, those systems are controlled by a regulatory standard: Federal Motor Vehicle Safety Standard (FMVSS) 108 (lamps, reflective devices, and associated equipment). The standard is intended to ensure adequate illumination of the roadway and the visibility of motor vehicles, in both daylight and darkness or in other conditions of reduced visibility. FMVSS 108 guides manufacturers in the location and number of vehicle lights and in the testing of headlamp bulb output. However, the standard does not include minimum illumination distance or on-vehicle performance testing of lighting systems. Rather, manufacturers self-certify that their lights meet the criteria for bulb output, using the results of component (or bench) tests (operating tests carried out on parts that have been removed from a

[30] The 15 NTSB cases were coded according to the position of the sun at local time and differed from the FARS coding. Some events categorized as occurring in daylight might actually have happened during the twilight hour before sunrise or after sunset.

vehicle). The standard, written in the 1960s, dates from a time when lamp bulbs were more homogeneous than now.

The Insurance Institute for Highway Safety began evaluating headlamps when its Highway Loss Data Institute showed fewer claims on vehicles equipped with swiveling headlights (IIHS 2012). The Insurance Institute for Highway Safety's new car headlight ratings are recent, with the first ones released in March 2016. The tests showed that most cars had poorly performing headlight systems, even though the vehicles met the FMVSSs for their lighting systems. Of the 31 midsize 2016 cars rated, only 1 received a "good" rating and 11 were rated "acceptable."[31]

The Insurance Institute for Highway Safety uses factory-delivered models without adjusting headlight aim. Vehicles are run on a test track while engineers measure how far vehicle lighting extends with an intensity of 5 lux for five path conditions: straight, curve left, curve right (those three are measured at a radius of 800 feet), sharp curve left, and sharp curve right (both are measured at a radius of 500 feet).[32] Today, vehicles of the same model can be equipped with a choice of different headlamp systems, depending on the purchase options. The Insurance Institute for Highway Safety's evaluation of 31 vehicle models in 2016 considered 82 different headlamp systems.

Incorporating headlight evaluations has resulted in fewer models receiving a Top Safety Pick rating from the Insurance Institute for Highway Safety.[33] In 2017, just 15 new vehicle models qualified for the Top Safety Pick+ award after the requirements were strengthened to include headlights rated good. The models included four small cars, three midsize cars, five large luxury cars, two midsize nonluxury SUVs, and one midsize luxury SUV. No minivans, pickups, or minicars earned the highest award. Second-tier Top Safety Picks require headlights rated acceptable or good; 47 vehicle models received that rating. More than half of the tested midsize SUV headlights were rated marginal or poor.

Both the Insurance Institute for Highway Safety and Consumer Reports conduct on-vehicle evaluations of automotive headlights, but their methods differ. Consumer Reports aligns headlamps in an indoor laboratory and then tests them on an outdoor track.[34] The Insurance Institute for Highway Safety tests lighting performance using factory-delivered models without adjusting the aim of the headlights. Vehicles are tested on an active course at night using sensors to measure light projected onto the road. The NTSB concludes that vehicle headlight systems require an evaluation that is more advanced than bench testing of bulb output. The NTSB therefore recommends that NHTSA revise FMVSS 108 to include performance-based standards for vehicle

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[31] For more information, see the March 30, 2016, news release from the Highway Loss Data Institute (http://www.iihs.org/iihs/news/desktopnews/first-ever-iihs-headlight-ratings-show-most-need-improvement).

[32] *Lux* is a measure of light on a surface.

[33] The Insurance Institute for Highway Safety has been recognizing vehicles with Top Safety Pick since the 2006 model year to help consumers identify vehicles with the highest safety ratings without having to evaluate information about individual tests. The Top Safety Pick+ accolade was introduced in the 2013 model year to recognize vehicles that offer superior safety.

[34] Consumer Reports uses a static vehicle position (which therefore cannot test swivel lighting systems) and tests only one variant of a model.

headlight systems correctly aimed on the road and tested on-vehicle to account for headlight height and lighting performance.

Vehicle headlight systems must balance light projected onto the road against the glare projected to oncoming drivers. As automotive lighting technology has changed from incandescent bulbs to high-intensity discharge bulbs and light-emitting diodes (LEDs), headlamps have grown brighter. New lighting systems are more sophisticated, incorporating the ability to automatically switch between high and low beams and vary the level of light depending on oncoming vehicles. The curve-adaptive, swiveling headlights available on some new cars can pivot in the direction of travel to improve visibility on curves and at intersections.[35]

In response to public complaints about headlight glare, NHTSA conducted a series of studies on headlight factors and driver performance.[36] That work, summarized in NHTSA (2008), employed field measurements, laboratory studies, computer analysis, and instrumented vehicles. The factors related to increased complaints about glare were as follows:

- Bulb type (high-intensity discharge lighting systems are more intense than halogen headlamps).
- Lamp intensity (higher intensity increases oncoming driver discomfort).
- Mounting height (higher headlamps increase the discomfort of oncoming drivers).
- Mis-aim (increases the discomfort of oncoming drivers as well as their disability due to glare).
- Time of exposure to passing drivers (longer exposure increases a driver's visual adaptive recovery time).

One solution for reducing glare is to install adaptive lights that automatically adjust their intensity based on ambient street lighting or nearby cars. Adaptive-driving-beam headlights continuously adjust the high-beam pattern, offering high-beam visibility except for a segment of the beam that is blocked to limit glare for oncoming drivers. Some adaptive-driving-beam systems use a matrix of individually dimmable LEDs to selectively control light output. The systems use a forward-facing camera to identify oncoming vehicles and selectively dim or turn off LEDs to limit glare. A related technology for laser headlights can also independently control the lights. The definition given for an adaptive driving beam by the Society of Automotive Engineers (as quoted in Mazzae and others 2015), is as follows:

[35] A new system prototyped by Carnegie Mellon researchers but not yet on the market is programmable automotive headlights. The programmable headlight is a colocated imaging and illumination system consisting of a camera, a processor, and a spatial light modulator. The camera captures images of the road. The processor analyzes the images and computes an illumination pattern. The spatial light modulator modulates light with high resolution over space and time (Tamburo and others 2014).

[36] For a list of the studies, see the NHTSA website on research into headlighting (https://one.nhtsa.gov/Research/Human-Factors/Headlighting).

> [a] long-range forward visibility beam that adapts to the presence of opposing and preceding vehicles by modifying portions of its beam pattern to avoid glare above lower beam photometry levels to the drivers of opposing and preceding vehicles.

Lighting systems that can adapt to oncoming traffic already exist. European standards permit adaptive-driving-beam headlights, which allow beams to light the road without producing the glare that can blind oncoming drivers. US Department of Transportation rules permit a low beam and a high beam, but they do not allow vehicles manufactured for sale in the United States to adaptively alter light levels between high and low. Manufacturers have petitioned NHTSA to revise FMVSS 108 to allow adaptive-driving-beam headlights.[37] The NTSB concludes that motor vehicle safety standards should not limit advanced vehicle lighting systems that have been shown to have safety benefits. The NTSB therefore recommends that NHTSA revise FMVSS 108 to allow adaptive headlight systems.

4.1.2 Vehicle Physical Designs

US regulations do not incorporate vehicle requirements intended to protect pedestrians. Yet crash data indicate that the issue of vehicle design warrants attention. While the cause of death in the 15 fatal pedestrian crashes the NTSB investigated was most often reported as multiple blunt force injuries, head injuries were recorded in 12 of the cases. In five of the cases, head injuries were listed as the cause of death.

European tests of pedestrian crashes have shown that improving the physical design of vehicles can reduce pedestrian injuries and fatalities, particularly those resulting from head impacts against a vehicle's stiff hood or windshield (Liers and Hannawald 2011; Strandroth and others 2011). In addition to physical vehicle designs that are less likely to injure pedestrians (such as modified hood lines and lower bumpers that can soften the blow to a pedestrian's head and legs during a crash), other design improvements include better sightlines and the use of rearview camera sensors to detect pedestrians.[38]

NHTSA recognized developments in the harmonization of vehicle regulations and in pedestrian safety research in other countries.[39] Many European and Asian countries with less vehicle-focused urban designs have supported pedestrian safety, in both urban planning and vehicle design. More than a decade ago, in light of international work to develop global technical regulations for pedestrian safety, NHTSA's Vehicle Research and Test Center conducted 88 head impact tests on 11 vehicles selected to represent the US fleet (Mallory, Stammen, and Meyerson 2007; Mallory and others 2012). Additional analysis using cases from NHTSA's Pedestrian Crash

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[37] Two years ago, Toyota petitioned to allow adaptive-driving-beam headlights. Audi joined Toyota, as did BMW and Mercedes-Benz. See the related *Road and Track* article (https://www.roadandtrack.com/car-culture/a25827/the-enginerdy-dept-dot-in-the-dark-headlight-tech/).

[38] Vehicles can also be designed with pliable hoods that will deform to absorb the impact if a pedestrian is thrown onto them. Designers can lower a vehicle's front-end bumpers and use softer materials, such as foam and crushable plastic, to reduce the severity of impacts on legs.

[39] Australia has accomplished notable work on vehicle design for pedestrian safety. For general research, see the Australian Department of Infrastructure website (https://bitre.gov.au/publications/2015/is_070.aspx). For specific information about work on vehicle design carried out at the Centre for Automotive Safety Research at the University of Adelaide, see the website of the center's impact laboratory (http://casr.adelaide.edu.au/impactlab/)

Data Study (1994–1998) found that the two most frequent combinations of injury and vehicle part were lower extremity injury from bumper contact and head injury from windshield impact. The test results did not consistently associate larger vehicles with more serious head injury. For example, the large Chevrolet Silverado truck was one of the best performers, while the smaller Jeep Wrangler was among the worst.

NHTSA's *Vehicle Safety and Fuel Economy Rulemaking and Research Priority Plan* for 2011 through 2013 (NHTSA 2011) proposed to put regulations in place affecting the hood and bumper areas of light vehicles (gross weight ≤ 10,000 pounds) to reduce the injuries and fatalities of pedestrians struck by motor vehicles. NHTSA's plan referenced, and was to consider, global technical regulation (GTR) No. 9 ("Pedestrian Safety") established by the United Nations Economic Commission for Europe (European Commission) in November 2008 to reduce the levels of injury sustained by pedestrians from frontal impacts with motor vehicles. [40] As discussed below, NHTSA has not yet acted to incorporate GTR No. 9 in its rulemaking.

Even though advanced automation is expected to improve vehicle safety, lessening the severity of injuries to pedestrians at low impact speeds will require incorporating passive protection into vehicle design. Research into 523 pedestrian crashes, and modeled outcomes based on two autonomous vehicle algorithms, found that even under the best conditions, autonomous vehicles are unlikely to avoid every pedestrian-to-vehicle crash (Detwiller and Gabler 2017). The authors concluded that autonomous vehicles of the future will require safety features such as soft, pedestrian-safe bumpers, crushable hoods, or air bags on the outside of the vehicle.

Vehicles with physical designs that are less likely to injure pedestrians have been tested and incorporated into New Car Assessment Programs (NCAPs) in other countries. In 2001, the European Commission introduced a voluntary agreement for hood design that offered passive pedestrian protection. The European NCAP (Euro NCAP), beginning with a pedestrian protection requirement in 2005, includes hood design for pedestrian safety as a component.[41] ANCAP (NCAP for Australia and Asia) also includes pedestrian safety design assessments.[42] In Euro NCAP, a pedestrian protection score incorporates head impact (introduced in 1997 and updated in 2013), upper leg impact (introduced in 1997 and updated in 2015), lower leg impact (introduced in 1997 and updated in 2014), and automatic emergency braking (introduced in 2016). Figures 5 through 8 illustrate different types of damage to vehicles traveling at similar speeds (between 30 and 35 mph), as documented in the NTSB's investigation of 15 fatal pedestrian collisions during 2016.

[40] The European Commission, set up in 1947, is one of five regional United Nations commissions. The European Commission introduced the first agreement for the worldwide technical harmonization of vehicles in 1958. GTR No. 9 was established as addendum 9 to the "Agreement Concerning the Establishing of Global Technical Regulations for Wheeled Vehicles, Equipment and Parts Which Can Be Fitted and/or Used on Wheeled Vehicles," dated June 25, 1998 (1998 Agreement).

[41] Manufacturers provide active pedestrian data that are run through computer simulations using the Human Body Model.

[42] For more information, see the ANCAP website explaining its safety tests (http://www.ancap.com.au/crash-testing-explained Safety testing).

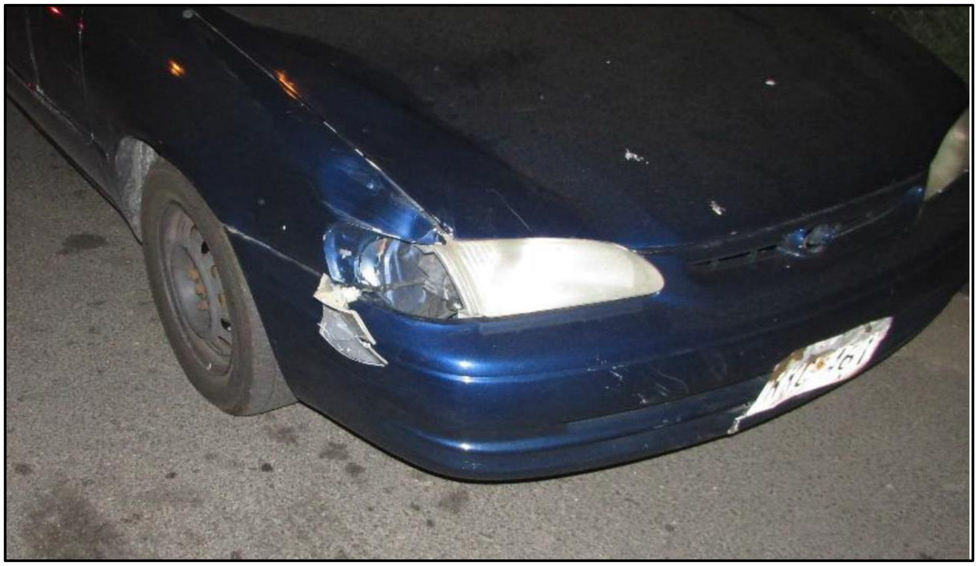

Figure 5. Damage to 1998 Toyota Corolla traveling straight at reported speed of 33 mph, Riverdale Park, Maryland, April 2016 (NTSB 2018a).

Figure 6. Damage to 2016 Ford truck turning left on two-lane road at reported speed of 34 mph, Lewiston, Maine, November 2016 (NTSB 2018n).

Figure 7. Damage to 2000 Mercedes-Benz sedan traveling straight on four-lane road at reported speed of 30 mph, Washington, DC, August 2016 (NTSB 2018m).

Figure 8. Damage to 2007 Toyota SUV traveling straight on two-lane road at reported speed of 30 mph, Old Saybrook, Connecticut, August 2016 (NTSB 2018l).

Global NCAP, an international crash testing organization, stated in a letter to the President of the United States on March 19, 2018, that the purpose of GTR No. 9 was "to mitigate the risk of head injury by encouraging deformation of the hood."[43] The requirement has been applied in Japan as well as in the European Union. In December 2015, NHTSA proposed to include GTR No. 9 in its NCAP. At the time, NHTSA noted that pedestrian protection measures in Europe and Japan "have likely contributed to a downward trend in pedestrian fatalities" and argued that "including pedestrian protection in the NCAP program would be a step toward realizing similar downward trends experienced in regions of the world that include pedestrians in their consumer information programs."[44]

To date, the NCAP in the United States has not been revised as proposed. In its letter, Global NCAP explained that "American manufacturers based in the E[uropean] U[nion] are already meeting these requirements and so there is no technological challenge to apply the U[nited] N[ations] pedestrian protection regulations."[45] The NTSB concludes that incorporating pedestrian injury mitigation into vehicle hood and bumper designs would improve pedestrian safety. The NTSB therefore recommends that NHTSA develop performance test criteria for vehicle designs that reduce injuries to pedestrians.

4.1.3 Collision Avoidance Technologies

The last two decades have witnessed the rise of vehicle-based technologies designed to prevent crashes. The NTSB's work on crash avoidance technology has played a role in that development. In 2001, an NTSB special investigation of rear-end crashes focused on technology as a potential countermeasure and recommended the development of system performance standards (NTSB 2001).[46] In 2015, the NTSB again took up the subject of rear-end crashes and examined the efficacy of collision avoidance technologies in preventing them (NTSB 2015).[47] Although pedestrian crashes were not the focus of the NTSB's report, it considered system performance standards, assessment protocols, and testing for automatic emergency braking.

In addition to developing technologies aimed at preventing crashes in general, automotive manufacturers have begun developing collision avoidance technologies focused on pedestrians in particular. Pedestrian detection systems can identify vehicle–pedestrian conflicts in a vehicle's forward path and respond by warning the driver or engaging automatic emergency braking, to slow the vehicle's speed or prevent it from hitting a pedestrian (Sandt and Owens 2017). Collision avoidance systems can be installed on both luxury and economy models.

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[43] For more information about the Global NCAP letter, see the news story at the following website: http://www.safetywissen.com/#/object/A11/A11.htp736772mbz0h8udw352823ggmb6w63657067223/safetywissen.

[44] *Federal Register*, vol. 80, December 16, 2015: 78521-78591.

[45] Euro NCAP categories include head impact, upper leg, lower leg, and automatic emergency braking for pedestrians.

[46] Safety Recommendations H-01-6 and -7 for commercial vehicles and H-01-8 for passenger vehicles.

[47] The NTSB made its first recommendation for collision avoidance technology in 1995 (H-95-44), when it asked the US Secretary of Transportation to begin testing collision warning systems in commercial fleets (NTSB 1995). Because of a lack of progress in addressing the issue, the recommendation was classified "Closed—Unacceptable Action" in 1999.

Collision avoidance systems respond differently, depending on the location and the anticipated movement of a pedestrian in a vehicle's path. Driver warning systems hold the most promise for situations where a vehicle is passing a person walking along a parallel path (along the roadway's direction of travel). In those conditions, a warning to the driver might allow him or her enough time to control the vehicle's path in relation to the pedestrian. (Such would have been the situation for the pedestrian fatality in the Town of Geneva, Wisconsin, which the NTSB investigated; see appendix A for a description.) But in crossing-path situations (where pedestrians step into the route of traffic, at a crosswalk or not), a warning would probably come too late for the driver to react or respond. In those cases, an automated braking system, rather than a collision warning system, would be the system of choice. Such performance characteristics should be distinctly identified in nomenclature, system design criteria, system documentation, and performance testing.

Advances in collision avoidance systems are ongoing. In addition to independent systems that use camera sensors and computers to assess the driving environment, systems are under development that use heat-sensing technology to detect pedestrians who are not visible because of obstructions (Negied, Hemeyed, and Fayek 2015). A different approach is connected vehicle technology. Vehicle-to-pedestrian crash avoidance systems, for example, use wireless technology such as cell phones to alert drivers of the presence of pedestrians via dedicated short-range communication systems. Algorithms for vehicle-to-pedestrian systems identify pedestrians, calculate the time to a crash, determine whether to activate the warning system, prefill the braking system (prepare for braking by filling the brake hydraulics with fluid), and execute automatic emergency braking if the driver does not react. As connected vehicles move to implementation, it is expected that they will incorporate vehicle-to-pedestrian avoidance systems.

NHTSA-sponsored research has already added to our knowledge about pedestrian crash avoidance systems (Swanson and others 2016). In 2017, NHTSA sponsored a benefit/cost evaluation of pedestrian crash avoidance systems. The study found that intervention to lower speeds reduced both the number of injured pedestrians from crashes avoided and the level of injuries to pedestrians in unavoidable crashes (Yanagisawa and others 2017). As noted earlier, NHTSA began updating its NCAP and issued a request for comments in December 2015, but the update is not complete.[48]

Euro NCAP tests automatic emergency braking to avoid pedestrians in three scenarios: (1) a running adult crosses in front of the vehicle from the driver's side; (2) a walking adult crosses from the passenger's side; and (3) a child runs from between parked cars on the passenger's side. The evaluation recognizes that the technology behind automatic emergency braking for pedestrians may not be able to avoid all collisions. Consequently, Euro NCAP rewards the technology only if

[48] The NTSB provided written comments on the NCAP in 2016, along with more than 300 other commenters. An analysis of the comments would serve as the next significant step in updating the NCAP. NHTSA has not published such an analysis.

pedestrian impact tests show that the car has a forgiving front design. The evaluation protocol, version 9.0.2, was last updated in November 2017.[49]

SAE International is developing standard specifications and requirements for pedestrian test mannequins and recently published a recommendation related to vehicle pedestrian detection systems.[50] Having different manufacturers use a standard target mannequin will further the goal of evaluating and comparing different collision avoidance systems. For the same reason, standard test speeds, sensor types, camera angles, vehicle orientation, crash type, location of vehicle strike, and other parameters should be incorporated into performance tests of automated systems. The NTSB concludes that for different automated pedestrian safety systems to be compared, there needs to be a standard set of test conditions to rate their performance. The NTSB therefore recommends that NHTSA develop performance test criteria for manufacturers to use in evaluating the extent to which automated pedestrian safety systems in light vehicles will prevent or mitigate pedestrian injury.

One way to advance safety systems and promote them in the marketplace is to inform consumers and respond to their demand. That approach led to recent vehicle requirements such as electronic stability control systems and roof strength standards. Information about safety systems can be introduced through the NCAP and the Insurance Institute for Highway Safety's rating system, among others. Pedestrian detection and collision avoidance systems should be considered in the assessments used by consumers to evaluate the safety of new vehicles. The NTSB concludes that the public would benefit from knowing that the model vehicle they are considering for purchase has pedestrian-safe design characteristics, and their choices could in turn affect the implementation of pedestrian safety systems in new car designs. The NTSB therefore recommends that NHTSA incorporate pedestrian safety systems, including pedestrian collision avoidance systems and other more-passive safety systems, into the NCAP.

Hybrid electric vehicles generate very little noise when operating under battery power, making them hard for pedestrians to detect.[51] In December 2016, NHTSA issued a final rule establishing FMVSS 141, which sets minimum sound requirements for hybrid and electric vehicles.[52] In February 2018, NHTSA published a revised FMVSS 141, based on petitions for reconsideration.[53] Under the new safety regulations, hybrids and electric cars will be equipped with a device that emits a sound to alert passersby that the vehicle is running. Manufacturers have until September 1, 2020, to meet the requirement. This is a positive step by the regulator.

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[49] See the Euro NCAP website on protection for vulnerable road users (https://www.euroncap.com/en/for-engineers/protocols/pedestrian-protection/).

[50] SAE International issued Active Safety Pedestrian Test Mannequin Recommendation J3116 on June 1, 2017. See the SAE website for details (https://www.sae.org/standards/content/j3116_201706/).

[51] The Highway Loss Data Institute studied injury-only claim frequency for hybrid vehicles. The frequency was estimated to be 19.6 percent higher for hybrids than for their nonhybrid counterparts (IIHS 2011).

[52] *Federal Register*, vol. 81, December 14, 2016: 90416–90522.

[53] *Federal Register*, vol. 83, February 26, 2018: 8182–8198.

4.2 Infrastructure Planning for Pedestrian Safety

Transportation planners and engineers in local jurisdictions are asking what steps they should take to better design streets and walking networks for pedestrian use. The Federal Highway Administration's role in pedestrian safety is to guide transportation agencies in identifying and prioritizing systemic safety improvements that will reduce injuries and fatalities. The Office of Safety at the Federal Highway Administration describes the systemic approach to improving safety as follows (FHWA 2013):

> a data-driven process that involves analytical techniques to identify sites for potential safety improvement and suggests projects for safety investment not typically identified through the traditional site analysis approach.

The Office of Safety cites four benefits of a systemic approach to local jurisdiction planning: (1) solves an unmet need in transportation safety, (2) uses a risk-based approach to prevent crashes, (3) results in a comprehensive road safety program, and (4) advances a cost-effective means of addressing safety concerns. To implement a systemic approach to pedestrian safety, local transportation agencies need to consider what risk factors are associated with pedestrian-related crashes, where risk factors exist in their local travel network, and what countermeasures can be implemented at those locations to mitigate the risks.

4.2.1 Pedestrian Safety Action Plans

Traditional street systems, designed for motor vehicle traffic, may not serve pedestrians well, for several highway engineering reasons:

- They may lack street design elements such as sidewalks, crosswalks, curb extensions, and speed bumps.
- They encourage high speeds.
- They have complex intersections with multiple turn lanes.
- Pedestrians have long waits at some crossings.
- Arterial roads through urban environments have wide, multiple lanes that are difficult to cross.
- Urban thoroughfares can separate neighborhoods from shopping, work, and entertainment.

Local safety action plans seek to safely incorporate pedestrians into the transportation network. Plans developed by municipalities can focus resources to yield the greatest possible reduction in the number of pedestrians who are severely or fatally injured by motor vehicles. The objectives of a pedestrian safety action plan are to establish a risk assessment framework (probably extending across several funding cycles), identify data requirements for selecting and evaluating actions, and prioritize countermeasures for increasing safety.

A plan for developing pedestrian safety action plans, prepared for the Federal Highway Administration and NHTSA by the Highway Safety Research Center at the University of North Carolina, calls for analyzing safety data, seeking public input, and coordinating the planning process (FHWA 2009).[54] It also recommends engaging with citizen groups, local public agencies, affected private sector interests, and the media, as well as coordinating with other local plans.[55]

States include components specific to pedestrian safety in their strategic highway safety plans.[56] Arizona, for example, completed a statewide bicycle and pedestrian safety plan in 2003. The state revised its plan in 2009 to include a goal of achieving a 20-percent reduction in pedestrian crashes (both fatal and nonfatal) by 2016. In July 2017, Arizona reported that since 2009, there had been safety improvements in many but not all of the targeted high-crash roadway segments, and that total pedestrian crashes had decreased by 5 percent (ADOT 2017).

Florida published a pedestrian and bicycle strategic safety plan in 2013 (FDOT 2013). At the time, Florida's pedestrian fatalities were double the national average, with the highest rate of any state in the country. The goal of the Florida Department of Transportation was to reduce pedestrian fatalities by 5 percent a year. The state's 2017 annual report on its safety plan noted that pedestrian fatalities had increased 3.6 percent since 2015. The report speculated that the increase might be due in part to increases in vehicle miles traveled and in the state population during the period. New Jersey published a pedestrian safety action plan "toolbox" in March 2014. Partly funded by a NHTSA grant, Michigan developed its first pedestrian safety plan in 2016, allocating monies to Ann Arbor, Royal Oak, Detroit, and Grand Rapids. Strategic highway safety plans encourage the states to prioritize pedestrian safety, although state efforts have not affected the total number of US pedestrian fatalities so far.

On the other hand, the pedestrian safety plans that cities have developed as part of Vision Zero, which can include targeting high-injury networks in specific urban areas, have proven effective. In New York City, more than 50 percent of the people killed in traffic crashes from 2005 to 2009 were pedestrians. During 2010–2011, the city developed a pedestrian safety action plan, which it updated in 2014. At the NTSB public forum on pedestrian safety, representatives of the New York City Department of Transportation described their work in data analysis, planning, and community outreach aimed at reengineering the urban environment for pedestrian safety. Their success is well documented (Sadik-Kahn and Solomonow 2017). In the city's 2018 Vision Zero report, the mayor noted that where major engineering changes had been made since 2005, fatalities had decreased by 34 percent—twice the rate of improvement at other locations in the city (NYC 2018).

New York City is cited as an example because of its success in reducing fatalities, but other cities have also developed pedestrian safety plans. San Francisco's 2017–2018 plan (the city

[54] The plan was originally developed in 2006 and revised in 2009 and 2017. The 2017 revision includes planning for bicycle safety (FHWA 2017).

[55] Other local plans could include state highway safety improvement plans, community transportation and mobility plans, Americans with Disabilities Act transition plans (efforts to make local facilities and programs accessible to all), trails or greenway plans, capital improvement plans, and area-specific or neighborhood plans.

[56] Strategic highway safety plans are a federal requirement, most recently updated in the FAST Act (2015).

adopted Vision Zero as a policy in 2014) illustrates how identifying high-crash roads allows a city to focus its safety projects.[57] By analyzing injury and crash data, planners determined that 61 percent of severe and fatal traffic injuries occurred on just 13 percent of the city's roads (San Francisco Department of Public Health 2017). With countermeasures targeted to those areas, the city saw a 20-percent decrease in pedestrian fatalities from 2015 to 2016. Other California cities reported similar results. San Diego determined that 30 percent of collisions occurred in eight street corridors, while San Jose found that slightly over 50 percent of fatalities occurred on 3 percent of its streets in 2014.[58] In 2015, Portland, Oregon, identified 30 high-crash streets and intersections, representing only 8 percent of the city's streets but accounting for 57 percent of deadly crashes.[59] The NTSB concludes that effective street designs for pedestrian safety are highly context-dependent and should be managed by local interests; however, states and cities would benefit from resources, tools, and funding support to develop and implement effective plans.

4.2.2 Design Guides

Design guides are used by state and local community planners and highway engineers to develop pedestrian safety action plans and related projects. Of the highway engineering and planning guides that focus on safety improvements, some outline assessment methods (such as the forthcoming guidebook based on analyses performed for the Federal Highway Administration's systemic pedestrian safety project[60]). Others target specific traffic designs (such as *A Guide for Reducing Collisions Involving Pedestrians*, published by the NCHRP as part of its guidance for implementing AASHTO's strategic highway safety plan [NCHRP 2004]). Still others provide guidance for pedestrian markings in the context of roadway traffic control (such as the Federal Highway Administration's *Manual on Uniform Traffic Control Devices*[61]).

The online tool "Pedestrian Safety Guide and Countermeasure Selection System" lists engineering, education, enforcement, encouragement, and evaluation countermeasures for improving pedestrian safety.[62] The Institute of Transportation Engineers also publishes several guides, including a handbook for the design of traffic control devices (ITE 2013). Its guide for designing walkable urban streets (ITE 2010) expands on AASHTO's "Green Book"—a policy document for the design of highways and streets (AASHTO 2001).

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[57] A pamphlet describing San Francisco's Vision Zero strategic plan for 2017–2018 can be found at the following website: https://issuu.com/sfmta_marketing/docs/vision_zero_action_strategy_final_d.

[58] For details about Vision Zero in San Diego and the city's pedestrian collision analysis, see San Diego's Vision Zero website (https://www.sandiego.gov/vision-zero). For information about Vision Zero in San Jose, see the city's website for its 2-year action plan (http://www.sanjoseca.gov/DocumentCenter/View/74828).

[59] See the case study of Portland's Vision Zero approach at https://visionzeronetwork.org/project/taming-speed-for-safety-portland-case-study/.

[60] For a description of Project NCHRP-17-73, see the Transportation Research Board website (http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3876).

[61] The manual, known as the MUTCD, specifies the standards by which traffic signs, road surface markings, and signals are designed, installed, and used.

[62] For guides, case studies, and resources, see the PEDSAFE website (http://www.pedbikesafe.org/PEDSAFE/).

The National Association of City Transportation Officials publishes a set of design guides that survey the principles of making city streets safe and inviting for pedestrians.[63] The *Urban Street Design Guide* (NACTO 2013) characterizes types of streets and the design principles appropriate to them. The association holds regular training sessions on street design for members and nonmembers.

The Federal Highway Administration periodically issues guidance memorandums that describe proven safety countermeasures to promote infrastructure-oriented safety treatments and strategies.[64] As discussed at the NTSB pedestrian safety forum (section 3.3), they include countermeasures for pedestrian safety such as pedestrian crossing islands and traffic-calming infrastructure changes that cause drivers to slow down. While designated proven, assessments are conducted by each state's department of transportation in accordance with chapter 9 of the AASHTO (2010) *Highway Safety Manual*. State evaluation work is also guided by the Federal Highway Administration's *Reliability of Safety Management Methods* (FHWA 2016b). Evaluation methods vary.

The Federal Highway Administration engaged the Pedestrian and Bicycle Information Center to develop a resource listing the design elements and guidance that apply to pedestrian safety. The information was updated in November 2017 to include funding opportunities.[65] Similar information for the use of design guidelines can be found on the Pedestrian and Bicycle Information Center website.[66] The NTSB concludes that the design guidance needed to develop effective pedestrian safety action plans is readily available to local transportation planners.

4.2.3 Expanding Local Site-Specific Planning Activities

The Federal Highway Administration and its state transportation department partners have traditionally addressed major infrastructure projects, such as interstate highways, state road projects, and bridges. Such projects connect communities that vary in population density and geography. By comparison, pedestrian transportation projects are site-specific, context-sensitive, and hyperlocal. The US Department of Transportation and the Federal Highway Administration in recent years have created programs targeted to local, site-specific projects. This section examines those initiatives, recognizes their efforts and their limitations, and recommends an expanded program to engage local pedestrian safety projects.

In fall 2014, the Department of Transportation launched the Safer People, Safer Streets initiative to address safety issues in nonmotorized transportation. The initiative had three elements:

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63 For the contents of each guide, see the NACTO website (https://nacto.org/publications/design-guides/).

64 The guidance memorandums and information about specific treatments and strategies can be found at the Office of Safety's website on proven safety countermeasures (https://safety.fhwa.dot.gov/provencountermeasures/).

65 Pedestrian and bicycle funding opportunities are listed by the Federal Highway Administration at https://www.fhwa.dot.gov/environment/bicycle_pedestrian/funding/funding_opportunities.cfm.

66 See the design resource index on the Pedestrian and Bicycle Information Center website (http://www.pedbikeinfo.org/planning/facilities_designresourceindex.cfm).

Safety Assessments, Mayors' Challenge, and Safer Policies.[67] The Mayors' Challenge worked with stakeholders to identify and remove barriers to improving nonmotorized transportation safety.[68] As part of Safer Streets, the Department of Transportation conducted research, developed planning resources, and highlighted tools for a range of transportation professionals.[69]

The Federal Highway Administration's Focused Approach to Safety program provides resources to eligible, high-priority states for addressing critical safety challenges.[70] One emphasis area is pedestrian and bicycle crashes (the others are intersection crashes and roadway departures). The program focuses on states and cities with a high number of pedestrian fatalities and injuries (being selected by the Department of Transportation as a focus city calls attention to prioritizing safety efforts).[71] As discussed in sections 4.2.1 and 4.2.2, the Federal Highway Administration has developed plans and guides for use by local jurisdictions in improving pedestrian safety. Each state has a bicycle and pedestrian coordinator, and each Federal Highway Administration division office has a point of contact.

Another Federal Highway Administration initiative, Every Day Counts, is currently in its fourth year (EDC-4 Innovations for 2017–2018).[72] Every Day Counts is a state-based approach to implementing projects that promote safety, reduce congestion, or improve sustainability. One innovation in EDC-4 is the Safe Transportation for Every Pedestrian (STEP) program.[73] STEP promotes five pedestrian safety countermeasures.[74] Communities deploy the pedestrian safety improvements according to their specific roadway contexts and needs. The program aligns with the Department of Transportation's Safer People, Safer Streets initiative and is an important part of the Federal Highway Administration's *Strategic Agenda for Pedestrian and Bicycle Transportation*, a collaborative framework for pedestrian and bicycle planning, design, and research that is being developed over the next 5 years.

In October 2016, the Federal Highway Administration, the National Safety Council, the Federal Motor Carrier Safety Administration, and NHTSA launched the Road to Zero initiative,

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[67] A summary report on the Safer People, Safer Streets initiative, published in October 2015, is available at https://www.transportation.gov/ped-bike-safety/pedestrian-and-bicyclist-safety-assessment-report.

[68] The Mayors' Challenge activities were (1) take a Complete Streets approach; (2) identify and address barriers to make streets safe and convenient for all road uses; (3) gather and track biking and walking data; (4) use designs that are appropriate to the context of the street and its use; (5) take advantage of opportunities to create and complete ped–bike networks through maintenance; (6) improve walking and biking safety laws and regulations; (7) educate and enforce proper road use behavior by all. For more information, see the website describing success stories from the Mayors' Challenge (https://www.transportation.gov/mayors-challenge).

[69] For information offered under the fourth challenge to mayors, see "Design Right" (https://cms.dot.gov/sites/dot.gov/files/docs/Challenge4_DesignRight.pdf).

[70] The Focused Approach to Safety is described at https://safety.fhwa.dot.gov/fas/.

[71] In a memorandum dated July 29, 2015, the associate administrator for safety at the Federal Highway Administration noted that focus cities were among the top 50 cities for pedestrian fatalities. In 2015, the selection criteria were adjusted to include bicyclists for the 20 cities with the largest number of pedestrian and bicyclist fatalities and any city that had a fatality rate per population higher than the average of the top 50 cities.

[72] See the Federal Highway Administration website for Every Day Counts (https://www.fhwa.dot.gov/innovation/everydaycounts/).

[73] See the STEP website (https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/step.cfm).

[74] The five countermeasures are road diets, pedestrian hybrid beacons (a type of stop control), pedestrian refuge islands, raised crosswalks, and crosswalk visibility enhancements (such as lighting and markings).

with the goal of eliminating roadway deaths by 2050. The Department of Transportation committed $1 million a year for 3 years to fund grants. The National Safety Council administers the grants and is contributing $1 million over 3 years to support the coalition.

The Federal Highway Administration is moving toward supporting planning efforts in midsize cities, as evidenced by its recent grant history. America Walks, a nonprofit national organization working with communities to create safe and accessible walking conditions, received a 2018 Road to Zero grant from the National Safety Council to provide technical assistance to pedestrian safety programs for midsize cities. This role does not appear to be formalized or financially supported for small urban areas.

Between 2014 and 2018, the effect of the Road to Zero program did not, of itself, dramatically affect overall pedestrian safety metrics. That is understandable, because of the focused approach to targeted communities and because infrastructure projects require a long time for planning, construction, and public acceptance. As a result, infrastructure changes can be slow to show results. While recognizing the programs put in place by the Federal Highway Administration to improve pedestrian safety, the NTSB concludes that addressing the pedestrian safety design changes needed for many of our urban environments will take substantially more resources. The NTSB therefore recommends that the Federal Highway Administration expand its support of state and local safety projects beyond focus cities to promote municipal pedestrian safety action plans that develop a network of safety improvements.

4.3 Improved Pedestrian Safety Data

In discussing pedestrian safety data at the NTSB public forum, presenters noted that we know less about travel frequency, purpose, routes, and safety for pedestrians than for most any other category of road user. That lack of information is particularly important, considering that pedestrians account for one in six highway fatalities. Data-driven solutions and project prioritization based on outcome measures are accepted highway concepts. However, gaps in data concerning pedestrians' use of transportation networks and details about pedestrian safety limit our understanding. In turn, data gaps hamper the prioritization of projects and the application of limited federal, state, and local funding.

The Department of Transportation's strategic plan for 2018–2022 cites safety as the first of four goals. Its systemic safety objective for accomplishing that goal lists improved data first. The plan states that the department will

> integrate traditional data sources with new, external data sources, grow data analysis capabilities, and promote the use of safety and cybersecurity data to enable evidence-based policy-making. In addition, data will be used to inform how [the Department of Transportation] sets safety standards . . . . (DOT 2018,12)

Section 4.3.1 considers the lack of metrics on pedestrian exposure and how that lack constrains our understanding of safety risk. Section 4.3.2 recognizes the limitations in pedestrian crash data used for research. Section 4.3.3 moves beyond fatal crashes to consider our understanding of pedestrian injuries in nonfatal crashes. Section 4.3.4 examines safety performance metrics.

4.3.1 Pedestrian Exposure Data

We know that pedestrian fatalities have increased over the last few years, but is that because more people are walking as a form of transportation? Do urban versus rural demographics tell us about where people walk? It takes good exposure data to answer those questions. Most pedestrian activity is collected by observational research or in phone surveys. More-sophisticated methods than multiyear surveys are available to monitor walking patterns, particularly in dense urban areas, but those data can be difficult and expensive to process. For specific urban locations, pedestrian activity can be factored into traffic designs. However, individual project metrics are generally not aggregated into state or national numbers that qualify pedestrian safety. This section looks at the opportunity for and uses of better data on pedestrian activity.

The National Household Travel Survey includes a section on person travel. However, the survey, which has been conducted six times in the last 35 years, yields only a periodic sample of walking behavior. While past surveys have estimated walking trips, new developments in computer vision techniques are improving the accuracy of data collection as well as reducing the costs.[75] A guidebook on volume data collection, published by the Transportation Research Board in 2014, examines some of those processes (TRB 2014). Research under way to develop enhanced methodologies will be released in 2020.[76] Methodologies for estimating the number of walking trips for an urban intersection, block, or corridor are available to urban planners.

Pedestrian trip data are needed to support local traffic-calming projects (which use various means, such as raised crosswalks and lane narrowing, to slow cars as they move through neighborhoods) and to validate that traffic calming serves to increase pedestrian use of the transportation network. But collection and analysis of those data is limited. Dense datasets on the nonmotorized transport flow for local jurisdictions can be difficult to establish, maintain, and analyze. Specialized methods for collecting, managing, and using traffic data are continually evolving. Pedestrian-counting technology (pneumatic tube counters, inductive loop counters, computer vision traffic sensors, microwave sensors, infrared sensors) can be employed to improve exposure data.[77] Surrogate data that include movements associated with pedestrians can also be useful (Wi-Fi and Bluetooth records, software application data, and traffic control pushbuttons used to activate crossing signals). Urban planners need data on the number of pedestrians who use the roads, both to identify overall trends and to develop plans for specific intersections. Different location-specific data should have compatible formats to allow their aggregation into larger geographic areas.

[75] Computer vision uses intelligent processing of digital images captured by a video camera to count pedestrians.

[76] *Enhancing Pedestrian Volume Estimation and Developing HCM [Highway Capacity Manual] Pedestrian Methodologies for Safe and Sustainable Communities* (NCHRP 17-87, 2020 Q4). The Transportation Research Board's report to the AASHTO Technical Committee on Nonmotorized Transportation lists the report as a current project due for completion in 2020 (http://www.trb.org/NCHRP/Pages/Report-to-AASHTO-Tech-Committee-on-Nonmotorized-Tr-776.aspx).

[77] Pneumatic tube counters use rubber tubes placed across a road that activate a recording device when pressed. Inductive loop counters work similarly, using coils installed on the road surface that send an electronic signal to a counting device when someone or something passes over them. Microwave sensors transmit low-energy microwave radiation and analyze the reflected signal. Infrared sensors detect and count targets that are warmer than their surroundings.

To gather meaningful data that can be compared between jurisdictions and consolidated into national safety trends, we need a consensus on common metrics. Work by metropolitan planning organizations and state governments to collect pedestrian exposure data and define a common framework is needed to allow combining data sources. These activities are required by, and are being conducted as part of, local pedestrian safety action plans (discussed in section 4.2.1). For data to be compatible across jurisdictions, however, federal guidance is useful. Work is under way to improve the Federal Highway Administration's pedestrian data. The Travel Monitoring Analysis System is available as a layer of the National Transportation Atlas Database, published by the Bureau of Transportation Statistics at the US Department of Transportation. The Travel Monitoring Analysis System, one of the US government's open databases, uses geospatially referenced data collected by the Federal Highway Administration from state departments of transportation to monitor vehicle traffic.[78] No comparable national network is available for pedestrian traffic.

In discussing key research gaps, the background report on the Federal Highway Administration's Pedestrian Safety Strategic Plan, prepared by the Highway Safety Research Center at the University of North Carolina, identifies a research need in the collection and evaluation of pedestrian exposure data (FHWA 2010). To improve analysis and decision-making, the report calls for using national exposure data to examine the relationship between pedestrian exposure and safety. The report also identifies pedestrian exposure as a useful metric for evaluating the effects of new street design elements related to pedestrians. The NTSB concludes that planners need localized pedestrian data to support the decision-making process for urban pedestrian plans and to prioritize infrastructure projects; in addition, the larger safety community needs national data about pedestrian use of the transportation network. The NTSB therefore recommends that the Federal Highway Administration develop standard definitions and establish methods that states and metropolitan planning organizations can use to collect pedestrian exposure data, then define a common framework that will allow those data sources to be combined into a national metric of pedestrian activity.

4.3.2 Crash Data for System Development and Research

In addition to their use in safety analysis, crash records are employed for a variety of research and system development purposes—for example, to analyze vehicle designs and injury outcomes, or to model and validate collision avoidance systems. The NHTSA National Center for Statistical Analysis identifies injury mechanisms and the associated crash dynamics in motor vehicle crashes. It also evaluates the effectiveness of crashworthiness, crash avoidance, and traffic safety efforts, and regularly publishes crash statistics, traffic safety fact sheets, and research notes containing information on crashes at both national and state levels.[79]

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[78] Active efforts are also supported by the Federal Highway Administration, AASHTO, the Institute of Transportation Engineers, and the American Society of Civil Engineers through joint involvement in the National Travel Monitoring Exposition and Conference. The Federal Highway Administration released an updated edition of its *Traffic Monitoring Guide* in 2016 to provide guidance to state highway agencies (FHWA 2016c). To access the government's open data, go to the data.gov website.

[79] As an example, the National Center for Statistical Analysis published a research note analyzing how vehicle age and model year relate to the severity of driver injuries in fatal crashes (NHTSA 2013).

A specific data set addressing pedestrian crashes was developed in the 1990s—NHTSA's 1994–1998 Pedestrian Crash Data Study. That data set provided detailed crash information on 521 cases collected at six sites across the United States. A previous set of pedestrian crash files existed in NASS for 1982–1986. The need for an updated data set was identified in 1992, in response to new, aerodynamically designed vehicles entering the marketplace (Chidester and Isenberg 2001, 1).

The Pedestrian Crash Data Study has been used to determine whether vehicle designs create the same or different types of injuries. Epidemiological studies on pedestrian crash victims indicate that the head and lower extremities are the most frequently injured parts of the body (Liu and others 2016). The front bumper is the major source of injury to the lower extremities, and the location of head impacts differs depending on the vehicle profile. Because the new car market now favors SUVs over smaller sedans, the safety of those designs in pedestrian crashes needs reevaluation.

Research in 2017 by the Virginia Tech Transportation Institute, with support from Toyota's Collaborative Safety Research Center, identified cases from the Pedestrian Crash Data Study as the most recent quality data set suitable for modeling pedestrian collision avoidance systems (Detwiller and Gabler 2017). Thus, research to estimate the efficacy of pedestrian safety systems for the future had to rely on 20-year-old data. Because computer systems are used to evaluate the algorithms in pedestrian avoidance software, researchers need a current, well-documented set of crash data to input into the systems, rather than outdated information. Vehicle injury outcomes and modeling of collision avoidance systems are just two of many examples of the research use of pedestrian crash data.

The NTSB concludes that the most complete set of pedestrian crash data available for safety analysis and research is more than two decades old, collected at a time when vehicle designs were substantially different from those of current models. The NTSB therefore recommends that NHTSA develop a detailed pedestrian crash data set that represents the current, complete range of crash types and that can be used for local and state analysis and to model and simulate pedestrian collision avoidance systems.

4.3.3 Improved Aggregated Event Data

The US Department of Transportation, the states, and municipalities are all sources of crash data. States have in the past developed systems that link crash reports to medical data to improve the completeness of pedestrian safety data, including both fatal and nonfatal injury data and location patterns of where crashes occur. An important example of a state linkage system was the Crash Outcome Data Evaluation System (CODES), originated by NHTSA in 1992. In 2009, NHTSA advised the states that it planned to stop providing funding and technical assistance for CODES.[80] In 2013, NHTSA ended federal support of the CODES program. Without funding support, fewer and fewer states are linking crash and injury data, although some states continue to do so. In 2015, NHTSA and the Centers for Disease Control and Prevention identified both facilitators and barriers to the process of linking data (Milani and others 2015). Also in 2015,

[80] In 2009, NHTSA only partially funded the CODES program.

NHTSA released an examination of CODES methodologies (Cook and others 2015). Statutory requirements for obtaining and reporting data, including personal privacy requirements, were identified as a barrier to linking data. NHTSA and the Centers for Disease Control and Prevention have recommended addressing the problem by using probabilistic linking algorithms to connect groups by characteristic rather than individual identity.

As evidenced by the efforts of other countries to link injury and fatality information, this is an important safety metric. For example, Sweden has implemented a nationwide database, called STRADA (Swedish Traffic Accident Data Acquisition), that integrates police crash data with hospital admissions data. The STRADA database addresses the underreporting problem common to walking and biking, thereby giving Swedish engineers and planners a more complete picture of the transportation network.[81]

In the United States, the Transportation Research Board has established "scan teams" of engineers and other transportation professionals to exchange information and technology.[82] Teams identify novel practices in their fields of interest, assess the potential benefits of applying the practices in other settings, make field visits, and report the results. In May 2009, an international scan team of 12 transportation professionals with expertise in bicycling and walking visited five countries in Europe. The team found that integrating crash and hospital data improves the picture of pedestrian safety. The team's report noted that "some of the host countries are paying meticulous attention to crash and injury data to determine which road designs are safest for pedestrians and bicyclists" (FHWA, AASHTO, and NCHRP 2009, 5). Combining injury with fatality data allows assessment of the degree of harm for different crash characteristics.

In lieu of CODES data, NHTSA proposed that NASS/GES, and later CRSS, could be used as a source of data on nonfatal crashes. The system has limitations, however.[83] One important drawback is coding differences in the data. For example, injury data are coded by police officers on a five-point scale (known as the KABCO scale): killed, incapacitated, nonincapacitating, possible injury, or no injury. Research has shown that the KABCO scale does not effectively capture injury severity or actual injury outcomes, as measured by the Maximum Abbreviated Injury Score.[84] Other injury scales include the four levels used by the California Highway Patrol (killed, severely injured, other visible injury, or complaint of injury). Moreover, because police coding of injuries is not linked to the health data in hospital records, it cannot be cross-checked.

A more complete picture of all pedestrian injuries would help improve the walking network and guide the development of safety countermeasures. Data linkage is the next pivotal step in preventing motor vehicle injuries to pedestrians. In researching the CODES data as they existed several years ago, the NTSB confirmed, as stated earlier, that some states and cities have continued

[81] Note that Sweden initiated Vision Zero.

[82] AASHTO, the Federal Highway Administration, and others have been active in technology transfers at the international level through such activities as NCHRP Project 20-36, "Highway Research and Technology—International Information Sharing."

[83] The last NASS/GES dataset was for 2015, but the data history is still available on the NHTSA webpage (https://www.nhtsa.gov/research-data/national-automotive-sampling-system-nass).

[84] See Birch, Cook, and Dischinger (2014); Compton (2005); Farmer (2003); Popkin and others (1991).

the work of linking hospital injury data with traffic fatality and injury records associated with police reports.[85] As local planning organizations develop plans for Vision Zero, municipalities have staffed epidemiologists to maintain linked data for local planning analysis.[86] In 2017, as noted in section 4.2.1, San Francisco used injury and crash data to identify the most dangerous road segments for pedestrians for the purpose of focusing its safety countermeasures. The city's analysis validated earlier work estimating that pedestrian injuries in San Francisco were underreported by more than 20 percent (Sciortino and others 2005).

Data linkage is important and timely: (1) It improves national motor vehicle crash surveillance by connecting police crash reports and medical data. The connection produces a complete picture of nonfatal motor vehicle crashes, their risk and protective factors, health outcomes, and costs. Without linked data, it is difficult, and in some cases impossible, to understand the causes of crashes and the medical outcomes. (2) States need data linkage to identify injury prevention opportunities before, during, and after a crash. Linked data can equip states to assess what types of crashes and medical outcomes are the most common and costly and to determine the most cost-effective ways of preventing injuries. The NTSB concludes that a state data system linking state police crash reports to hospital intake and emergency room medical records would facilitate the development of targeted countermeasures to reduce pedestrian crashes and the injury severity of those crashes.

To link hospital injury data with other information requires a process for protecting patient privacy. The Centers for Disease Control and Prevention have worked with NHTSA in the past to establish such processes and develop guidelines for states in using hospital data. The state highway community (AASHTO) recognizes the value of linking data and has worked to develop guidance.[87] The NTSB therefore recommends that NHTSA and the Centers for Disease Control and Prevention develop and implement a plan for the states to combine highway crash data and injury health data, with the goal of producing a national database of pedestrian injuries and fatalities.

The NTSB's safety study, *Crashes Involving Single-Unit Trucks That Resulted in Injuries and Deaths* (NTSB 2013a), compared the risks of single-unit truck crashes with those of tractor-trailer crashes. CODES data served as the primary source of data regarding injury severity and hospitalizations in relation to truck and accident characteristics. On July 2, 2013, as a result of the study, the NTSB recommended that the US Department of Transportation take the following action:

> Develop and implement a plan to ensure the continued collection of data as performed for the Trucks in Fatal Accidents database and the continuation of state linkage to hospital and

[85] Linking is done using a method of probabilistic matching, called LinkSolve, developed under the original CODES program. An overview of linking health data is found at https://www.ncbi.nlm.nih.gov/books/NBK253312/.

[86] In 2010, the mayor of San Francisco directed the city to develop linked data (for 2013–2015) that were used to create high-injury network maps for the city. The mayor also funded staffing for an epidemiologist for that function.

[87] AASHTO's work on NCHRP project 20-7, "Research for the AASHTO Standing Committee on Highways," has a history of addressing data needs. Past projects include NCHRP 17-43, "Long-Term Roadside Crash Data Collection Program"; NCHRP 17-57, "Development of a Comprehensive Approach for Serious Traffic Crash Injury Measurement and Reporting Systems"; and NCHRP 20-24(37)K, "Measuring Performance among State DOTs [Departments of Transportation]: Sharing Good Practices—Safety (Serious Injuries)."

police-reported data as performed by the Crash Outcome Data Evaluation System. (H-13-26)

The safety goal of the recommendation was to establish a comprehensive approach to characterizing fatalities and injuries for an identified class of heavy vehicles. In June 2014, the NTSB received a response to the recommendation from the US Department of Transportation, noting work by the Federal Highway Administration. In 2014, the Federal Highway Administration published a notice of proposed rulemaking to establish performance measures for states to use when counting the numbers of fatalities and serious nonfatal injuries occurring on all public roads, and to estimate both fatality and serious injury rates per vehicle mile traveled.[88] The notice of proposed rulemaking noted that the Department of Transportation recommends that states determine serious injuries using a reporting system that links injury outcomes from hospital medical records to crash reports. The performance measures were intended to help states carry out the federal Highway Safety Improvement Program (HSIP).

The HSIP is a federal aid program to the states for reducing traffic fatalities and serious injuries on all public roads, including non-state-owned roads and roads on tribal land. The HSIP, legislated under Title 23 *United States Code*, section 148, requires states to develop a data-driven, strategic approach to highway safety improvement.[89] State transportation departments have established performance measures for use in carrying out the program. States are expected to establish statewide targets for each of five safety performance measures, one of which is the number of nonmotorized fatalities and nonmotorized serious injuries. By April 15, 2019, states are required to report serious injuries in compliance with the new definition in the final rule for the safety performance measures.[90]

While we typically think of pedestrians and bicyclists as separate groups, the HSIP nonmotorized safety performance measure combines pedestrian and bicycle fatalities. Moreover, the measure combines fatalities with a much less well-defined measure of nonmotorized serious injuries. According the Federal Highway Administration, the numbers are combined to account for the volatility of small data sets in some states and to minimize different reporting metrics. The number of nonmotorized serious injuries is the total number for pedestrians and bicyclists, as defined by the American National Standard *Manual on Classifications of Motor Vehicle Traffic Crashes* (ANSI 2017).[91]

By comparison, NHTSA procedures for grant funding have separate measures that address nonmotorized users—one for pedestrian fatalities and one for bicyclist fatalities. The number of nonmotorized fatalities is the total number of fatalities with FARS person-level attribute codes: (5) pedestrian, (6) bicyclist, (7) other cyclist, and (8) person on personal conveyance. Because the

[88] *Federal Register*, vol. 79, March 11, 2014: 13846–13871.

[89] The *Highway Safety Improvement Manual* describes the overall program.

[90] The final rule was published in the *Federal Register* on March 15, 2016, with an effective date of April 14, 2016. The final rule adds Part 490 to Title 23 *Code of Federal Regulations*.

[91] For states that do not use the American National Standard definition in their motor vehicle crash database, a serious-injury conversion table gives equivalent definitions.

coding distinctions are found in records of fatalities, NHTSA does not include a performance measure for serious injuries to pedestrians or bicyclists.

Based on the US Department of Transportation's response, and considering the notice of proposed rulemaking, the NTSB classified Safety Recommendation H-13-26 as "Open—Acceptable Response" on September 9, 2016. In subsequent correspondence, NHTSA reported on transitioning CODES to state responsibility and cataloged 4 years of state-linked data applications (Kindelberger and Milani 2015), as well as examining the application of CODES in several states (Cook and others 2015). NHTSA stated that it did not intend to pursue additional resources for those programs. This special investigation of pedestrian safety illustrates that data needs include all types of highway users (not just heavy trucks, the subject of Safety Recommendation H-13-26). Recognizing the need to understand serious nonfatal injuries that occur on all public roads, and in view of NHTSA's stated position, the NTSB reclassifies Safety Recommendation H-13-26 as "Closed—Superseded" and proposes Safety Recommendation H-18-45 in its place.

Effectively combining different data sets (as discussed here for injuries and fatalities) has several requirements, including standard data dictionaries, regular and compatible reporting cycles, and terms of use. Many requirements were worked out for the CODES program. However, most states no longer maintain the data networks that fed CODES. A unified or common data structure is therefore lacking. The NTSB concludes that to facilitate the aggregation of state data into a national picture of pedestrian fatalities and injuries, a common data structure needs to be used by the many jurisdictions compiling the data. The NTSB therefore recommends that NHTSA examine the past framework of CODES and establish methods that states and metropolitan planning organizations can use to collect pedestrian event data, then define a common framework that will allow those data sources to be combined.

5 Conclusions

5.1 Findings

1. Vehicle headlight systems require an evaluation that is more advanced than bench testing of bulb output.

2. Motor vehicle safety standards should not limit advanced vehicle lighting systems that have been shown to have safety benefits.

3. Incorporating pedestrian injury mitigation into vehicle hood and bumper designs would improve pedestrian safety.

4. For different automated pedestrian safety systems to be compared, there needs to be a standard set of test conditions to rate their performance.

5. The public would benefit from knowing that the model vehicle they are considering for purchase has pedestrian-safe design characteristics, and their choices could in turn affect the implementation of pedestrian safety systems in new car designs.

6. Effective street designs for pedestrian safety are highly context-dependent and should be managed by local interests; however, states and cities would benefit from resources, tools, and funding support to develop and implement effective plans.

7. The design guidance needed to develop effective pedestrian safety action plans is readily available to local transportation planners.

8. Addressing the pedestrian safety design changes needed for many of our urban environments will take substantially more resources.

9. Planners need localized pedestrian data to support the decision-making process for urban pedestrian plans and to prioritize infrastructure projects; in addition, the larger safety community needs national data about pedestrian use of the transportation network.

10. The most complete set of pedestrian crash data available for safety analysis and research is more than two decades old, collected at a time when vehicle designs were substantially different from those of current models.

11. A state data system linking state police crash reports to hospital intake and emergency room medical records would facilitate the development of targeted countermeasures to reduce pedestrian crashes and the injury severity of those crashes.

12. To facilitate the aggregation of state data into a national picture of pedestrian fatalities and injuries, a common data structure needs to be used by the many jurisdictions compiling the data.

6 Recommendations

6.1 New Recommendations

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

To the National Highway Traffic Safety Administration:

> Revise Federal Motor Vehicle Safety Standard 108 to include performance-based standards for vehicle headlight systems correctly aimed on the road and tested on-vehicle to account for headlight height and lighting performance. (H-18-39)
>
> Revise Federal Motor Vehicle Safety Standard 108 to allow adaptive headlight systems. (H-18-40)
>
> Develop performance test criteria for vehicle designs that reduce injuries to pedestrians. (H-18-41)
>
> Develop performance test criteria for manufacturers to use in evaluating the extent to which automated pedestrian safety systems in light vehicles will prevent or mitigate pedestrian injury. (H-18-42)
>
> Incorporate pedestrian safety systems, including pedestrian collision avoidance systems and other more-passive safety systems, into the New Car Assessment Program. (H-18-43)
>
> Develop a detailed pedestrian crash data set that represents the current, complete range of crash types and that can be used for local and state analysis and to model and simulate pedestrian collision avoidance systems. (H-18-44)
>
> Work with the Centers for Disease Control and Prevention to develop and implement a plan for the states to combine highway crash data and injury health data, with the goal of producing a national database of pedestrian injuries and fatalities. (H-18-45)
>
> Examine the past framework of the Crash Outcome Data Evaluation System and establish methods that states and metropolitan planning organizations can use to collect pedestrian event data, then define a common framework that will allow those data sources to be combined. (H-18-46)

To the Federal Highway Administration:

> Expand your support of state and local safety projects beyond focus cities to promote municipal pedestrian safety action plans that develop a network of safety improvements. (H-18-47)

> Develop standard definitions and establish methods that states and metropolitan planning organizations can use to collect pedestrian exposure data, then define a common framework that will allow those data sources to be combined into a national metric of pedestrian activity. (H-18-48)

To the Centers for Disease Control and Prevention:

> Work with the National Highway Traffic Safety Administration to develop and implement a plan for the states to combine highway crash data and injury health data, with the goal of producing a national database of pedestrian injuries and fatalities. (H-18-49)

6.2 Previously Issued Recommendation Reclassified in This Report

Safety Recommendation H-13-26, which was issued to the US Department of Transportation on July 3, 2013, is reclassified "Closed—Superseded":

> Develop and implement a plan to ensure the continued collection of data as performed for the Trucks in Fatal Accidents database and the continuation of state linkage to hospital and police-reported data as performed by the Crash Outcome Data Evaluation System. (H-13-26)

The recommendation is superseded by Safety Recommendation H-18-45.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

ROBERT L. SUMWALT, III
Chairman

BRUCE LANDSBERG
Vice Chairman

EARL F. WEENER
Member

T. BELLA DINH-ZARR
Member

JENNIFER HOMENDY
Member

Adopted: September 25, 2018

Board Member Statement

Board Member Earl F. Weener filed the following concurring and dissenting statement on October 3, 2018.

As a resident of a metro area, I am glad we addressed the issue of pedestrian deaths as a result of collisions with vehicles. I agree that technology offers a very promising future where many of these fatal interactions could be avoided. However, I am concerned that the recommendations we made, even if adopted as swiftly as could possibly be hoped for, will take years to save a life. To that end I feel compelled to share a few thoughts.

Of the fifteen investigations we completed as a basis for this report, fourteen involved either a pedestrian who was under the influence of an intoxicant or a large vehicle, such as an SUV or bus. Some cases involved both. It is understandable that drivers of larger vehicles may have trouble seeing pedestrians, particularly those of smaller stature, in crosswalks or other situations when the vehicle is accelerating from a stopped position. I think that it is particularly important for manufacturers of these higher profile vehicles to take note of available pedestrian detection and collision avoidance technologies and, whenever possible, adopt these lifesaving devices.

We have emphasized the need to keep impaired drivers off the road, but especially because of their relative vulnerability, it is also imperative to keep impaired pedestrians out of the road. Impairment can be caused by alcohol and other drugs. It can also be caused by distraction. It is up to local authorities to determine how to address changing or growing trends in drug use or personal electronic devices or any other behavior that puts a pedestrian population at risk of injury or death. Some jurisdictions have taken proactive measures, such as Hawaii, which has passed a law prohibiting looking down at a phone, instead of right and left, before crossing a road.

I was also very disheartened to see two of our investigations relating to the preventable death of children trying to get to school. These cases should motivate school districts and parents to consider risk assessments of how and when they are asking children, especially very young children, to commute. While improved headlights will undoubtedly save lives, changing manufacturing rules and getting better headlights into a wide selection of the private vehicle fleet will take years. It is possible to take action now. A wide variety of retro-reflective and lighting options exist that could improve the conspicuity of child pedestrians as we wait for the much-needed improvements in headlights.

It is my hope that state and local governments keep in mind the need for public education and enforcement of any existing measures available to them that will serve to keep pedestrians out of harm’s way.

Vice Chairman Bruce Landsberg joined in this statement.

Appendix A: Pedestrian Crashes

The fatal pedestrian crashes investigated in support of the pedestrian safety project and this special investigation report are summarized below. They span an approximately 6-month period, from April to November 2016, and are given in order of occurrence.

The cases were selected on the basis of investigative staff availability and consideration for the opportunity to identify and coordinate a timely investigative response. The set does not reflect the distribution of national pedestrian fatalities (FARS) data. Nor does it include hit-and-run crashes, although historically, as many as one in five pedestrian fatalities are caused by hit-and-run vehicles (NHTSA 2018). Hit-and-run drivers do not stop to render aid. Because the movement of the crash vehicles was of primary investigative interest, no hit-and-run crashes were among the cases selected for the project.

The NTSB determined the probable cause for each pedestrian crash investigated. Local law enforcement officials were responsible for determining violations of state laws and for filing criminal charges, as appropriate. In cases involving criminal prosecution, a determination of the court's decision might not have been available at the time of the NTSB's investigation. However, information about law enforcement actions, such as issuing citations or filing other criminal charges, is included in the NTSB public docket if available.

Instructions for Accessing NTSB Investigative Docket

Factual evidence collected during investigations is released to a public docket, available on the NTSB website. From the www.ntsb.gov homepage, the center top tab "Investigations" offers a dropdown for NTSB Accident Dockets. The Docket Management Page offers a search button option. Entering an accident identifier, such as HWY16SH009, will bring up an active link. Entering only the state (Maryland) and city (Riverdale Park) will bring up a history of recent cases from that location, from which the case of interest can be selected. The docket can include other documents from the investigation.

Fatal Pedstrian Collision with Car, Riverdale Park, Maryland, April 24, 2016 (HWY16SH009)

About 9:16 p.m. on Sunday, April 24, 2016, a 1998 Toyota Corolla four-door sedan was traveling north on Kenilworth Avenue (State Route 201) in Riverdale Park, Prince George's County, Maryland. As the 50-year-old female driver approached the intersection of Kenilworth Avenue and Tuckerman Street, the traffic signal for northbound vehicles was green. The driver observed a male pedestrian walking east in the middle of the intersection, trying to cross Kenilworth Avenue. The driver applied the brakes and attempted to steer left, away from the pedestrian, but the car struck him in the left northbound through lane of the intersection (figure A-1).

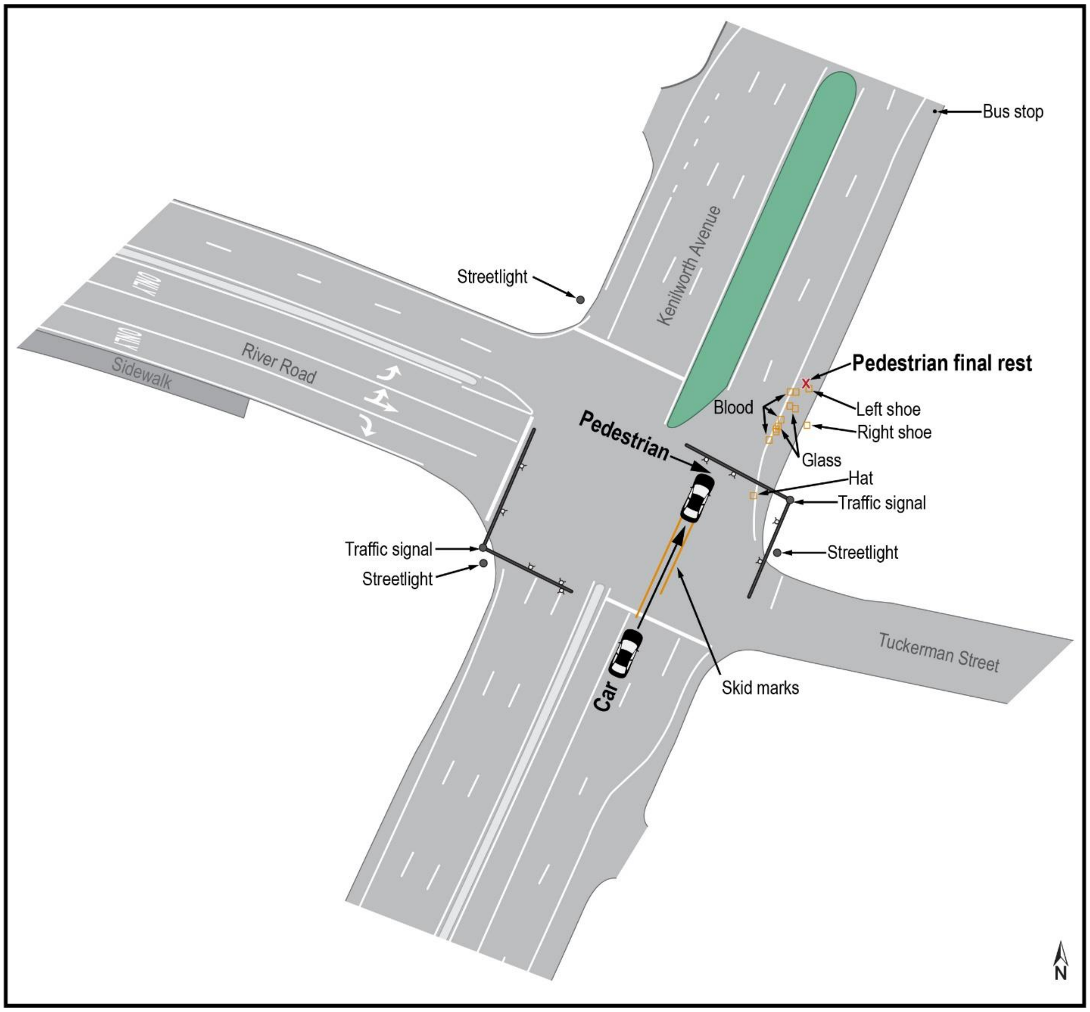

Figure A-1. Diagram of crash scene showing path of car along Kenilworth Avenue and pedestrian's path in front of automobile, which continued forward an unspecified distance after impact. Also shown are pedestrian's final rest position, as well as locations of blood and pedestrian's belongings on roadway, traffic signals, streetlights, and nearby bus stop.

Because of the impact, the 55-year-old pedestrian rode up onto the vehicle's hood and collided with the passenger side of the windshield before rolling off the right side of the car. After sliding along the pavement, the pedestrian came to rest 52 feet from the point of impact. The driver stopped at the scene, then left the area to seek assistance, calling 911 at 9:21 p.m. After the driver left the scene, a Riverdale Park police officer, on routine patrol, encountered the pedestrian lying facedown on the right shoulder of the road. The officer requested medical assistance for the pedestrian. The pedestrian was transported to Prince George's Hospital Center, where he died of his injuries.

The NTSB determined that the probable cause of the crash was the pedestrian's decision to cross a multilane arterial roadway in the middle of the intersection. Contributing to his poor decision-making was impairment from alcohol. Also contributing to the crash was the intersection design, which failed to consider pedestrian traffic.

Fatal Collision with Sport Utility Vehicle, Falls Church, Virginia, May 18, 2016 (HWY16SH012)

About 3:40 p.m. on Wednesday, May 18, 2016, a 2012 Jeep Wrangler SUV was making a left turn from the left-turn lane on southbound Glen Carlyn Drive onto eastbound Leesburg Pike (State Route 7) in Falls Church, Virginia. The SUV had a green left-turn arrow and was the first vehicle in a queue. As the 51-year-old male driver turned, a 71-year-old male pedestrian tried to cross Leesburg Pike from south to north, in front of the turning vehicle. According to a witness, the pedestrian was outside the crosswalk, the traffic signal facing him was red, and the pedestrian control indicated not to walk. The driver steered right in an effort to go behind the pedestrian, but the left front corner of the vehicle struck him (figure A-2).

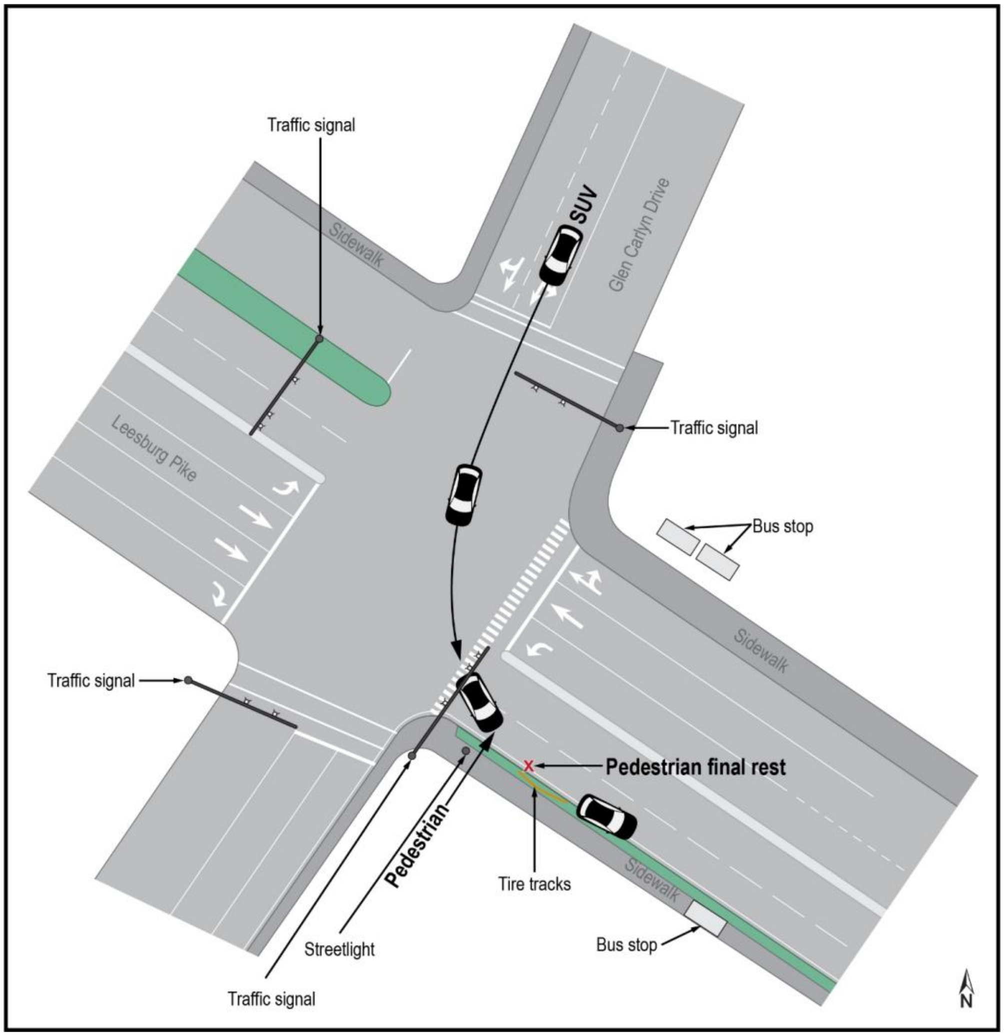

Figure A-2. Diagram of crash site showing path of SUV as it traveled through intersection to collide with pedestrian, final rest positions of pedestrian and SUV, and location of crosswalks, bus stops, traffic signals, and streetlight near collision point.

The pedestrian was thrown to the ground and run over by the SUV's left tires. After the collision, the driver steered off the roadway, over the curb, and onto the grass next to the curb. (No skid marks were found, but the SUV's tire tracks went from the curb onto the grass.) The pedestrian came to rest in the right eastbound lane of Leesburg Pike near the curb, approximately 15 feet from the point of impact.

The NTSB determined that the probable cause of the crash was a combination of the pedestrian's attempt to cross a busy multilane arterial roadway outside the crosswalk, while the pedestrian control signal indicated not to walk, and the driver's failure, while executing a left turn, to enter the leftmost lane of the roadway being entered.

Fatal Pedestrian Collision with Pickup Truck, Falls Church, Virginia, June 4, 2016 (HWY16SH013)

About 10:18 p.m. on Saturday, June 4, 2016, a 2006 Ford F-250 super-duty cab pickup truck occupied by a 46-year-old male driver and a female passenger was southbound on Graham Road (State Route 1720) in Falls Church, Virginia, south of the intersection of Graham Road and Arlington Boulevard (State Route 50). The pickup was in the left lane nearest Graham Road's median divider. As the pickup approached the midblock pedestrian crosswalk, which had no traffic signal, two male pedestrians in the crosswalk ran across Graham Road (from east to west) in front of the oncoming vehicle. Although the driver braked hard, the pickup struck one of the pedestrians, throwing him forward of the vehicle. The 53-year-old pedestrian slid along the pavement about 20 feet before coming to final rest (figure A-3). The vehicle came to a controlled stop straddling the crosswalk. The pedestrian was transported by ambulance to Fairfax Hospital, where he was pronounced dead.

The NTSB determined that the probable cause of the crash was the pedestrian's decision to run across the multilane roadway in front of the oncoming car. Contributing to his poor decision-making was impairment from the effects of alcohol intoxication and recent use of cocaine.

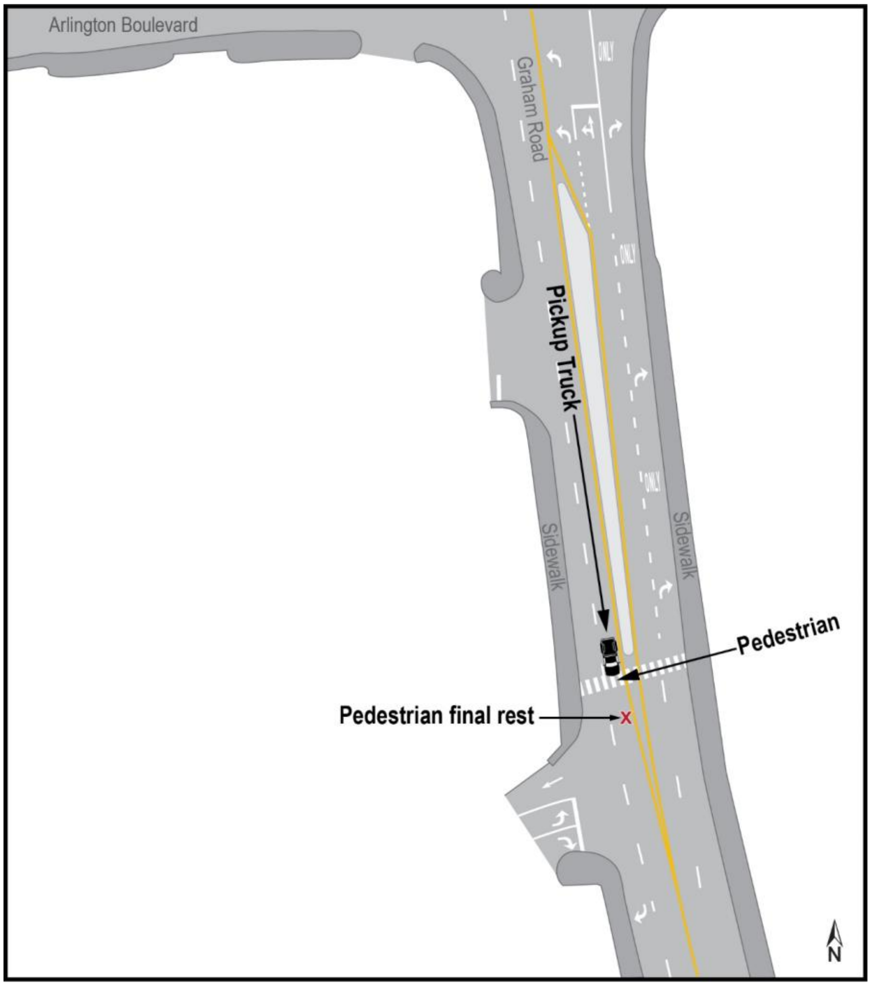

Figure A-3. Diagram of collision site showing crosswalk, direction pickup truck traveled, direction pedestrian traveled, and where pedestrian came to final rest.

Fatal Pedestrian Collision with Sport Utility Vehicle, Upper Marlboro, Maryland, June 24, 2016 (HWY16SH016)

About 12:30 p.m. on Friday, June 24, 2016, a 2010 Cadillac Escalade SUV operated by a 69-year-old male was stopped for a red traffic signal in the northeastbound travel lane of Chesterton Drive at Watkins Park Drive (State Route 193) in Upper Marlboro, Prince George's County, Maryland. Meanwhile, a 76-year-old male pedestrian was standing on the opposite side of Chesterton Drive, near a pedestrian crosswalk, waiting to cross Watkins Park Drive. When the traffic signal on Chesterton Drive cycled to green and the pedestrian signal cycled to WALK, the driver entered the intersection and the pedestrian entered the crosswalk. As the driver made a left turn into the left northwestbound lane of Watkins Park Drive and the pedestrian reached the same lane, the SUV struck the pedestrian while he was in the crosswalk, causing him to fall to the roadway (figure A-4). On colliding with the pedestrian, the driver sharply applied the brakes, stopping the SUV in the left northwestbound lane.

A Prince George's County police officer was exiting the parking lot to the right of the intersection and observed the collision. The collision was also captured by a forward-facing video camera on the police car. The officer rendered aid to the pedestrian and radioed for medical assistance. The pedestrian was transported by ambulance to the Prince George's Hospital Center, where he died of his injuries.

The NTSB determined that the probable cause of the crash was the driver's failure, while making a left turn, to yield to the pedestrian in the crosswalk.

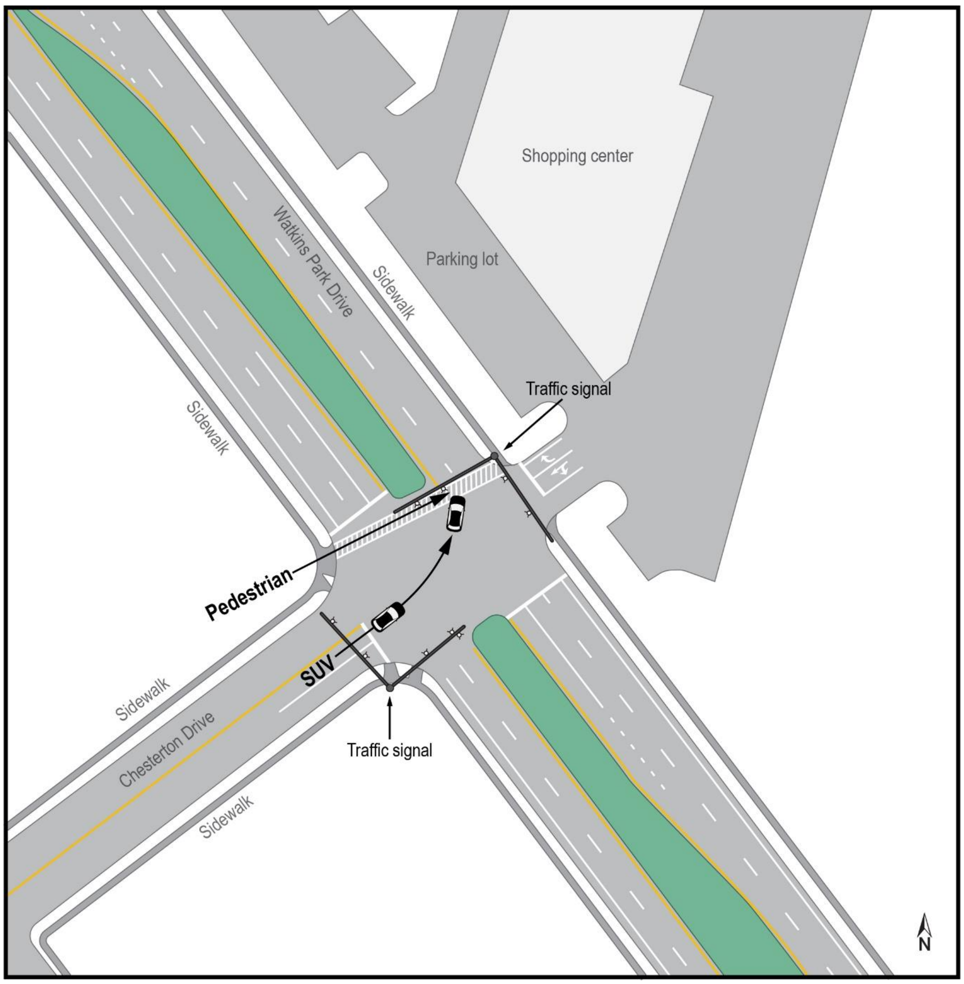

Figure A-4. Diagram of crash scene showing path of SUV and pedestrian's path on crosswalk, with exit from parking lot near crash site.

Fatal Pedestrian Collision with Car, Capitol Heights, Maryland, July 20, 2016 (HWY16SH021)

On Wednesday, July 20, 2016, about 4:19 p.m., a 2015 Volkswagen Jetta occupied by a 19-year-old female driver and a 17-year-year-old male passenger was eastbound on Central Avenue (State Route 214) near the Addison Road Metrorail (Metro) station in Capitol Heights, Prince George's County, Maryland. Meanwhile, an 18-year-old male pedestrian had crossed the eastbound lanes of Central Avenue and was standing in a crosswalk on the median that separates the opposing lanes of travel. As the driver approached the median, she lost control of her vehicle, which traveled onto the median and struck a traffic sign, a concrete raised curb, the pedestrian, a pedestrian warning sign, and a barrier fence along the north side of the median. The vehicle then left the median, continued about 200 feet east, crossing all westbound lanes of Central Avenue, and came to final rest on the sidewalk. According to the Maryland police report, the pedestrian was dragged by the car into the westbound lanes (figure A-5). A Metro transit police officer who was in the station's parking lot responded and summoned the fire department. The pedestrian was pronounced dead at the scene.

The NTSB determined that the probable cause of the crash was the unlicensed driver's excessive speed and failure to maintain control of the car so as to avoid colliding with the pedestrian.

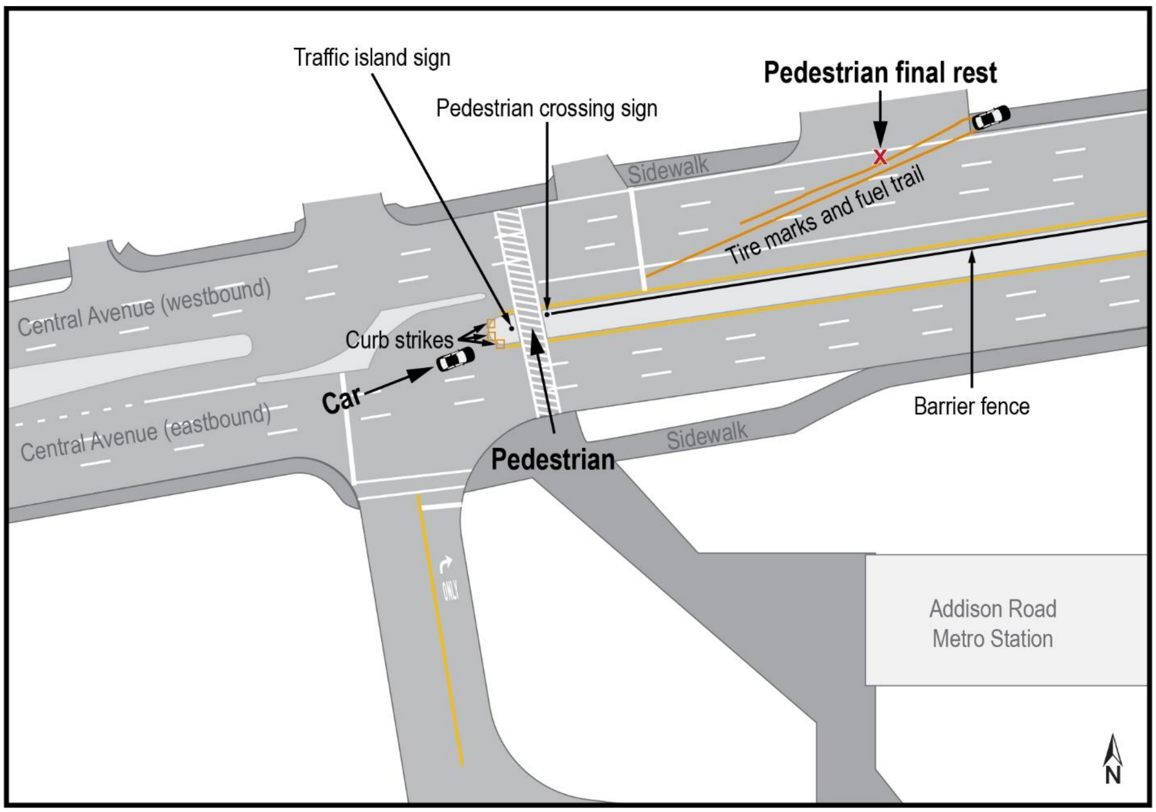

Figure A-5. Diagram of crash scene showing crosswalk on Central Avenue, car's path, pedestrian's path on crosswalk and final rest position, and Addison Road Metro station

Fatal Pedestrian Collision with Sport Utility Vehicle, Old Saybrook, Connecticut, August 16, 2016 (HWY16SH024)

About 8:11 p.m. on Tuesday, August 16, 2016, a 2007 Toyota FJ Cruiser SUV driven by a 73-year-old male was southbound on Maple Avenue in Old Saybrook, Middlesex County, Connecticut. At the intersection of Maple Avenue and Cambridge Court West, an 89-year-old male pedestrian walked from the west side of Maple Avenue to the soft dirt shoulder on the east side, according to a witness, then turned around and crossed the northbound lane of Maple Avenue. He walked about 2 feet into the southbound lane, where he was struck by the left front fender of the SUV (figure A-6). The pedestrian came to rest in the northbound lane of Maple Avenue. The SUV came to final rest south of the intersection. The pedestrian was transported to Middlesex Hospital–Shoreline Medical Center in Westbrook, Connecticut, where he was pronounced dead.

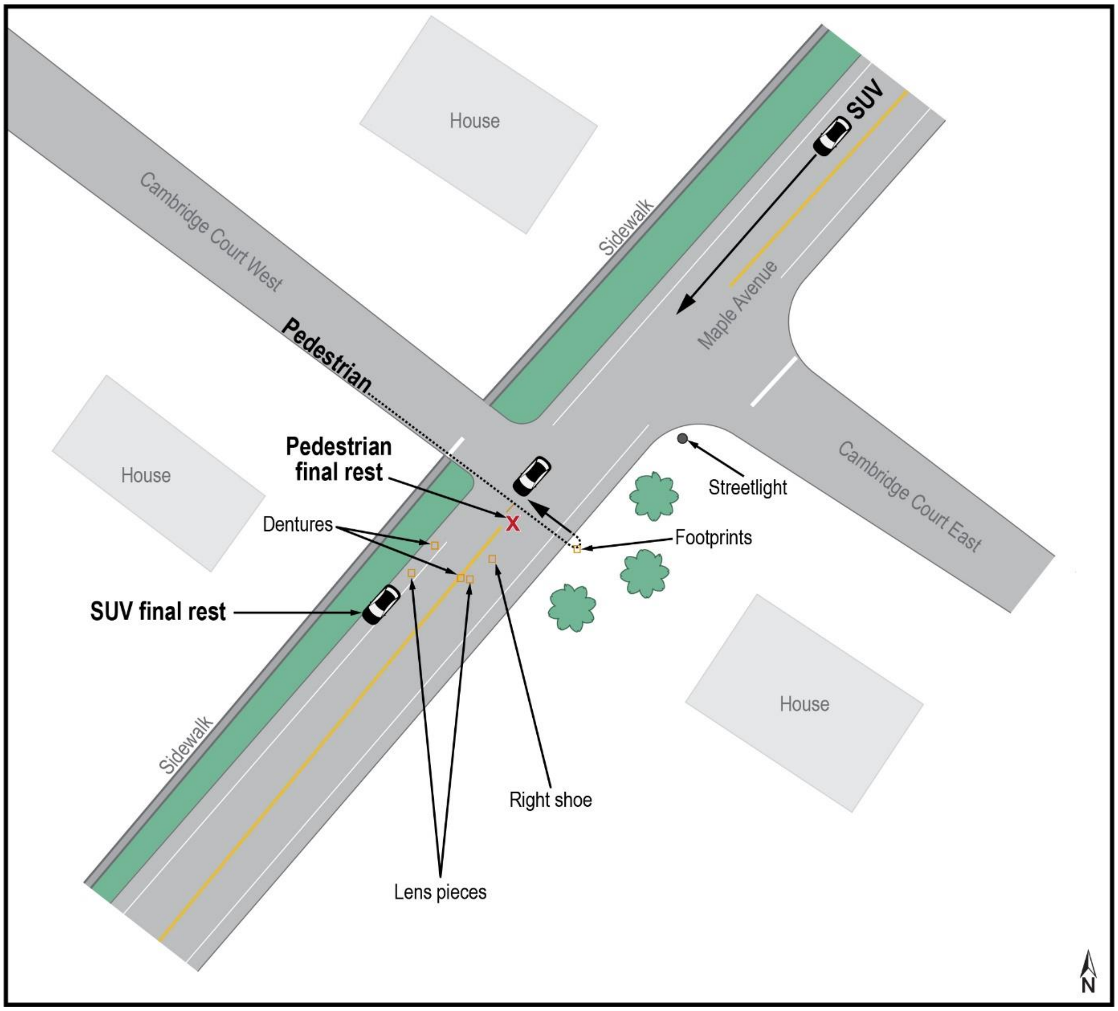

Figure A-6. Diagram of crash scene showing pedestrian's path back and forth across Maple Avenue, path of SUV on Maple Avenue, and final rest positions of pedestrian and SUV. Debris on roadway is also indicated.

The NTSB determined that the probable cause of the crash was the decision of the pedestrian to walk across the multilane roadway in front of the oncoming vehicle. Contributing to the cause of the crash were the driver's poor vision and the low-light conditions.

Fatal Pedestrian Collision with Sport Utility Vehicle, Town of Geneva, Wisconsin, August 16, 2016 (HWY16SH022)

On Tuesday, August 16, 2016, about 11:25 p.m., a 2001 Ford Expedition SUV was traveling east on State Highway 50 in the Town of Geneva, Walworth County, Wisconsin. The SUV was in the right eastbound lane and, according to the 44-year-old male driver, was traveling at the posted speed of 55 mph. At the same time, a 54-year-old female was walking east in the right eastbound lane of the highway, just past Chapin Road. Shortly after passing through the intersection with Chapin Road, the SUV struck the pedestrian (figure A-7).

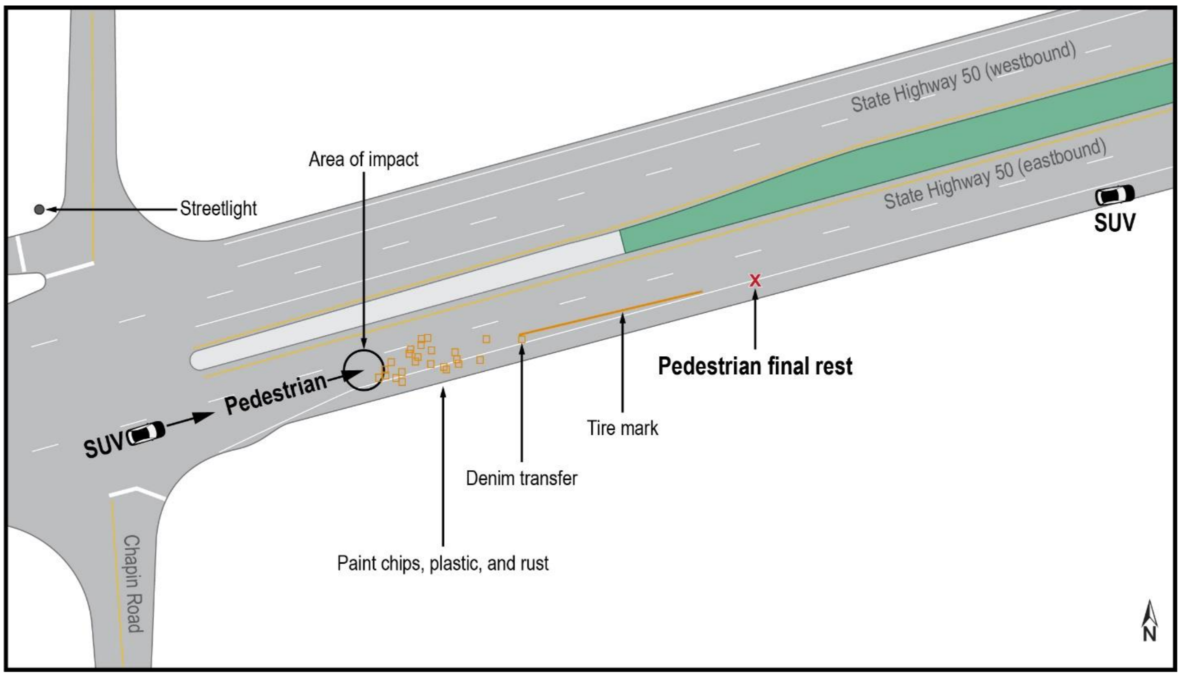

Figure A-7. Diagram of crash scene showing path of pedestrian and SUV, area of impact, roadway debris, pedestrian's final rest position, and final location of SUV.

The pedestrian rode onto the vehicle's hood and collided with the right leading edge of the roof, just above the windshield. She also struck the right side of the SUV's roof-mounted luggage rack before falling to the ground behind the moving vehicle. The pedestrian then traveled along the pavement about 175 feet before coming to rest on the solid white line separating the right traffic lane from the right shoulder. The SUV driver applied his brakes, and the vehicle came to rest on the right shoulder of the highway about 350 feet east of the impact area. The pedestrian was fatally injured. The SUV driver was not injured.

The NTSB determined that the probable cause of the crash was the pedestrian's decision to walk in the travel lane with her back to traffic. Contributing to her poor decision-making was impairment from the effects of alcohol intoxication.

Fatal Pedestrian Collision with Car, Washington, DC, August 18, 2018 (HWY16SH023)

On Thursday, August 18, 2016, about 2:20 a.m., a 2000 Mercedes-Benz CLK 320 coupe was traveling south on 9th Street NW in Washington, DC. As the 31-year-old driver approached the intersection of 9th and P streets, the traffic signal for southbound vehicular traffic was green. A 44-year-old male, walking with a female companion, attempted to cross 9th Street from the southeast corner of the intersection (figure A-8). Neither pedestrian was in the crosswalk. The driver reported that she saw the pedestrians in the roadway and attempted to steer left to avoid them. The car struck the male pedestrian at the right-side bumper area, causing him to ride up onto the hood and propelling him into the windshield on the passenger side. The pedestrian rolled off the right side of the car and came to rest in the roadway. He was transported to MedStar Washington Hospital Center, where he died of his injuries. The female pedestrian was not injured.

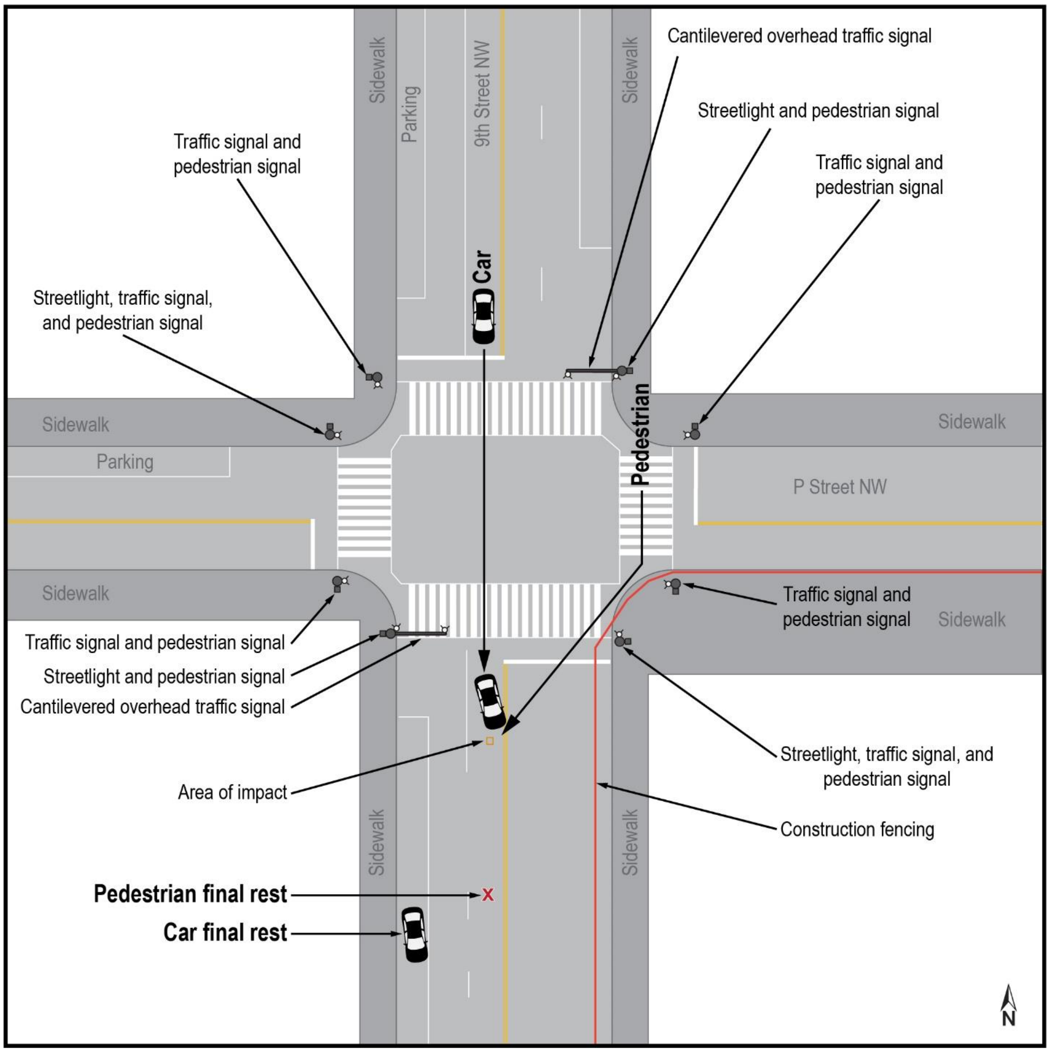

Figure A-8. Diagram of crash scene showing path of vehicle, path of pedestrian, location of traffic control signals and construction fencing on sidewalk and street, location where pedestrian collided with car, and pedestrian's and car's final rest positions.

The NTSB determined that the probable cause of the crash was the pedestrian's decision to cross the street outside the crosswalk and against the traffic signal. Contributing to his poor decision-making was alcohol impairment. Further contributing to the crash was the driver's impairment from alcohol, which most likely diminished her ability to detect and avoid the pedestrian.

Fatal Pedestrian Collision with Sport Utility Vehicle, Alexandria, Virginia, August 30, 2016 (HWY16SH025)

About 6:17 a.m. on Tuesday, August 30, 2016, a 2008 GMC Yukon SUV, driven by a 69-year-old female, was traveling south in the left southwestbound lane of Richmond Highway (US Route 1) about 9 miles southwest of Alexandria, Virginia. A 56-year-old male pedestrian had walked into the southwestbound lanes from the northwest side of the highway. The pedestrian continued to walk south in the left lane for a short distance until the right front of the SUV struck him, causing fatal injuries. The driver told responding police officers that she did not see the pedestrian until it was too late. Investigators found no evidence of preimpact braking and no postimpact skid marks. The area of impact was 100 feet southwest of the intersection of Richmond Highway and Gregory Drive (figure A-9).

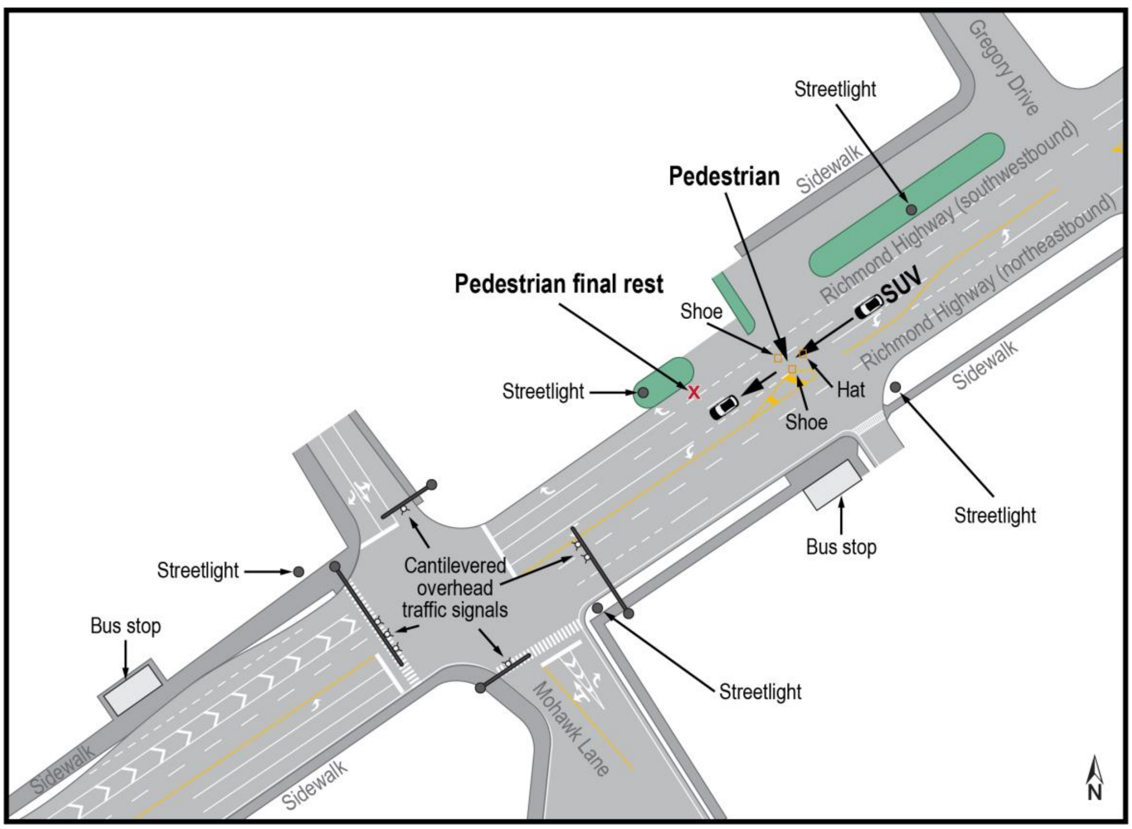

Figure A-9. Diagram showing path of SUV on Richmond Highway, point of impact, pedestrian final rest, roadway debris, and surrounding features, such as streetlights and bus stops.

After the collision, the SUV driver stopped in the left southwestbound lane of travel, about 11 feet from the pedestrian. The driver stayed on the scene until the police arrived. The pedestrian came to rest on the roadway in the right-turn lane of southwestbound Richmond Highway near the curb, about 112 feet from the point of impact. The Fairfax County Police Department documented a debris field near the impact point between the pedestrian and the SUV.

The NTSB determined that the probable cause of the crash was the pedestrian's decision to walk in the travel lane of a multilane arterial roadway, in low-light conditions, outside the crosswalk. Contributing to his poor decision-making was impairment from alcohol intoxication.

Fatal Pedestrian Collision with Car, Washington, DC, October 2, 2016 (HWY17SH001)

Early on the morning of Sunday, October 2, 2016, an altercation started between four brothers in a restaurant/bar in the 5300 block of Georgia Avenue NW (US Route 29) in Washington, DC. Two of the brothers left the restaurant/bar and got into a 2008 Dodge Charger parked on the avenue just south of the establishment. The 21-year-old driver drove a block and a half north and made a U-turn. About 3 a.m., as the car traveled south on Georgia Avenue in the direction of the restaurant/bar, the driver's 23-year-old brother ran midblock into the southbound lanes, and the car struck him (figure A-10).[1]

From the postcrash state of the car and evidence on the roadway, investigators determined that after being struck, the pedestrian rolled off the car's hood and fell onto the asphalt on the driver's side. Officers from the Metropolitan Police Department of the District of Columbia arrived on scene at 3:05 a.m., and emergency medical personnel followed 3 minutes later. The pedestrian was taken to MedStar Washington Hospital Center, where he was pronounced dead at 3:29 a.m.

The NTSB determined that the probable cause of the crash was the pedestrian's decision to run in front of the moving car. Contributing to his poor decision-making was impairment from the effects of alcohol intoxication. Also contributing to the crash was the driver's impairment from the effects of alcohol, which most likely diminished his ability to detect and avoid the pedestrian.

[1] Police could not determine the car's speed because of an absence of evidence such as skid marks or notable vehicle damage. In a postcrash interview, the driver told police he did not know how fast he was going.

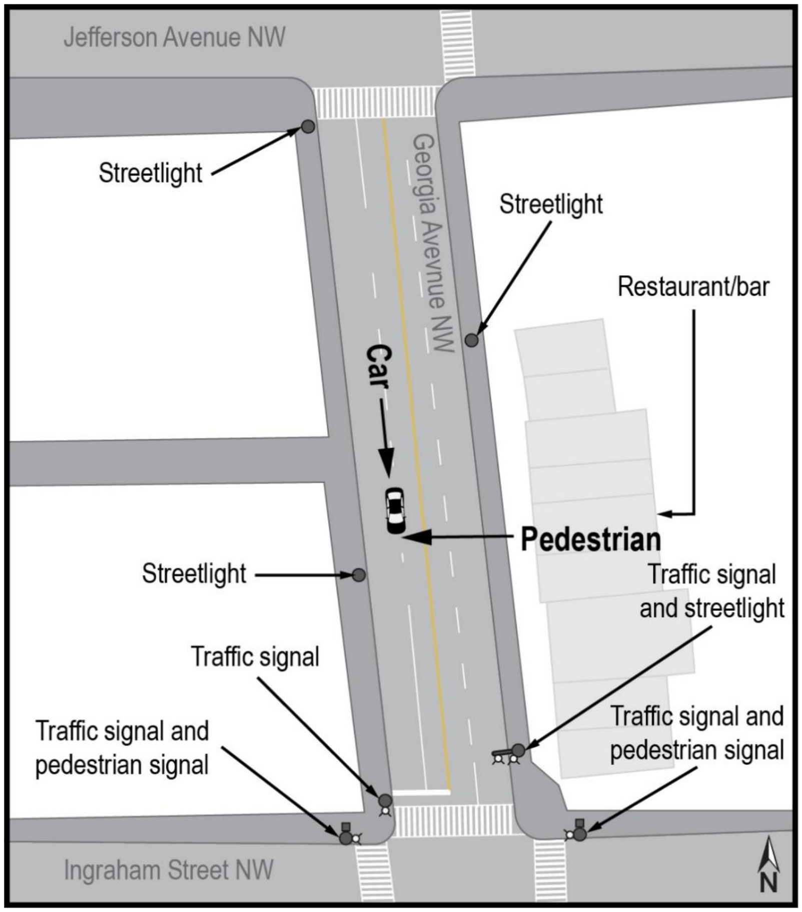

Figure A-10. Diagram of crash scene showing path of crash car on Georgia Avenue NW and pedestrian's path across street to point of impact. Also shown is location of restaurant/bar that pedestrian left just before crash.

Fatal Pedestrian Collision with Transit Bus, New York City, New York, October 4, 2016 (HWY17SH003)

About 9:50 a.m. on Tuesday, October 4, 2016, a 2012 Nova Bus articulated transit bus operated by the New York City Metropolitan Transportation Authority was traveling south on Avenue D on the Lower East Side of New York City. As the 57-year-old male driver approached the intersection of Avenue D and East Houston Street, the traffic signal for southbound vehicles was red. The bus stopped in the left-turn lane, the second vehicle in line. According to interviews, while the bus was stopped, a passenger walked to the front and, standing forward of the white standee line, began to talk to the driver. When the traffic signal turned green, the driver pulled the bus into the intersection, then stopped to yield to oncoming traffic.

On a WALK signal, a 73-year-old female pedestrian stepped into the crosswalk from the curb on the northeast corner and began walking south across East Houston Street. The bus driver and the passenger continued to talk. The pedestrian crossed the westbound traffic lanes and stepped onto the concrete median. When she stepped off the median to cross the eastbound lanes, the driver executed a left turn onto East Houston Street (figure A-11). By that time, the pedestrian signal was flashing DON'T WALK. The right front bumper of the bus struck the pedestrian in the eastbound lane, 77.5 feet from the northeast curb.[2] The pedestrian was dragged beneath the bus a short way before it stopped. The pedestrian was pronounced dead at the scene and her body transported to the Manhattan Office of the Chief Medical Examiner of New York City for an autopsy.

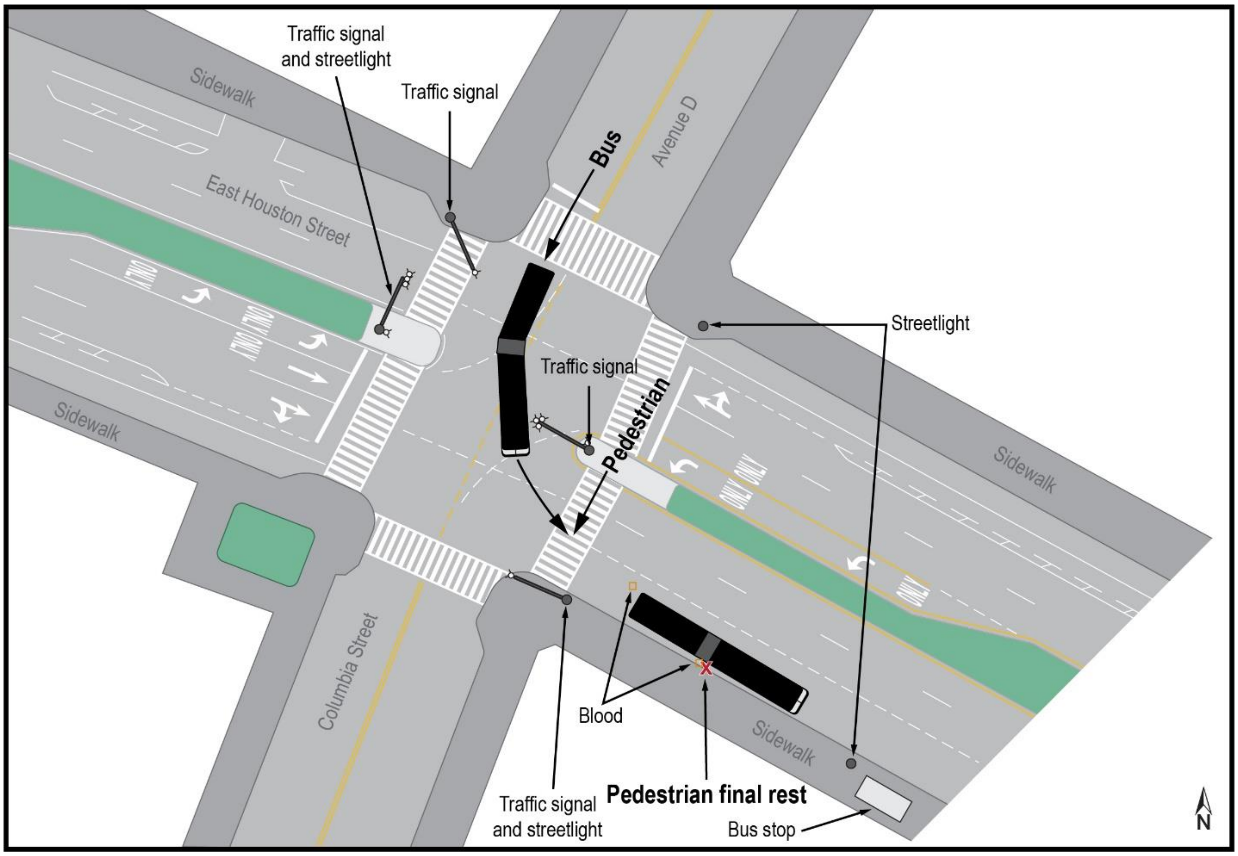

Figure A-11. Diagram of crash scene showing path of transit bus through intersection, path of pedestrian in crosswalk, and position of pedestrian at final rest.

The NTSB determined that the probable cause of the crash was the bus driver's failure to yield the right-of-way to the pedestrian in the marked crosswalk. Contributing to the crash was distraction caused by a passenger on the bus and the driver's failure to adhere to the company policy that prohibits drivers from talking to passengers while a bus is in motion.

Fatal Pedstrian Collision with Minivan, Thief River Falls, Minnesota, October 6, 2016 (HWY17SH002)

About 7:00 a.m. on Thursday, October 6, 2016, a school bus was southbound on State Highway 59 about 10 miles south of Thief River Falls, Pennington County, Minnesota. The bus was occupied by the driver and about 12 student passengers, who were on their way to Challenger

[2] The total distance across East Houston Street was 89.5 feet.

elementary School in Thief River Falls. The bus had been traveling north, but the driver missed a scheduled stop and turned around to pick up a 7-year-old boy and his two siblings (ages 13 and 11) who were waiting on the east side of the highway (ordinarily, the boarding side for their bus).

At the same time, a 69-year-old female was driving a minivan north on the highway. As the school bus was coming to a stop and activating its flashing yellow lights, the 7-year-old started across the highway toward the bus and crossed in front of the minivan, which struck him.[3] The boy rode onto the vehicle's hood and collided with the lower right windshield. He then traveled forward about 100 feet before coming to rest in a ditch on the east side of the highway.

The driver of the minivan applied the brakes and came to rest on the right shoulder 229 feet north of the area of impact. Minnesota State Patrol troopers responded to the scene and mapped the final rest positions of the pedestrian and the minivan, as well as evidence on the roadway (figure A-12)**.** The Pennington County Sheriff's Office also responded and assisted at the scene. The pedestrian was fatally injured. The minivan driver and the pedestrian's two siblings were not injured.

The NTSB determined that the probable cause of the crash was a combination of the pedestrian running across the highway travel lane in the path of the oncoming minivan; the minivan driver's speed; and the low-light conditions, which would have limited the minivan driver's ability to see the pedestrian. Further contributing to the crash was the bus driver's failure to pick the students up at their designated stop.

[3] According to a video recorded on the school bus, one of the 7-year-old's siblings crossed the highway ahead of him and reached the bus without incident.

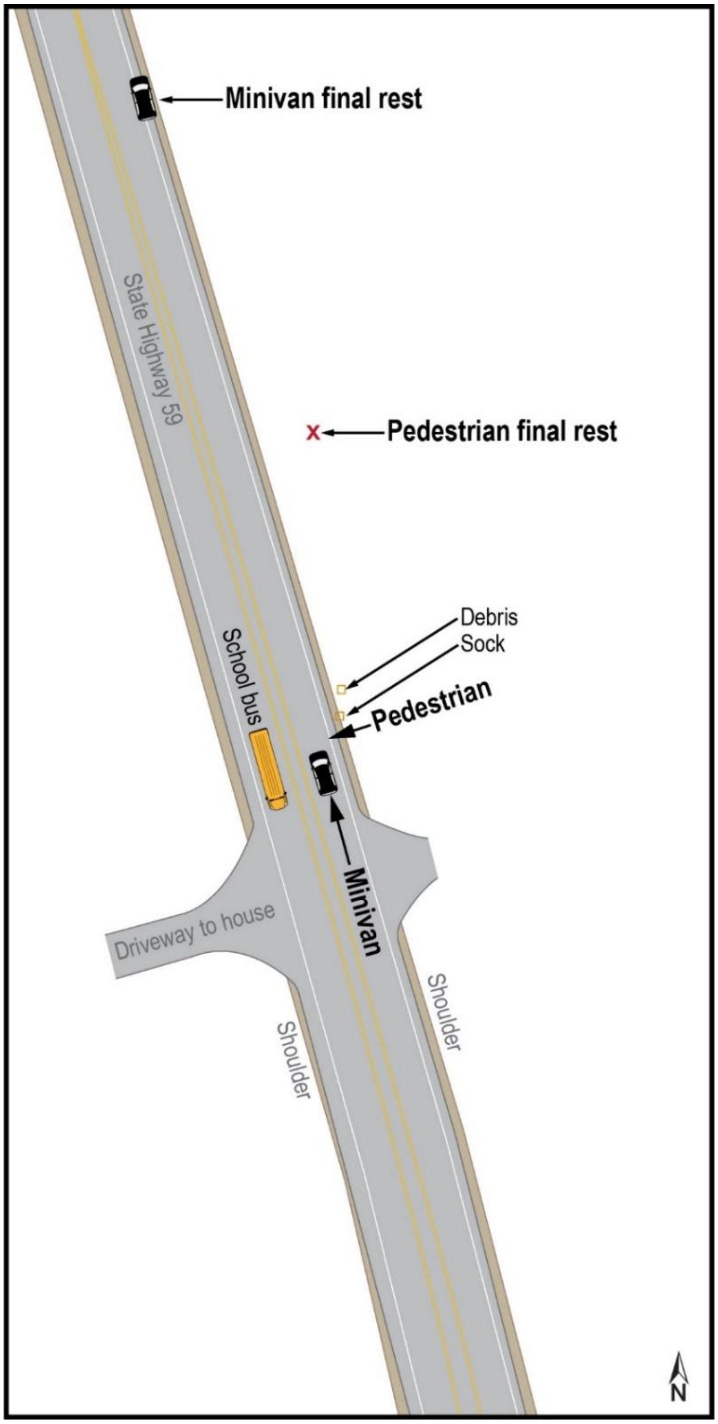

Figure A-12. Diagram of crash scene showing location of school bus, path of minivan, point of impact with pedestrian, and final rest positions of pedestrian and minivan. Bus stopped across highway from where pedestrian was waiting, near driveway to his house.

Fatal Pedestrian Collision with School Bus, New York City, New York, October 14, 2016 (HWY17SH004)

About 12:25 p.m. on Friday, October 14, 2016, a 2007 Ford school bus owned and operated by Mar-Can Transportation, Inc., was eastbound on West Fordham Road in the borough of the Bronx, New York City, New York. The investigation determined that the 47-year-old male driver was operating the bus while off duty, without passengers. (He was scheduled to start his afternoon shift 1 hour later.) As the bus approached the intersection of West Fordham Road and Sedgwick Avenue, the driver attempted to turn right onto Sedgwick Avenue. The bus was traveling in the left through lane on West Fordham Road, with another vehicle beside it in the right lane. The bus driver accelerated and made an abrupt turn in front of the other vehicle, causing its driver to slam on the brakes to avoid colliding with the bus. The bus overshot the turn and ended up on the east side of the double yellow line on Sedgwick Avenue, where it struck a 43-year-old female pedestrian in the crosswalk (figure A-13).

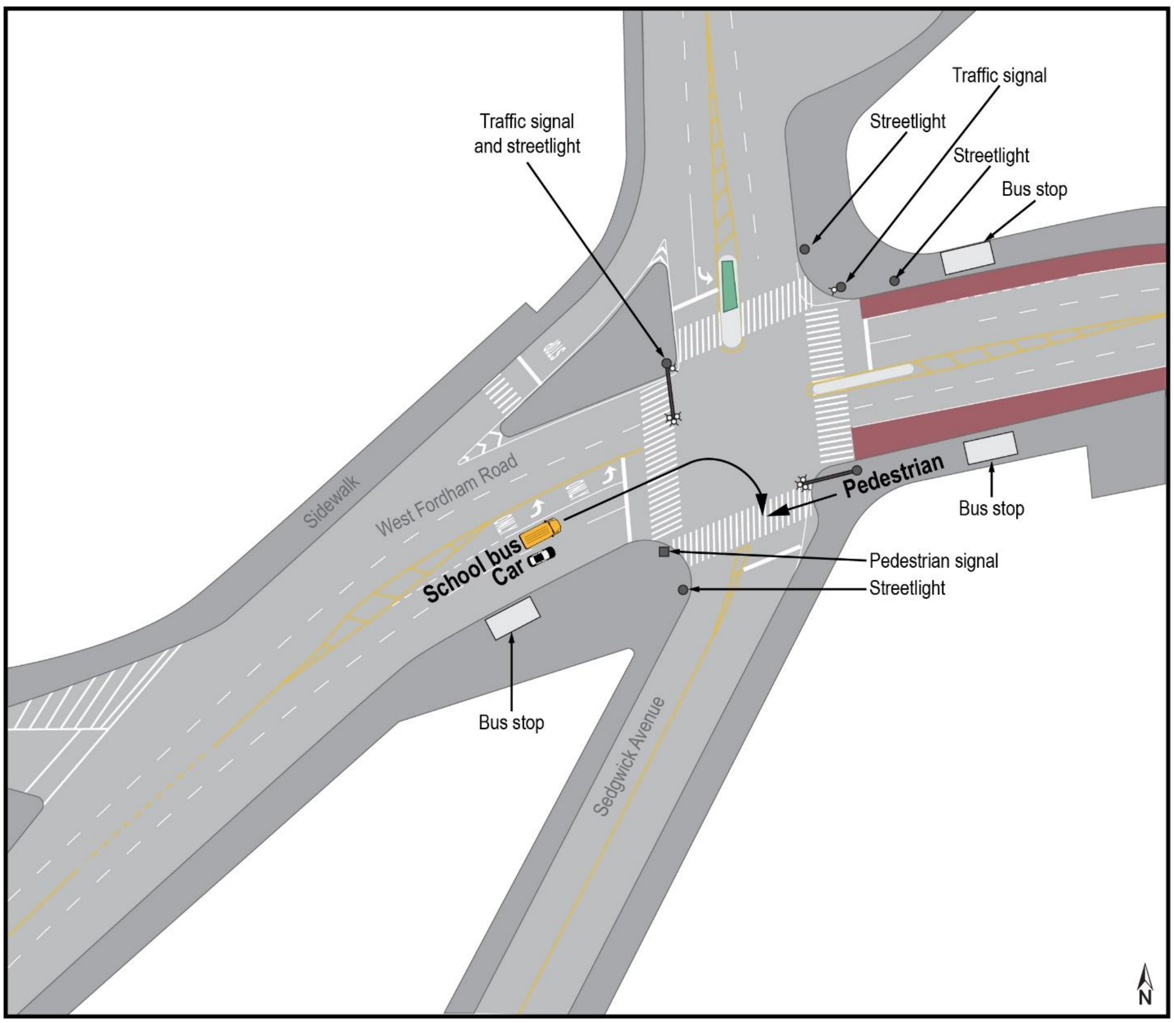

Figure A-13. Diagram of crash scene showing path of bus as it turned right from West Fordham Road onto Sedgwick Avenue and struck pedestrian in crosswalk. Also shown are traffic signals, streetlights, and bus stops in immediate area.

The pedestrian had been walking on the south side of West Fordham Road and was crossing Sedgwick Avenue westbound in the marked crosswalk on a pedestrian WALK signal. Witnesses reported that the pedestrian had just left one of the businesses immediately east of the intersection and was carrying several bags of groceries. Being struck by the school bus caused the pedestrian to fall facedown onto the roadway, where the right front tire of the bus ran over her. Several witnesses screamed at the driver to stop. The driver continued forward, and the bus's right rear tire ran over the pedestrian.

A second pedestrian, who had been walking across Sedgwick Avenue several feet in front of the struck pedestrian, was unharmed. The struck pedestrian was transported by ambulance to St. Barnabas Hospital in the Bronx, where she died of her injuries.

The NTSB determined that the probable cause of the crash was the school bus driver's failure to stop for the pedestrian crossing the street in a marked crosswalk and on a WALK signal. Contributing to the crash was the driver's improper turn from the through lane (which included failing to yield to a vehicle in the right lane and turning into the wrong lane of the street the pedestrian was crossing).

Fatal Pedestrian Collision with Transit Bus, New York City, New York, October 21, 2016 (HWY17SH006)

About 5:30 p.m. on Friday, October 21, 2016, a 2006 Motor Coach Industries transit bus operated by the New York City Metropolitan Transportation Authority was traveling southwest on Water Street in Lower Manhattan, New York City. The bus, driven by a 63-year-old male, entered the intersection with Whitehall Street on a green traffic signal. (Water Street becomes State Street at this intersection.) The bus did not clear the intersection before the signal turned red. Instead, it stopped behind a line of vehicles waiting for the light to change one block west (at State Street and Peter Minuit Plaza). The bus blocked part of the crosswalk on Water/State Street.

A 58-year-old female pedestrian was waiting with a group of pedestrians on the southwest corner of the intersection. When the traffic light turned green on Whitehall Street, the pedestrian entered the marked crosswalk on the west side of the intersection, walking north. She was talking on her cell phone and walking slower than the rest of the group. The other pedestrians passed in front of the stopped bus and safely reached the sidewalk on the north side of Water/State Street. But as the pedestrian walked in front of the bus, the traffic signal one block west turned green, and the southwestbound vehicles on Water/State Street began to move, including the bus. (The light at Whitehall Street was still red, and the pedestrian was still crossing Water/State Street on a WALK signal.) The bus struck the pedestrian with the right side of its front bumper (figure A-14). The impact knocked the pedestrian to the ground, and the bus ran over her. As the bus continued west, it dragged the pedestrian underneath.

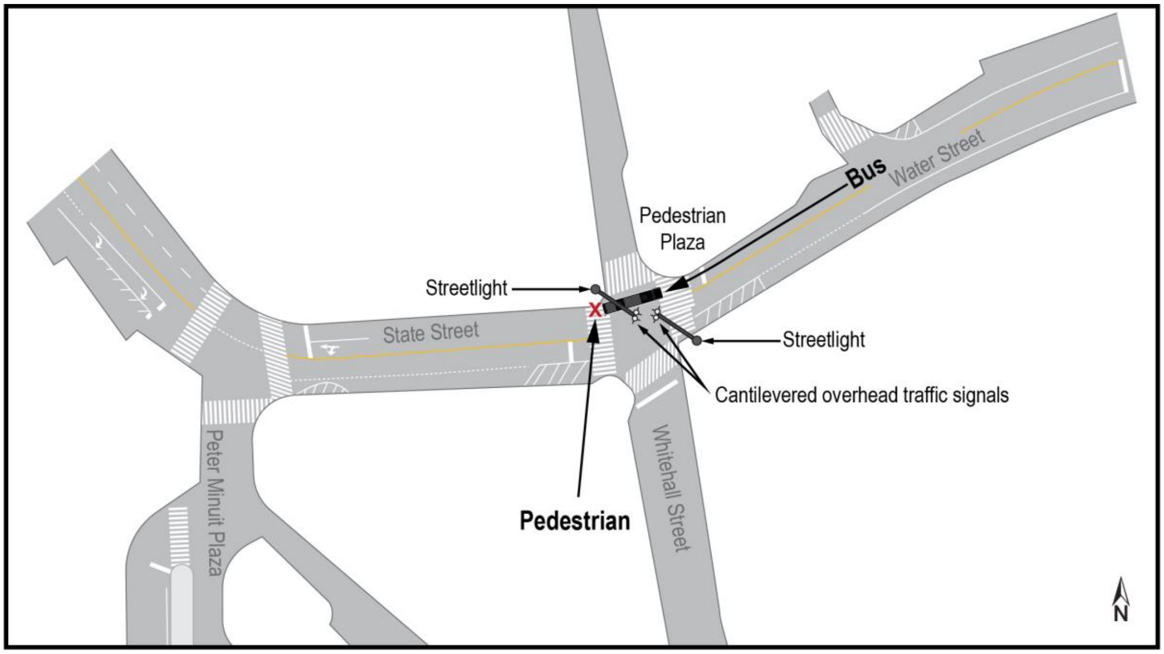

Figure A-14. Diagram of crash scene, showing crosswalk where transit bus struck pedestrian when it began moving west on Water/State Street.

The pedestrian, who was entangled in the bus's third axle, was dragged about half a mile before the bus stopped at the intersection of Trinity Place and Edgar Street. Witnesses at the intersection saw the pedestrian underneath the bus and alerted the driver and law enforcement officers. Members of the New York City Fire Department removed her body from under the bus and transferred it to the office of the New York City medical examiner for an autopsy.

The NTSB determined that the probable cause of the crash was the failure of the bus driver to check for pedestrians in the crosswalk immediately in front of the bus before he accelerated from a stopped position.

Fatal Pedestrian Collision with Pickup Truck, Lewiston, Maine, November 3, 2016 (HWY17SH008)

About 7:10 a.m. on Thursday, November 3, 2016, a 2009 Ford F-150 pickup truck was northbound on Main Street (US Route 202) in Lewiston, Androscoggin County, Maine. As the 54-year-old female driver approached the intersection of Main and Frye streets, a 13-year-old male pedestrian was crossing Main Street from west to east, in a marked crosswalk (figure A-15). According to the collision reconstruction report of the Lewiston Police Department, video from a nearby security camera shows the pedestrian

> walking northeast bound on the sidewalk. [The pedestrian] positions himself in the crosswalk (western side) on the side of the road. He appears to wait until traffic continues by. When there is a lull in traffic he proceeds to walk across Main St still in the crosswalk. As he passes the centerline he stops briefly and appears to look right to see . . . the vehicle heading towards him. [The pedestrian] attempts to get out of the way by running east

bound. [He] was not able to get out of the way of [the] vehicle. [He] is struck just beyond the crosswalk.

The driver stated that she did not see the pedestrian until just before her vehicle struck him, and investigators found no evidence that she braked before the impact. The pedestrian first struck the pickup's hood and grille, then became stuck underneath, near the right front wheel. The pickup dragged the pedestrian along the pavement for 176 feet before coming to rest. A passerby called 911. Emergency crews responded and pronounced the pedestrian dead at the scene.

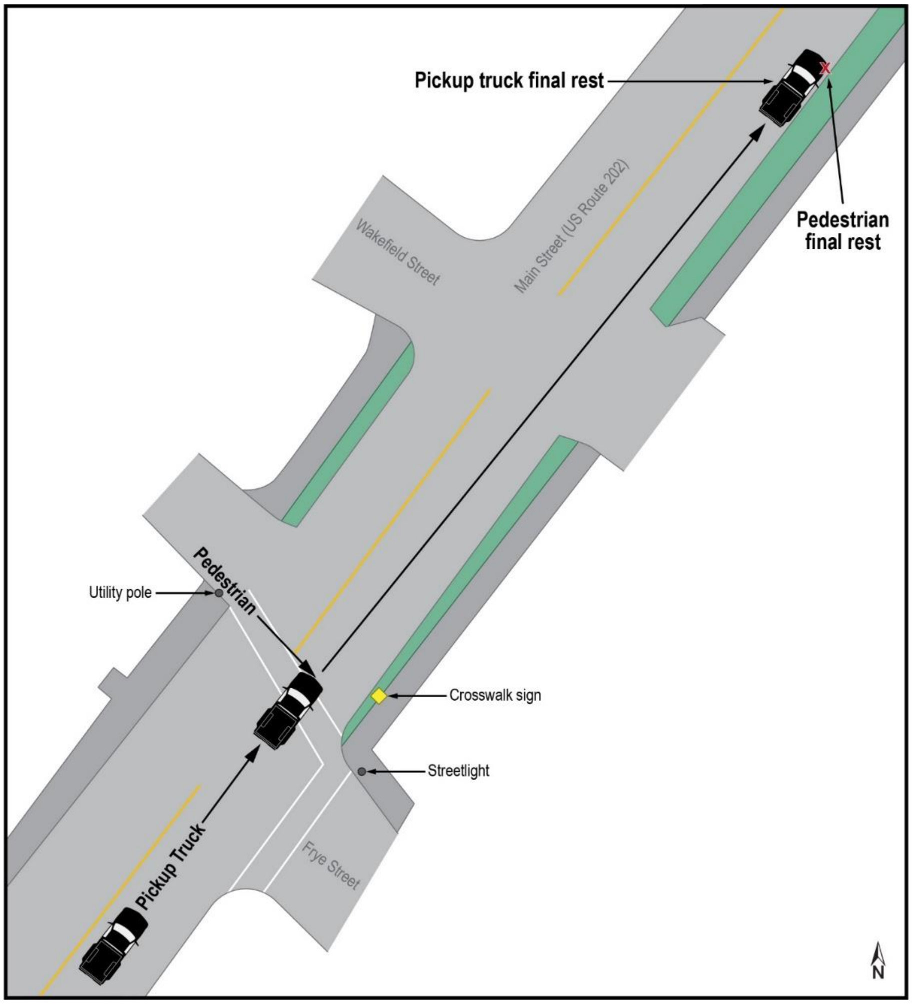

Figure A-15. Diagram of crash scene showing path of pickup truck, pedestrian's path in crosswalk to point of impact, and final rest positions of pickup and pedestrian.

The NTSB determined that the probable cause of the crash was the pickup truck's excessive speed and the driver's failure to yield the right-of-way to the pedestrian in the crosswalk. Contributing to the cause of the crash was diminished visibility due to the weather and low-light conditions.

Appendix B: Data Collection Form

Pedestrian Crash Investigation Data

FIRST: Identify all overhead wires, and sketch on rough scene diagram where you can and cannot use camera

1.0 SCENE

1.1 Crash Location

1.1.1 Town: ______________________________

1.1.2 State: ______________________________

1.1.3 Route name: ______________________________

1.1.4 Route number: ______________________________

1.1.5 Milepost: ______________________________

1.1.6 Speed limit: ______________________________

1.1.7 Number travel lanes: ______________________________

1.1.8 Road type *(See binder for definitions)*:

Interstate Expressway Arterial Collector Local

1.1.9 Road department: City County State Federal

1.1.10 Roadway alignment *(e.g., curved right or left, straight, etc.)*: ___________

1.1.11 Sidewalk: Yes No

1.1.12 Marked crosswalk: Yes No

1.1.13 Describe roadside terrain: ____

1.1.14 Intersection: Yes No

If yes, name cross street: ____

1.1.15 GPS latitude: ______________________________

1.1.16 GPS longitude: ______________________________

1.2 Date of crash: ______________________________

1.3 Local time: ______________________________

1.4 Weather conditions: ____

1.5 PROVIDE Scene diagram (*Send .pdf attachment*) of locations of the victim and vehicle along with any evidence showing the path of travel for the pedestrian and the vehicle. Note anything unusual about roadway surface or defects. Label diagram, and provide GoPro scan of vehicle and immediate highway location (could be two separate scans).

Listed below are suggestions for inclusion in the scene diagram.

1.5.1 Roadway point of impact (lighter objects typically land closer to impact area)
1.5.2 Area body first strikes the ground – point of first landing
1.5.3 Distance from point of impact to rest (total post-impact displacement)
1.5.4 Distance traveled in the air
1.5.5 Distance slid along the road/ground (ignore skid skips)
1.5.6 Pre- and post-impact length of vehicle skid marks
1.5.7 Angle between skid marks of vehicle and final rest position
1.5.8 Location of any victim personal effects and body evidence

Need data for calculating speeds and doing a time distance analysis. Suggest using .70 unless reasons lead to another value.

1.6 Describe other roadway evidence *(skid marks, ABS evidence, tire prints, surface scrapes, glass, vehicle parts, etc.)*:

1.7 Document any traffic control devices in the vicinity:

1.8 Describe surrounding features (s*chool zone, housing development, urban, industrial, rural, etc.)*:

1.9 Crash Type *(From FHWA PBCAT – Ped Bike Crash Analysis Tool. See binder for 3-digit code)*: ____

1.9.1 Motorist direction:

Northbound Southbound Eastbound Westbound Unknown

1.9.2 Motorist maneuver: Left turn Right turn Straight Unknown

1.9.3 Leg of intersection: Nearside Far side Unknown

1.9.4 Pedestrian direction: Northbound Southbound Eastbound Westbound Unknown

1.10 Number/letter code of intersection diagram in relation to movement of vehicle and pedestrian. *(See binder for diagrams.)*: _________________________

1.11 Timelines for both driver and pedestrian (24-hour or right before the crash):

1.12 Conspicuity analysis or evidence of obstructed view for both driver and pedestrian (environmental light conditions, dark clothing, area lighting, parked cars, utility poles, trees, etc.). Consider videotaping relatively same size person dressed similarly at same time of day.

1.13 PROVIDE police report (include 911 call time)

1.14 PROVIDE past crash history at same location and along road segment (5 years from state DOT or local)

2.0 PEDESTRIAN

2.1 Number of pedestrians *(NOTE: If more than one pedestrian was involved in the crash, open new form and complete this section for each additional pedestrian.)*: _________

2.2 Victim age or date of birth (DOB): _________________________

2.3 Victim sex: _________________________

2.4 Victim race: ____________________________

2.5 Alcohol involved: Yes No Unknown

2.6 Drug involved: Yes No Unknown

2.7 Victim height: ____________________________

2.8 Body measurements

2.8.1 From heels to knees: ____________________________

2.8.2 From heels to hips: ____________________________

2.8.3 From heels to navel: ____________________________

2.8.4 From heels to shoulders: ____________________________

2.9 Describe victim evidence on scene (including side of impact and any evidence of secondary impact with vehicle and ground, clothing, shoes, personal effects, cell phone, body parts, body fluids, etc.).

2.10 Was there evidence of the body being run over? Yes No

2.11 Cell phone recovered: Yes No

2.12 If yes, location of cell phone: Pocket Bag Apart from body

2.13 Final pedestrian position: Intersection Crosswalk Travel lane Shoulder Sidewalk Driveway Non-roadway

2.14 Pedestrian impact kinematics *(See binder for definitions.):*

Wrap Forward projection Fender vault Somersault Roof vault Dragged

2.15 Injury description; characterize blunt force trauma as (*Select as many as apply*):

Contusions Fractures Lacerations Abrasions

Describe injuries:

2.16 PROVIDE hospital medical records

2.17 PROVIDE toxicology report

2.18 PROVIDE victim's cell phone use records

2.19 PROVIDE autopsy or medical examiners report (including impact locations, internal injuries, head injuries, broken bones, tension wedge fracture in the leg)

3.0 VEHICLE

3.1 Hit and run: Yes No

3.2 Driver age or date of birth (DOB) : ____________________________

3.3 Driver sex: ____________________________

3.4 Driver race: ____________________________

3.5 Alcohol involved: Yes No Unknown

3.6 Drug involvement: Yes No Unknown

3.7 Driver injury: Yes No If injured, describe:

3.8 Driver citation: Yes No If cited, describe charges:

3.9 Driving history:

3.10 PROVIDE driver cell phone records

3.11 Vehicle make and model: ____________________________

3.12 Vehicle estimated original speed before crash: ____________________________

3.13 Vehicle speed at impact: ____________________________

3.14 PROVIDE vehicle photographs *(8-profile, all 4 sides, all 4 corners, and damage photographs as a series of progressively closer shots.)*

3.15 Describe vehicle *(e.g., mechanical condition, vehicle damage and debris, glass broken, molding and components missing, paint fragments, antenna, wipers, parts numbers).*

3.16 If vehicle is already impounded, was it moved by: Flatbed Towed

3.17 Vehicle measurements

- 3.17.1 Bumper height from ground to bottom of bumper: ______________
- 3.17.2 Bumper height from ground to top of bumper: ______________
- 3.17.3 Calculate bumper lead angle: ______________
- 3.17.4 Height of hood from ground to front edge: ______________
- 3.17.5 Height of hood at intersection with bottom of windshield: ______________
- 3.17.6 Length of hood from leading edge to bottom of windshield: ______________
- 3.17.7 Distance from leading edge of hood to top of windshield: ______________
- 3.17.8 Height of the roof: ______________

3.18 Air bag release: Yes No

3.19 PROVIDE air bag module for data download

3.20 PROVIDE video records from surrounding vehicles or buildings

4.0 PROBABLE CAUSE

5.0 DESCRIPTIVE NARRATIVE

Appendix C: Safety Forum Participants

Panel 1: Understanding Pedestrian Safety

Jessica Cicchino, PhD, Vice President of Research, Insurance Institute for Highway Safety

Krista Nordback, PhD, PE, Research Associate, Portland State University

Robert Viola, Senior Project Manager, New York City Department of Transportation

Richard Retting: National Practice Leader for Safety & Research at Sam Schwartz Consulting

Panel 2: Policy and Planning Safer Streets

Barbara McCann, Director, Office of Safety, Energy, and the Environment,
US Department of Transportation, Office of the Secretary of Transportation

Linda Bailey, Executive Director, National Association of City Transportation Officials

Luisa Paiewonsky, Director, Center for Infrastructure Systems and Technology, VOLPE National Transportation Systems Center

Ann Dellinger, PhD, MPH, Chief of the Home, Recreation, and Transportation Branch, Centers for Disease Control and Prevention

Panel 3: Enhancing Pedestrian Safety Through Design and Countermeasures

Carl Sundstrom, PE, Senior Researcher, University of North Carolina, Highway Safety Research Center

Fionnuala Quinn, PE, Executive Director, Bureau of Good Roads

Scott Kubly, Director, Seattle Department of Transportation

Gabriel Rousseau, PhD, Safety Operations Team Leader, Office of Safety Technologies, Federal Highway Administration

Panel 4: Improving Pedestrian Safety Through Vehicle Technology

Sven Zimmermann, Engineering Manager, Bosch Chassis Systems Control – Driver Assistance and Automated Driving

Bob Kreeb, Division Chief, Intelligent Technologies Research, National Highway Traffic Safety Administration

David Zuby, Executive Vice President and Chief Research Officer, Vehicle Research Center, Insurance Institute for Highway Safety and Highway Loss Data Institute

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