Virginia Commonwealth University
Transportation Safety Training Center
Virginia Multi-disciplinary Crash Investigation Team

Special Report Number 22 – August, 2012

ABSTRACT

This Special Report focuses on pedestrian crashes in the Commonwealth. Pedestrian crashes represent a small percentage of crashes in Virginia; however often result in serious injury or death to the pedestrian. This report discusses the unique challenges involved in pedestrian crash investigation. Driver and pedestrian factors are discussed as well as the roadway characteristics.

Four case studies are presented showing various factors in pedestrian crash investigation. The crashes presented highlight many issues that may arise during the investigation as well as the pedestrian actions while utilizing the roadways.

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INTRODUCTION

Although the vast majority of motor vehicle fatalities in the Commonwealth are motor vehicle occupants, a small but significant number are not. Pedestrian traffic fatalities in Virginia since 2000 have ranged from 8.6% to 10.7 % of total motor vehicle crash deaths.

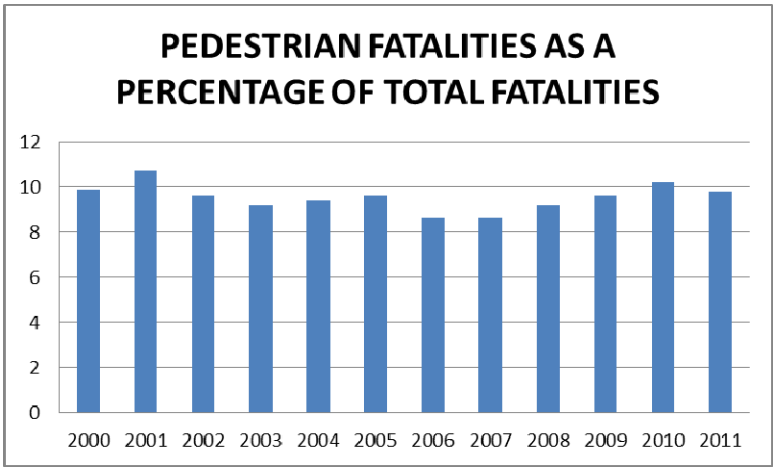


Figure 1

While motor vehicle deaths have significantly decreased since 2007 (from 1,007 to 762), the number of pedestrian traffic fatalities in Virginia, in comparison, dropped in 2008 but then has remained fairly consistent, especially over the past 4 years.

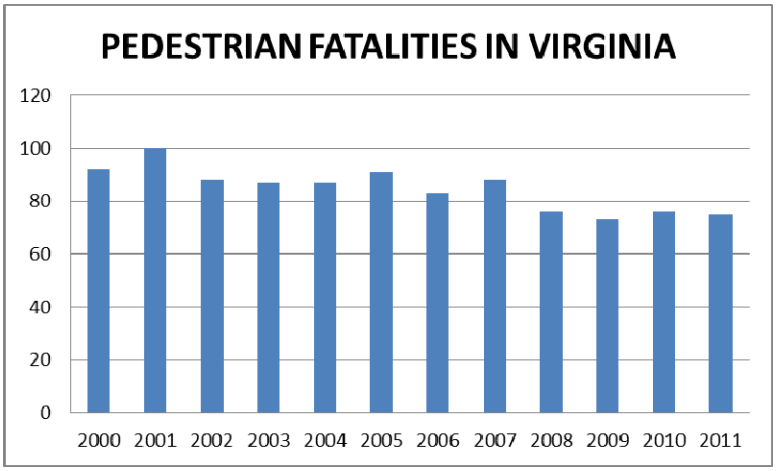


Figure 2

These figures are for reportable crashes and do not account for the deaths and/or injuries of pedestrians on private property.

In 2011, 75 pedestrians died and 1,712 were injured in Virginia as a result of motor vehicle crashes (DMV, 2011).

In the past, pedestrian safety education programs have targeted school aged children, focusd on creating good safety habits with regard to crossing streets and awareness of the hazards of motor vehicles. However, the vast majority (82.7%) of pedestrians killed in 2011 were over 18 years of age (DMV, 2011), and the victims' actions often played a signifcant role in the crash causation.

The Virginia Multi-disciplinary Crash Investigation Team analyzed FR300P reports for 69 of the 75 pedestrian fatalities that occurred in 2011 and found that in two thirds of these cases, the driver was not charged in the crash. Only a few of these were hit and run cases where drivers could not be identified. It is interesting to note that 18.8% of the crashes were hit and run, but many of these drivers may not have been deemed at fault or charged with offenses if they had stayed at the scene.

The analysis provided some additional insight into patterns and conditions that can be used to address crash risk. A primary factor, which has long been an identified problem in pedestrain crashes, relates to visibility and pedestrian conspicuity. Although most of the crashes occurred during good weather (86.7%) with dry roadway conditions (88.4%), a majority of the crashes occurred during hours of darkness (73.9%). The roadway had some type of lighting in about 45% of these cases, but the extent of that lighting is not specified. Only 3 of the 69 victims were reported as wearing any type of retroreflective material that would have assisted drivers in perceiving their presence.

Almost a fourth of all pedestrian traffic fatalities in Virginia occurred in an urban area with the victims crossing mid-block rather than at an intersection, the location where drivers are most likely to expect them. While only one was killed while crossing at an intersection in compliance with a traffic signal, 7.2% of those who died were struck while crossing against a signal. Travel distance played a role as well, since the greater the distance a pedestrian had to traverse, the longer he or she would be exposed to oncoming traffic. In 26% of the fatal crashes analyzed, the pedestrian was attempting to cross one or two travel lanes. The majority were attempting to cross three or more lanes, and 40.6% were crossing five or more lanes of traffic. Thirteen percent of the victims had been walking in the roadway against traffic when no sidewalks were present. In 7.2 % of

the cases, the victims had been standing in the roadway, and often they had previously exited a vehicle after a crash or mechanical problem. Another 7.2% were struck when the vehicle left the roadway and entered their path of travel. At least 4 of the victims (5.8%) were lying in the road when struck.

Excessive speed does not appear to play a major role in pedestrian crash causation. In the vast majority of the cases analyzed, the drivers were travelling at or below the posted speed limit prior to the crash. In 60.9% of the cases, the driver was reported as having taken no improper actions. While driver distraction was recorded in 21.7% of the cases, it remained unspecified in the "other" category, indicating the distraction was not due to cell phone use, radio, passengers, or fatigue. Only 4.3% of the drivers were reported to have been drinking prior to the crash; however, 27.5% of the pedestrians killed were reported to have been drinking prior to being struck.

This report takes an in-depth look at four fatal pedestrian crashes that occurred within the past year in Virginia, highlighting issues that are important to address with regard to pedestrian crash causation and mitigation, as well as unique challenges for those investigating and reconstructing these crashes.

CASE STUDY NUMBER 1

Type of Crash: Pedestrian struck by vehicle

Day, Time, Season: Wednesday, 11:23 P.M., Summer

Road/Weather: Primary road, clear & dry

Vehicles Involved: 2010 Nissan Rogue

Individuals involved: 60 year old male pedestrian (fatality)
59 year old female driver

Severity: One fatality; minor property damage

SUMMARY:

Shortly before midnight on a dry Wednesday evening in summer, a 59 year old female was driving to work in her 2010 Nissan Rogue Sport SUV. She was alone and was wearing her lap/shoulder belt. She had worked her normal day job from 9 A.M. to 5:30 P.M. and then had gone home. After sleeping from 7:30 P.M. to 10:40 P.M., she prepared for her second job, which she was scheduled to work from midnight to 8:00 A.M. She had driven approximately 2.7 miles of her 14 mile commute and was travelling in the left northbound lane.

The Nissan driver had been licensed in Virginia since 2003 and she was required to wear corrective lenses. Her driving history showed that she had been convicted of speeding 15-19 MPH above the limit on two separate occasions: once in 2007, when she exceeded the 55 MPH limit and once in 2010. She received four demerit points for each conviction and held a point balance of +1. The officer investigating the crash reported that she did not appear to be impaired in any way.

The road is a major north-south primary route located in an urban area with retail stores and shopping centers located on both sides of the highway. This section of the roadway is a transit bus route, so bus stops and entrance drives are interspersed between intersections. The northbound and southbound lanes are separated by a four foot concrete

median. The northbound section of the road has three through lanes, a right turn lane and a bus turnout (bus stop) adjacent to the right turn lane. Each lane is approximately 12 feet wide. The road is asphalt and in good condition. The grade of the road is level. The road is controlled by signs, signals and pavement markings. The signs are in good condition and the signals are in good operating condition.

The intersection is controlled by traffic signals and pedestrian crosswalks. The pedestrian attempted to cross roadway mid-block, approximately 168 feet north of the intersection, at some point between the bus stop and an entrance to a shopping center. There is overhead lighting but also a lot of visual clutter along the area. Retail signs and lights in parking lots compete visually with traffic signals and other vehicles. The speed limit is 45 MPH. The average daily traffic is 58,000 vehicles for this section of road (VDOT, 2010).

Photo #1: Crash scene looking North (travel direction of vehicle).

A 60 year old male was attempting to cross the road from east to west. Although he lived in the general vicinity, he did not have a permanent address and his previous activities are unknown. The investigating officer reported that the victim had been drinking prior to the crash, but his level of impairment was unknown. A toxicological analysis later showed that his BAC was .27%. Analysis of vitreous humor showed an alcohol content of .28%, a consistent finding. Tests conducted for a variety of other drugs returned negative results.

The pedestrian, who was 5 feet 6 inches tall and weighed 165 pounds, was wearing a muted orange shirt, blue jeans and black shoes. None of his clothing was retroreflective. He stepped into the northbound lanes at a midpoint in the block. He crossed two of the northbound lanes (from the driver's right to left), and into, the Nissan's path of travel, in the left lane.

When he was struck by the SUV, the pedestrian wrapped onto the vehicle, before being thrown forward onto the ground. The driver braked; however, the vehicle did not leave any skid marks. Both the Nissan and the pedestrian came to final rest in the left lane (figures 1 and 2), adjacent to the concrete median.

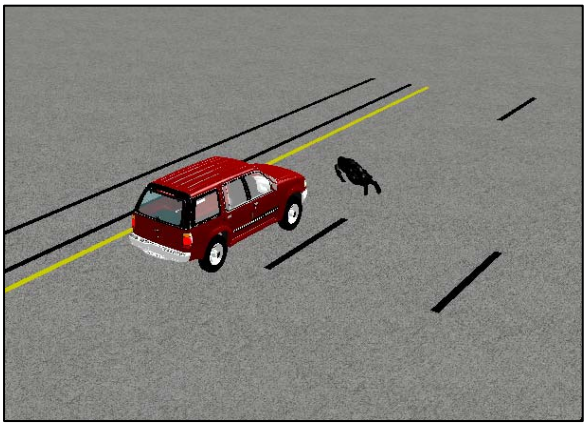


Figure 3: 3D depiction of final rest

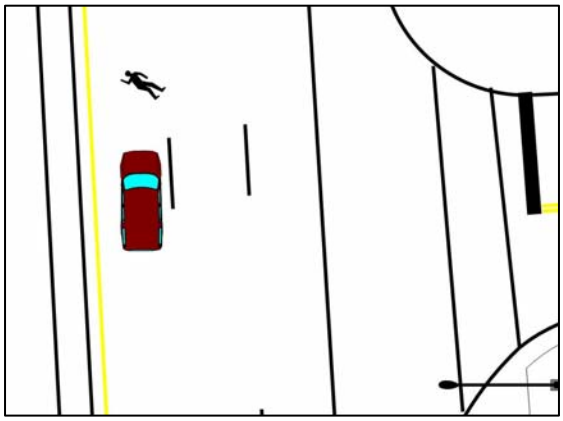


Figure 4: Final rest positions

As in many pedestrian crashes, little roadway evidence was located. No skid marks, shoe scuff marks or vehicle debris were left at the crash site to aid investigators in

determining the area of impact. The pedestrian had been wearing a hat, which was found approximately 60 feet from the victim's final rest position. Although not optimal as an indicator for area of impact, the hat was the only evidence related the pedestrian's pre-crash location. Consequently, the investigating officers used the hat location as the best evidence to determine the general area of impact.

A speed analysis from this crash was performed, applying the throw distance of 60 feet to Searle's formulas for determining minimum and maximum pedestrian speeds (see page37). These calculations yielded an estimated speed for the pedestrian ranging between 29 MPH to 35 MPH (42.5 feet per second to 51.31 feet per second). This is the range of forward speed that the pedestrian attained after being struck by the vehicle, and it is an indication that the Nissan had been travelling at least the lowest speed when it struck the pedestrian.

One of the issues to consider in pedestrian crashes is whether or not a driver had the ability to perceive and/or time to respond to the pedestrian encroaching upon her path of travel. When the Nissan driver passed through the intersection, she was approximately 168 feet from where her vehicle struck the pedestrian. If she had been able to perceive the victim at that point in time, she would have had less than 4 seconds to avoid the collision. However, several factors affected her response time.

First, she stated that she had glanced down at her speedometer as she went through the intersection and she never saw the pedestrian until impact. When drivers move their visual focus from the forward position, such as glancing into mirrors, looking to the side or taking their eyes off the road, perception-response time typically increases. The amount the gaze varies away from the center is called the amount of eccentricity and is measured in degrees to the left, right, up or down. For a driver looking down at a speedometer, the eccentricity is approximately 15 degrees.

In addition to the location of her gaze prior to the crash, the driver's visibility was limited. Perception-response studies have consistently shown that drivers have "significant difficulty recognizing pedestrians at night" (Wood, Tyrell & Carberry, 2003 and Muttart & Rosner, 2009). In this case, the darkness would have restricted the driver's ability to perceive the pedestrian, especially since he wore dark and muted clothing. None of his clothing would have reflected light, contrasted his shape against

the rest of the darkened environment or revealed his movements as he crossed the roadway. Although there is overhead roadway lighting and some from retail businesses, little light pooled directly onto the road itself. The Nissan's headlights would have illuminated some of the area in front of the vehicle, but beyond that, the pedestrian was not readily visible to the driver.

Using I.DRR software (Integrated Driver Response Research), the object dynamics and approximate headlight patterns were analyzed. Information gathered about the vehicle and the pedestrian were included, although some variables were approximated, using conservative estimates.

- The pedestrian's walking speed was estimated between 3.89 fps and 4.66 fps, or an average of 4.23 fps, based on a crossing distance of 36 feet.
- The angle of crossing was estimated at 90 degrees
- The headlights were estimated to be of average brightness for halogen lights.
- The pedestrian acceleration speeds ranged from 29 MPH to 35 MPH, so these were used as the most conservative speed range for the Nissan.
- The driver's eccentricity was estimated at 15 degrees from forward.

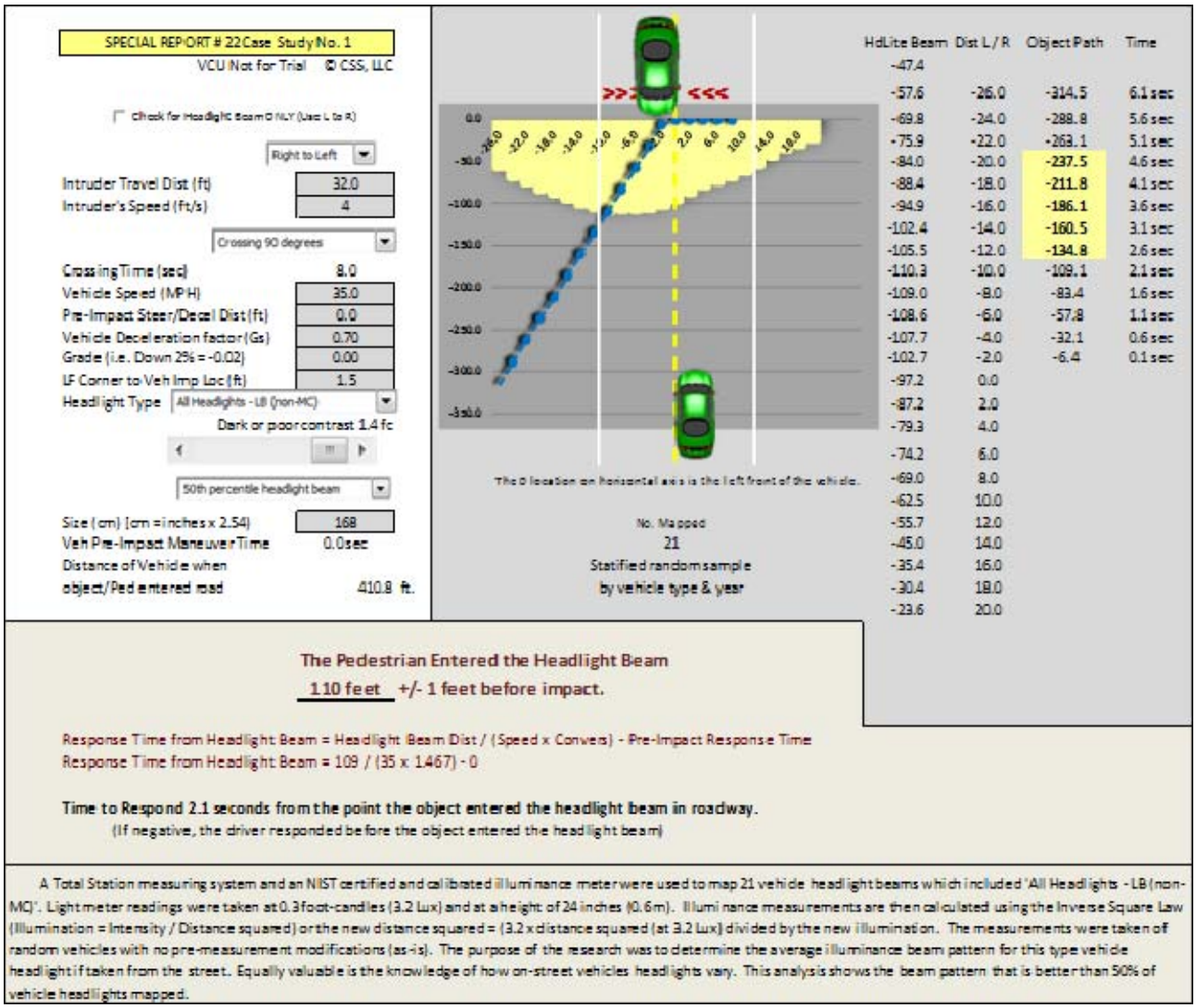


Figure 5: Headlight analysis page of I.DRR program.

The software analysis indicated that the pedestrian entered the headlight beam at a distance of 109 to 110 feet from the Nissan, with a maximum margin of error ± 6 feet (at the 29 MPH speed). The driver had between 2.1 and 2.6 seconds to respond. Pathway intrusion research shows that drivers, on average, take about 2.3 seconds to respond to pedestrians entering their path of travel. This left little or no time for braking to slow the vehicle or for the driver to successfully maneuver away from the imminent collision.

VMCIT members were unable to examine the vehicle, since the Nissan was released at the scene as no charges were filed. However photographic evidence shows that the vehicle sustained damage to the hood, mainly on the left side. The front bumper

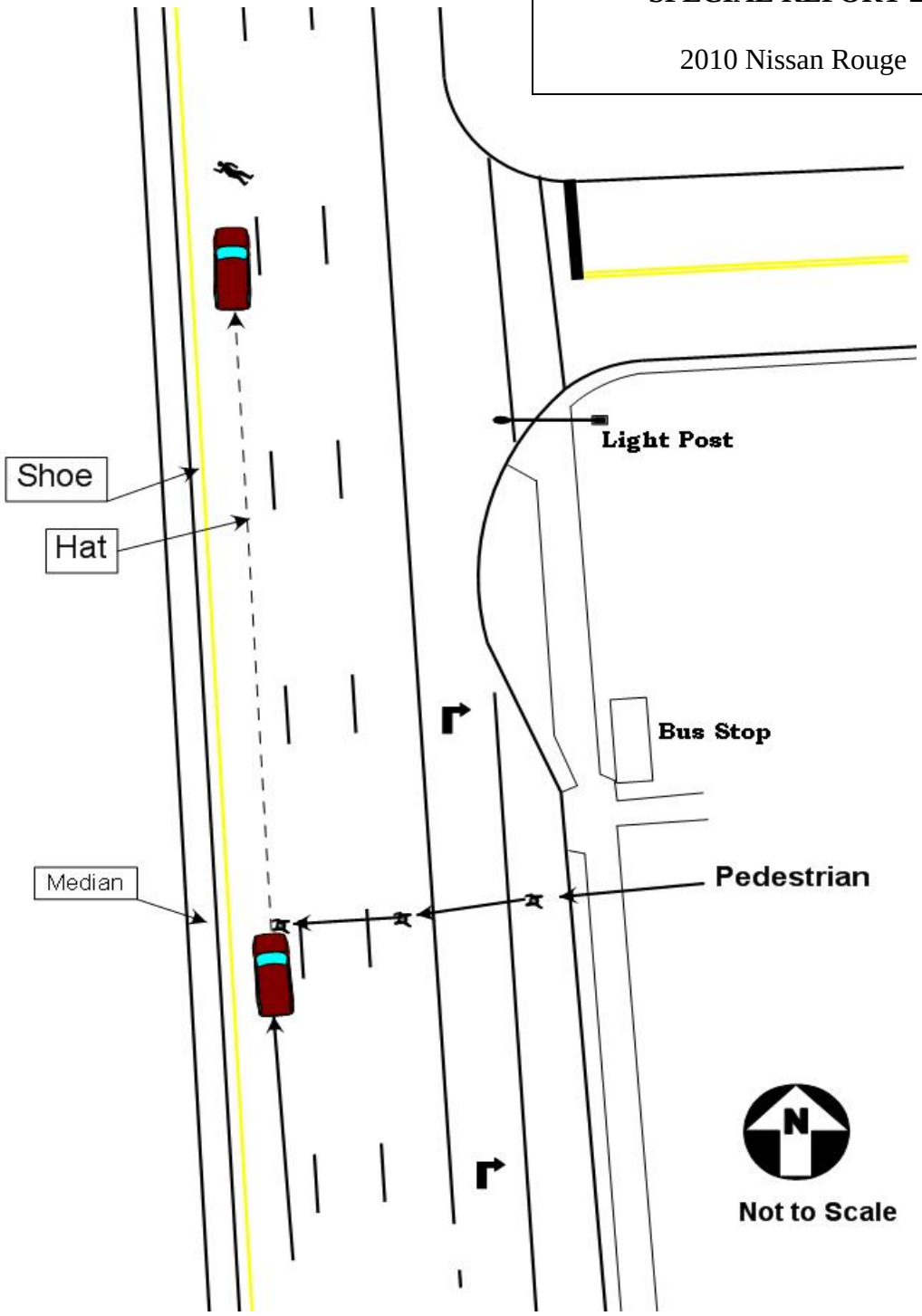
had a small scuff and the front license plate was knocked loose on the left side during the collision. The leading edge of the vehicle was measured at approximately 2 feet. The driver's frontal air bag deployed as a result of the collision. Nissan vehicles are not currently supported by the Crash Data Retrieval system, so no event data was obtained.

Photo #2: Nissan damage

The pedestrian suffered multiple blunt force injuries to his head, neck and torso. The most severe injuries included fractures to the cervical spine (neck) and the vertebral column (back), as well as fractures of the left iliac and ischium (hip) and multiple rib fractures on both the left and right sides. He did not suffer skull or extremity fractures, although there were lacerations on the left arm and abrasions across various areas, including the left head and cheek, the face, the abdominal area and the shins. Based on the injury pattern, the pedestrian was struck on his left side, which is consistent with his direction of travel. The higher and flattened leading edge of the Nissan resulted in most of the severe injuries occurring in the larger zone of initial contact and when the pedestrian's upper body wrapped onto the hood. The head and facial abrasions are likely the result of his impact with the ground after he was accelerated forward.

VIRGINIA MULTI-DISCIPLINARY CRASH INVESTIGATION TEAM SPECIAL REPORT 22

2010 Nissan Rouge



CASE STUDY NUMBER 2

Type of Crash: Pedestrian struck by pickup; hit and run

Day, Time, Season: Saturday, 10:50 P.M., Summer

Road/Weather: Primary road, clear & dry

Vehicles Involved: 1984 Ford F-150

Individuals involved: 21 year old female pedestrian (fatality)
40 year old male driver

Severity: One fatality; minor property damage

SUMMARY:

On a dry Saturday night in summer, a 1984 Ford F150 pickup was travelling north. The driver, a 40 year old male, had attended a fish fry and cookout earlier in the evening where, by his own admission, he had consumed alcoholic beverages, mainly beer. He and a male friend departed the gathering and were headed to another town. The driver was reportedly not wearing his lap/shoulder belt. It is unknown if his passenger was restrained.

The driver held a valid Virginia license with no restrictions. His driving record showed that he had completed a court referred driver improvement clinic late in 2008, but the conviction that led to that referral was not specified. Two months later, he was convicted of reckless driving generally, resulting in six demerit points. He was convicted in June of 2011 for operating an uninspected vehicle and unauthorized use of an inspection sticker, neither of which carried demerit point consequences. His record showed a point balance of +1. The investigating officer reported that the driver had been drinking prior to the crash, but that his level of impairment was unknown. Drug use was also cited.

The road is an undivided two lane north-south primary route located in a residential/business area. The lanes are separated by double yellow centerline pavement markings. Each lane is approximately 10 feet wide. The road is asphalt and in fair

condition but has some cracking. The shoulder is gravel/grass and slopes to a grass ditch. A sidewalk parallels the southbound side of the road across from the shopping center to the north, but the concrete surface ended approximately 300 feet prior to the crash location. The road is level and curves slightly to the right. It is controlled by signs and pavement markings. The signs are in good condition and the pavement markings are in fair condition. There is no overhead lighting and the speed limit is 45 MPH. The average daily traffic is 3400 vehicles for this section of road (VDOT, 2010).

Photo # 3: Daylight picture of the crash site.

The passenger in the pickup later stated that the driver ran off the road and onto the right shoulder several times as they were headed northbound. This caused enough concern that the passenger offered to drive, but the driver refused and they continued their trip.

At the same time, a 21 year old female was walking north along the northbound side of the roadway, although it is unknown if she was walking along the edge of the road or off of the road. There were no indications that she was impaired in any way prior to the crash. A toxicological analysis of her blood was negative for alcohol and drugs.

The pedestrian had been at home most of the evening and had walked to a grocery store approximately 2/10 of a mile away to purchase a few items, including a gallon of milk. She was walking with her back to oncoming traffic and was wearing white/cream colored capris pants and a black tee shirt (the floral colored print screen on front of tee would not have been visible to Ford driver). None of her clothing was retroreflective. Although some of her clothing was light in color, the pedestrian may not have been conspicuous under the dark conditions. As discussed in the previous case, the lack of retroreflective clothing would have made the pedestrian difficult to see as she walked along the roadway edge.

The pedestrian was nearing her home when she was struck from behind by the front right of the pickup. The driver did not stop. The victim was thrown forward and later found in a small grassy ditch off of the roadway. The only evidence to determine an area of impact was the gallon of milk she was carrying. The undamaged milk container was located just off of the road, 1.5 feet from the pavement edge. No skid marks, shoe scuffs, vehicle debris or other evidence was found by investigating officers at the scene to further assist in determining an area of impact. The distance from the milk carton to the victim's final rest measured 89 feet.

Applying a throw distance of 89 feet to Searle's pedestrian throw equations, minimum and maximum pedestrian speeds were calculated. The speed range using the Searle formulas is 35 MPH to 43 MPH (or 51.31fps to 63.98 fps). This is the forward speed that the pedestrian attained after being struck by the vehicle, and an indication that the Ford had been travelling at least that speed at impact.

This crash did not involve the pedestrian crossing the roadway in front of traffic, so it is not considered a pathway intrusion. The vehicle either travelled to the edge of the lane or onto the shoulder before striking the victim. Neither the driver nor the passenger, who was seated closer to the impacted area of the pickup, reported seeing the pedestrian prior to impact. Research studies that addressed pedestrian visibility under conditions

similar to this case have been analyzed using the I.DRR software and reported average recognition distances between 232 and 278 feet. However, such distances can be affected greatly by other factors, such as how far the pedestrian stood to the right of the vehicle as well as how distinguishable the pedestrian was from other objects near the road edge (shrubbery, trees, etc.). The driver's impaired state may also have affected his ability to discern and respond to the pedestrian.

The vehicle was slightly damaged from the impact, mainly to the right front corner and headlight assembly. The bumper and hood were slightly buckled and the contact damage spanned approximately 15 inches, measured from the right edge. The leading edge of the vehicle was between 16.5 inches to 21.5 inches above the ground. The hood height was found to be approximately 3.6 feet.

Photo # 4: Ford damage

The pedestrian, who was 5 feet 9 inches tall and weighed 225 pounds, suffered fatal blunt force injuries to her head, pelvis and lower extremities. Injury evidence is consistent with the pedestrian walking with her back to the vehicle. She had abrasions to the back of the knee and ankle areas of her left leg. A 2 ½ inch curvilinear imprint on her right buttock, along with an embedded glass fragment, are consistent with contact to the pickup's right front headlight assembly. Impact with the leading edge of the pickup is likely to have caused the victim's pelvic fractures (both left and right side), as well as abrasions to her lower back and buttocks. She wrapped onto the hood, but there was no evidence that she struck the windshield. Her body was then accelerated off to the right, landing beside the roadway, as the pickup continued forward. At some point, the victim suffered fractures to the base of her skull, along with brain hemorrhaging, in addition to a stretch injury of the left groin area and transection of the left iliac artery.

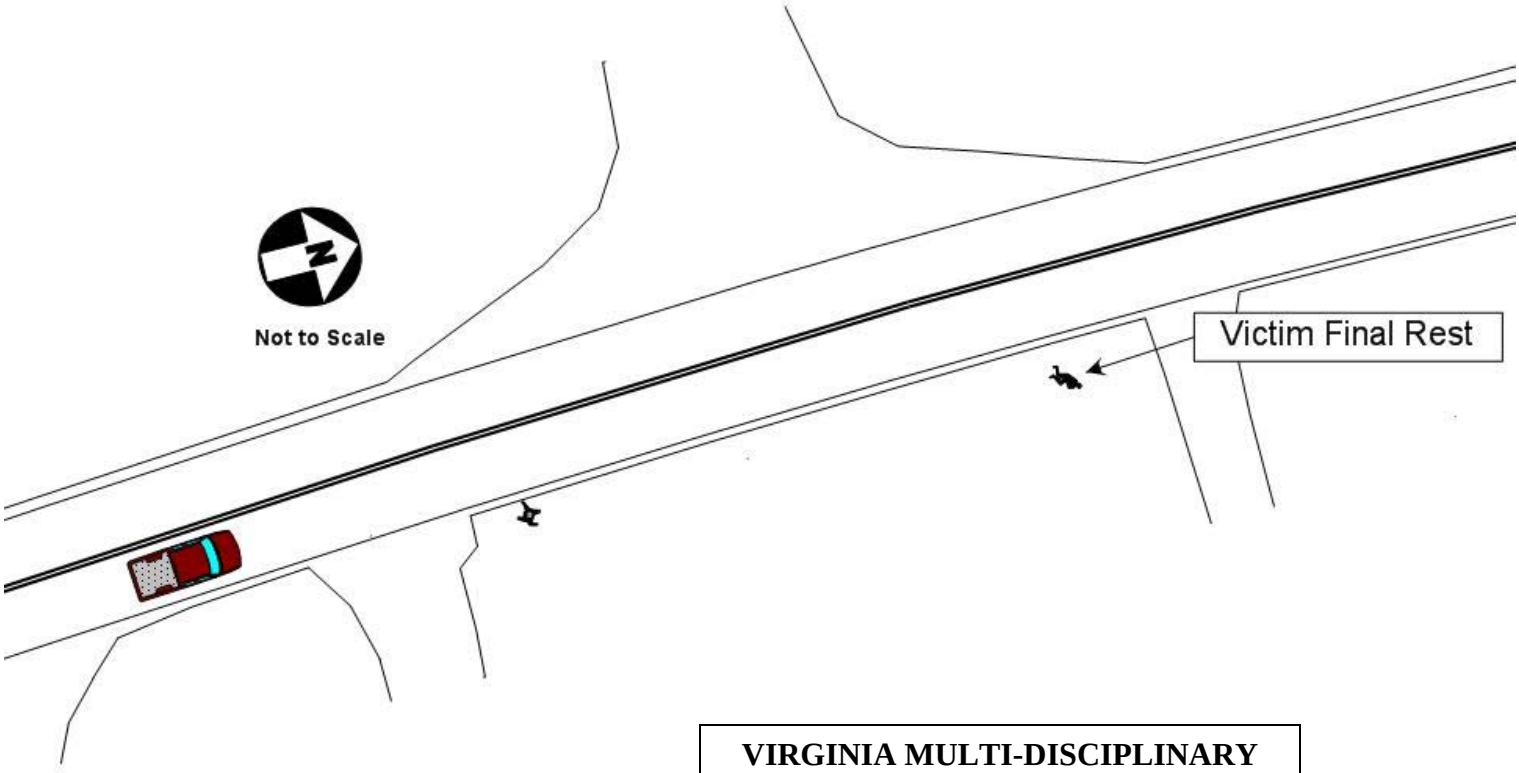
The Ford driver did not stop after striking the pedestrian, even though the passenger told him that the pickup had hit something. Once at their destination, the passenger found that he was unable to exit the vehicle through the right door: damage from the crash had made it inoperable. The passenger immediately got into a car with a female and departed.

At this point, the passenger was still upset and concerned. He called a friend, who drove through the area the passenger described and indicated that he didn't see anything. The friend continued on and picked up the passenger. Together they went back and drove through the crash location twice before stopping and checking the ditch area, where they found the victim. The passenger went to the door of the nearest house (the victim's home) and knocked on the door. The victim's mother answered and, as requested, called 911. She then went outside to check on the victim, discovering her daughter's body.

Police, fire and rescue units arrived on scene shortly thereafter. The pickup passenger gave police his identification information, but he did not indicate that he had knowledge of the crash. The police department issued an alert for a hit and run vehicle. It was later located by the police department in a neighboring jurisdiction and processed for evidence.

After leaving the scene, the passenger called the pickup driver to inform him that he had killed a pedestrian. The pickup driver stated later that he then consumed about 40 ounces of beer and smoked marijuana. He then went to the neighboring police department and turned himself in, stating that he thought he hit a deer. Over three hours had passed since the time of the crash, so the police did not perform blood tests, although the driver was given a field sobriety test and then interviewed. He admitted to having a passenger and identified the person who had been at the scene and discovered the body. The police department with jurisdiction for the crash visited the passenger at his home, where he cooperated fully, providing the timeline of events that evening.

After police completed their investigation, they charged the driver with involuntary manslaughter in a vehicle (§18.2-36) and failure to stop after an accident (§ 46.2-894), both Class 5 felonies. He pled guilty and was convicted on both charges, then sentenced to 10 years on the first offense with 4 years suspended and 10 years on the second with 8 years suspended.



VIRGINIA MULTI-DISCIPLINARY CRASH INVESTIGATION TEAM SPECIAL REPORT 22

1984 Ford F150

CASE STUDY NUMBER 3

Type of Crash: Pedestrian struck by vehicle

Day, Time, Season: Wednesday, 10:27 A.M., Summer

Road/Weather: Primary road, clear & dry

Vehicles Involved: 2000 Toyota Camry

Individuals involved: 39 year old male pedestrian (fatality)
20 year old female driver

Severity: One fatality; minor property damage

SUMMARY:

On a hot and dry Thursday morning in summer, a 20 year old female was driving a 2000 Toyota Camry, travelling southbound in the left lane on a major roadway. She was headed home after having worked from 4:30 A.M. to 10 A.M. and she was wearing her lap/shoulder belt. This driver reported that she had approximately four hours of sleep the previous night and that she had not consumed any alcohol or medications. She was familiar with the area, since this was her normal commute.

The driver held a valid Virginia license with a restriction requiring that she wear corrective lenses. She did not have any convictions or accidents reported on her driving record and carried a point balance of +2 (she had been licensed since 2009). According to the investigating officer's report, she did not have any impairment that affected her ability to operate a vehicle.

The road is a major north-south primary route located in an urban area. The northbound and southbound lanes are separated by double yellow centerline pavement markings. Approaching the crash site, there are two signalized, four way intersections in close proximity. The distance from the stop bar on the northern side of the first intersection to the stop bar on the northern side of the second intersection is approximately 220 feet. Approaching the second intersection, the southbound section of the road has two through lanes and a through/right turn lane. The southbound through

lanes are approximately 12 feet wide and the right lane is approximately 16 feet wide, which includes a 2 foot gutter and 6 inch curb. Approximately 165 feet south of the intersection, there is a bus stop adjacent to the right lane. On the northbound side of the road, south of the intersection, there are two through lanes, a left turn lane and a right turn lane. The total distance across all travel lanes is approximately 90 feet. The road is asphalt and in good condition, with a downgrade of 4 percent in the southbound direction. The road is controlled by signs, signals and pavement markings, although there are no crosswalk lines or pedestrian signals at this intersection. The signs are in good condition and the signals are in good operating condition. There is overhead lighting. The speed limit is 45 MPH. The average daily traffic is 34,000 vehicles for this section of road (VDOT, 2010).

Photo # 5: Southbound view of crash site. The pedestrian was attempting to cross from right to left from the bus stop on the right.

The driver of the Camry reported that she had been following another vehicle southbound in the left lane, but that vehicle was travelling about 15 MPH below the speed limit. She moved her car to the right lane, passed the other vehicle, and pulled back into the left lane as she approached the two intersections. As she moved forward and into the second intersection, she saw that the signal had changed to yellow. When she glanced back down, she saw what she initially thought was an object in the road, then realized it was a pedestrian wearing white clothing.

As the Camry approached and traversed the intersection, a 19 year old male was attempting to cross the road from west to east (from the driver's right to left). He entered the roadway midblock, approximately 163 feet south of the intersection, in the vicinity of the bus stop. He was 5 feet 7 inches tall and weighed 225 pounds, and he was wearing a white shirt, blue jeans and "flip flop" sandals.

This young man had a history of mental illness, including schizophrenia, and was thought to have been in the vicinity of a center where he received medical attention on an ongoing basis. The investigating officer reported that the pedestrian had no defects that might have contributed to the crash and a toxicological analysis of his blood was negative for the presence of alcohol. No other drug analyses were performed. There were no evidence or witness reports that could attest to his psychological state prior to the crash.

The pedestrian had traversed the right bus lane and the right through travel lane, and was in the left travel lane, when the Camry struck him. The Camry driver reported that she could not tell if he was moving when she first saw him. As soon as she realized a pedestrian was in her path of travel, she reported that she braked hard.

Although members of the VMCIT were unable to examine this vehicle, photographic evidence shows that the Toyota sustained damage to the hood and windshield, mainly on the left side. The left side mirror glass was knocked out as well.

Photo # 6: Toyota damage

The victim in this crash wrapped onto the left front of the vehicle and then was then thrown to the pavement. The pedestrian struck the pavement at or near the double center yellow line, which was evident by the tearing of the pavement marking tape. He then slid/tumbled to final rest in the north bound lane. A total throw distance, which was measured from the location of a "flip flop" and blood spatter on the roadway (see diagram below) and includes sliding distance, was determined to be 78.9 feet.

Photo # 7: Torn pavement marking tape

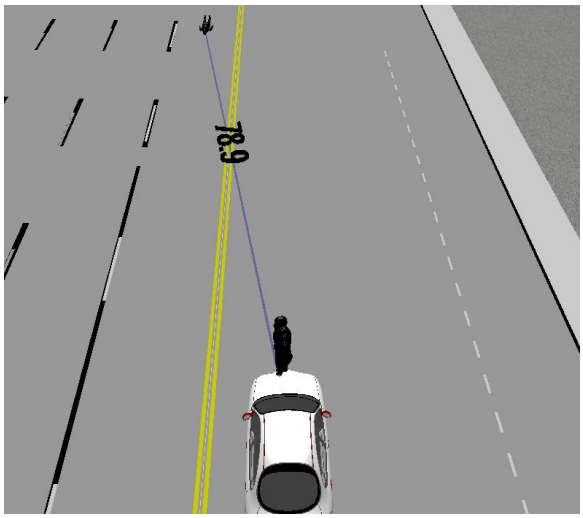


Figure 6: Throw distance illustration

The pedestrian suffered multiple blunt force injuries which resulted in his death. The ME performed an external examination but not a full autopsy. The findings included compound fractures of the left humerus (upper arm) and left fibula (lower leg). He had lacerations on both arms and the top of his head, as well as contusions and abrasions on his forehead, left chest, right hip and right leg. These injuries are consistent with being struck on the left side, wrapping onto the vehicle, then striking the paved roadway. The ME noted that the victim had no palpable head fractures and no crepitation of the neck, indicating no evidence of fractured vertebrae.

The vehicle braked, leaving no skid marks, coming to a stop 66.2 feet from the area of impact. Using the speed loss formula and an estimated coefficient of friction of .7, the speed of the vehicle was determined to be approximately 37 MPH (54.24 fps).

A second speed analysis from this crash was performed using the throw distance of 78.9 feet applied to the Searle formulas, which yielded an estimated speed for the pedestrian ranging between 33 MPH to 40 MPH (48.37 fps to 58.6 fps). This is the forward speed that the pedestrian attained after being struck by the vehicle, and an indication that the Camry had been travelling at least that speed when it struck the pedestrian.

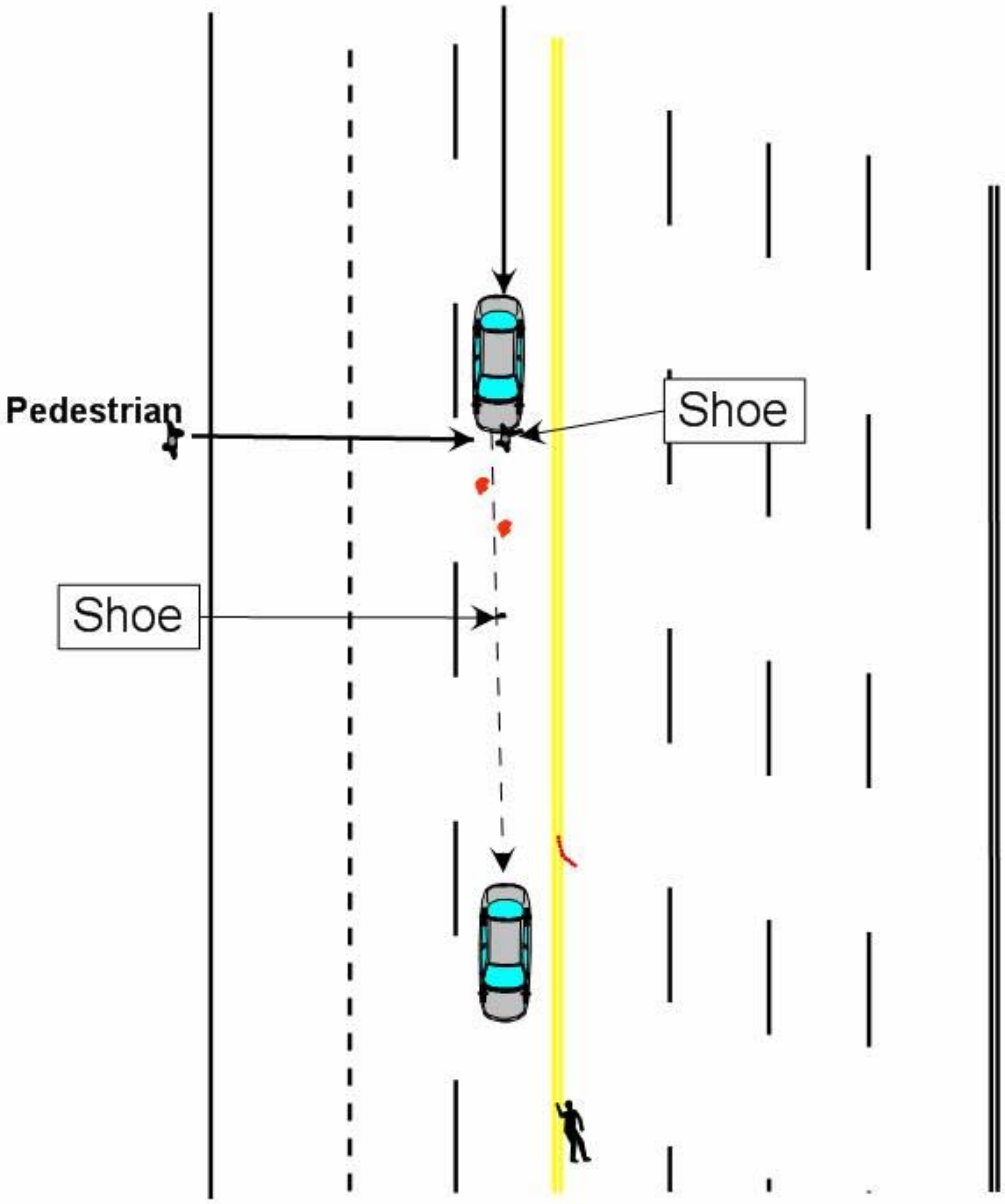
As in any pedestrian intrusion case, an investigator must consider whether or not the driver had the ability to perceive and/or time to respond to the pedestrian encroaching upon her path of travel. Based on the total distance he had to cross (90 feet) and considering the fact that he was crossing midblock, the pedestrian was estimated to be walking, on average, about 4.55 fps (between 4.23 fps to 4.82 fps, based on I.DRR analysis). He had travelled approximately 34 feet into the roadway before he was struck, indicating that he had been traversing the roadway for over 7 seconds at the time of the collision. Despite what seems to be a long period of possible visibility, other factors likely interfered with the driver's ability to detect and respond to the pedestrian.

First, she faced a cluttered visual field that may have made it more difficult to detect the man, reducing the amount of time available for her to respond. This urban roadway carries a high density of traffic, with vehicles frequently changing lanes, turning and stopping. The presence of two signal-controlled intersections in close proximity adds to the amount of visual information which drivers must observe, process and respond to. The road is lined with retail and office buildings, and busses are often stopping to discharge and pick up passengers. As a result, pedestrian foot traffic is not uncommon. However, drivers typically expect pedestrians to cross at intersections and not mid-block—and they respond more quickly to objects that are expected. This driver's ability to observe the pedestrian may have been physically blocked by other vehicles as he crossed the first two travel lanes. However, the fact that he was crossing mid-block—an area where drivers are less likely to anticipate pedestrians—may have further reduced the likelihood that he would be detected early enough for the driver to avoid the crash.

When the Toyota driver entered the second intersection, she was approximately 163 feet from where her vehicle struck the pedestrian. If she had been able to perceive the victim at that point, she would have had less than 3.4 seconds to avoid the collision. However, she stated that she had been looking up at the traffic signals as she entered the

second intersection, noting that the light was changing from green to yellow. If the driver had been looking forward, her perception response time would have been, on average, about 1.6 seconds (utilizing the research based I.DRR). Instead, her eccentricity increased significantly with her upward focus on the traffic signal, by as much as 25 degrees. The signal's position would have changed, rising in her visual field as she drove closer, and increasing the amount of eccentricity. With a 25 degree level, the traffic signal would have been comparable to the level of her rear view mirror. Under those conditions, her average perception response time would have increased to about 2.4 seconds. This would not have allowed her enough time to respond and steer or stop her vehicle to avoid the collision.

As soon as she stopped her vehicle, the driver exited. Additional vehicles also stopped and the driver ran to one, asking the occupant to call 911. Emergency responders arrived on the scene shortly thereafter and began providing traffic control and medical assistance. The victim was transported to a nearby hospital, where he was pronounced dead approximately 30 minutes after the crash. The investigating officer, a reconstruction specialist for the local police department, collected evidence and took measurements of the crash scene. The vehicle was towed from the scene and later released. No charges were placed against driver.



VIRGINIA MULTI-DISCIPLINARY CRASH INVESTIGATION TEAM SPECIAL REPORT 22

2000 Toyota Camry

Not to Scale

CASE STUDY NUMBER 4

Type of Crash: Pedestrian struck by vehicle

Day, Time, Season: Tuesday, 9:52 P.M., Fall

Road/Weather: Secondary street, misty & wet

Vehicles Involved: 2004 Gillig transit bus

Individuals involved: 18 year old female pedestrian (fatality)
56 year old female driver

Severity: One fatality; minor property damage

SUMMARY:

At approximately 9:52 P.M. on a misty Tuesday evening in the autumn, a city owned 2004 Gillig transit bus approached a signalized intersection on a university campus. The 56 year old female driver, who was wearing her lap/shoulder belt, was travelling south approaching a signalized intersection and preparing to make a left turn onto an eastbound road. The southbound approach has two lanes; one lane for the left turn traffic (approximately 11 feet wide) and a lane for through and right turn traffic (approximately 10 feet wide). The northbound lane is approximately 10 feet wide. The lanes are separated by two solid yellow lines centerline markings. There are two through lanes for the eastbound roadway at the intersection which merge into one lane. The lanes are approximately 13 feet wide and 11 feet wide respectively. The westbound approach has two lanes; one lane for left turn traffic (approximately 10 feet wide) and a lane for through and right turn traffic (approximately 8 feet wide). The lanes are separated by two solid yellow centerline markings.

The road is asphalt and in good condition. At the intersection, the grade of the road is level. The intersection is controlled by signs, traffic signals, pedestrian signals and pavement markings. The signs are in good condition and the signals are in good operating condition. The pavement and crosswalk markings are in fair condition. The speed limit is 25 MPH.

The driver held a valid Virginia Commercial Driver License (CDL) with endorsements for school and passenger busses. Her license carried a restriction which required that she wear corrective lenses while driving. Her driving history showed that she had one conviction the previous year for a defective speedometer, which resulted in no demerit points. She had a driver point balance of +5.

As the bus approached the intersection, the signal for through and turning traffic was green. The driver pulled the vehicle into the left turn lane. Since there was no approaching traffic, she did not stop, but began turning left, onto the eastbound leg of the intersecting secondary road.

Photo # 8: Daylight photograph, looking south as the bus approached the intersection to turn left.

At the same time, a pedestrian was walking southbound on the sidewalk that ran parallel to the northbound lane, to the bus driver's left. The pedestrian, an 18 year old female student at the university, was walking from a building on campus back to her dormitory room. She carried a bag of "take out" food and was talking on her cellular phone. This young woman wore black/dark clothing, including a "hoodie" type

sweatshirt with the hood up. A toxicological analysis (performed post-crash) of two blood samples and a vitreous humor sample were negative for alcohol and numerous drug screens. The investigating officer indicated in his report that the pedestrian did not appear to have any physical or psychological limitations that might have contributed to the crash.

As the pedestrian approached the intersection, the light for traffic travelling in her same direction was green. However, on the traffic signal pole, a pedestrian signal displayed a graphic "DON'T WALK" message (an orange upraised hand, a signal to stop). Despite the message, the young woman continued to walk forward into the intersection.

The VMCIT was able to view video footage from the bus. Several camera angles provide a unique view of the events. The bus driver approached the intersection and began to turn left on a green traffic signal, after on-coming traffic cleared the intersection. As the bus was turning left, the pedestrian stepped off the sidewalk to cross the roadway. Video evidence shows that, at the time the bus was turning, the pedestrian crossing signal displayed the orange upraised hand, indicating pedestrians should not cross. The young woman, ignoring the signal, crossed the first lane of traffic, where several vehicles had stopped at the traffic signal. In the video, she is difficult to see as she passed in front of (and then between) headlights for stopped traffic facing west. She traversed the two westbound lanes and entered the eastbound lane, where she was struck by the bus' left side view mirror (in the video, the mirror can be seen folding back as the pedestrian was struck). The woman then fell to the ground where she was run over by a rear wheel of the bus.

The bus' motion provided kinesthetic cues to the driver that she had hit something, and she can be heard on the video saying, "What was that?" She quickly stopped the vehicle and exited through the side door, discovering the victim. The driver immediately sought assistance and reported the crash. Police, fire and rescue personnel responded; the divisional state police reconstruction team, which included a commercial motor vehicle specialist, was called in as well.

An ME viewed the body at the scene and then had it transported to the District Office of the Chief Medical Examiner for further examination and identification (the pedestrian carried no identification on her person). The pedestrian died instantly as a result of extensive crushing head injuries, which included "marked destruction of skull with fractures of all facial bones", according to the ME's report. She had abrasions and contusions across various areas of her body surface, but no other fractures or crushing injuries were cited.

The VMCIT was unable to examine this vehicle. However, photographic evidence shows no damage to the bus.

The video evidence shows that the bus rocked twice as the pedestrian was run over. The time between the two bumps was approximately 1.9 seconds. According to the manufacturer's specifications, the wheel base on the bus was 19.3 feet. Using this information, the speed for the bus was determined to be approximately 7 MPH.

Photo # 9: Involved bus

Figure 7: Pre-crash relationship of pedestrian and bus.

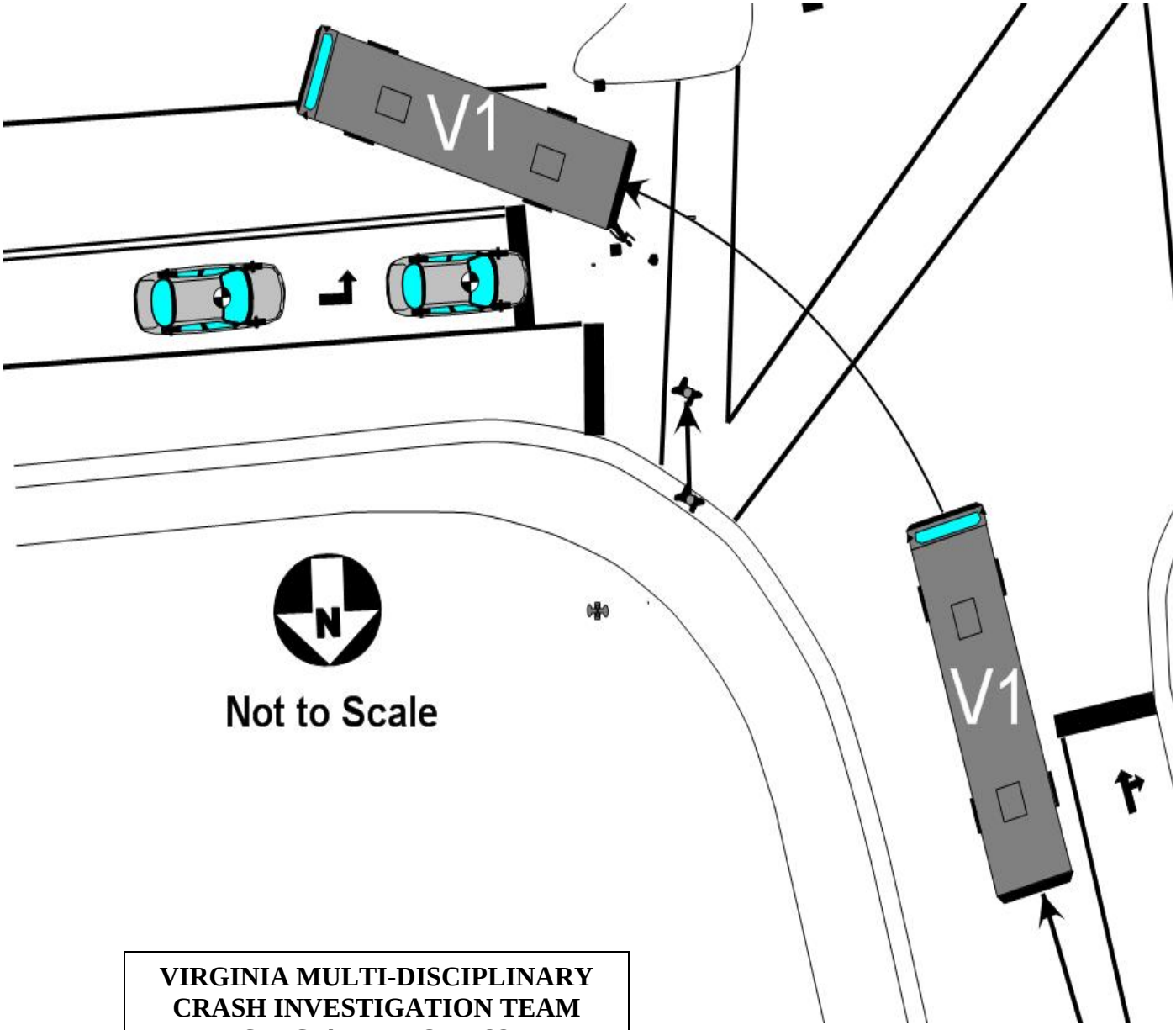
The pedestrian had a distance of 28 feet to cover from the northern curb to the island. She would have stepped onto the island to cross the other eastbound lane at a diagonal. She had crossed all of the 18 feet of westbound lanes and stepped into the eastbound lane when she was struck. I.DRR analysis suggests that the average walking speed for an individual in this type of intersection and crossing against the signal is about 4.66 fps, or ranging between 4.56 fps and 4.82 fps. The time for her to travel from the curb to the area of impact (approximately 20 feet) would have taken 4.1 seconds to 4.4 seconds.

A number of factors led to this unlikely event taking place. The crash occurred during hours of darkness with a light, misty rain falling. The intersection does have overhead lighting; however, these lights are "architectural" in nature, designed to illuminate the lawns and sidewalk. Light does not pool directly onto the roadway to illuminate objects in the travel path. The pedestrian wore black clothing, which made her indistinguishable from the roadway and background lawns and walls until she stepped in front of the headlights. If she had been wearing retroreflective clothing, the driver may have detected her to the left as both approached the intersection and potentially anticipated her being near or in the intersection.

Once the pedestrian entered the intersection, anyone looking in her direction, would have been affected by headlight glare, which was made worse by the mist. As light hit the tiny water droplets, it would have been redirected and scattered, making it difficult to determine patterns or edges of objects in the viewer's line of sight. Even on the video, when viewers know what they are seeking, the pedestrian is difficult to identify.

In addition to the visibility difficulties for the driver, the pedestrian's actions were a significant factor in this crash. The pedestrian limited her awareness of the environment by talking on a cell phone while she was walking. This distraction affected her perception on three levels: her mind was engaged in the ongoing conversation, leaving her less able to process sensory information from her surroundings. This may have resulted in her failing to respond to the "DON'T WALK" symbol displayed at the intersection, although she may have deliberately chosen to ignore the symbol as well. By holding the phone to her ear and listening as well as talking, she either physically or mentally blocked noises from the environment, including the sounds of approaching traffic behind and beside her. Third, by wearing the hood of her sweatshirt pulled up and forward, she decreased the breadth of her peripheral vision, meaning she was less likely to see vehicles approaching from the side unless she physically turned her head to scan the area. These actions showed a complete disregard for her surroundings and her personal safety, resulting in her walking toward the side of a moving bus, with tragic results.

After the crash, emergency personal gathered evidence at the scene, and the body was removed under direction from the ME. Once the bus was removed, the scene was cleared and the roadway, which had been closed, was re-opened. The driver was not charged with any violations; however, the case received significant media attention. University police took measures to increase awareness and educate students at the university about pedestrian safety by distributing emails and brochures, especially near the intersection.



VIRGINIA MULTI-DISCIPLINARY CRASH INVESTIGATION TEAM SPECIAL REPORT 22

2004 Gillig Bus

DISCUSSION

Although roadways are typically designed for motor vehicle traffic, pedestrians and bicyclists utilize the same space. Pedestrians and bicyclists are highly vulnerable in situations where they interact with traffic and, although pedestrians legally have the right of way in many contexts, this does not necessarily make them safe. Although pedestrian crashes are small in number when contrasted with overall highway crash statistics for Virginia, they are a consistent concern. In order to decrease the number and severity of these crashes, an integrated approach will need to focus, at a minimum, on engineering, education and enforcement remedies.

To more precisely address the problem of pedestrian crashes, the underlying contributing and causal factors must be identified and analyzed. Careful and thorough crash investigation and reconstruction are critical to the criminal justice process as well as for developing effective countermeasures.

Pedestrian Crash Reconstruction

Pedestrian crashes pose a unique challenge for law enforcement in evidence collection and speed analysis. Often, a pedestrian crash does not yield the same evidence that a typical vehicle-to-vehicle crash may. This is a challenge to investigators to locate and properly identify the evidence at the scene. Once data are gathered, an investigator must consider the many formulas (30+) that have been developed for use in pedestrian cases. Some of these formulas require entering case-specific data while others are based on data from research studies. The crash investigator must determine which formula to utilize that will best suit the particular crash under investigation. With the wide arrays of published formulas, proper training is required to ensure that valid information is correctly applied to the particular crash.

The area of impact will not be as easy to identify. The investigator must have an idea of the location and then carefully search for even a minuscule clue. This clue may be a shoe scuff, blood or tissue, debris, or signs of “tire loading” where the vehicle was pushed downward slightly at impact, causing a slight deviation in the skid. If there was

no skidding, there may just be a slight tire scuff. In any case, this evidence will be difficult to locate. Impact and final rest are vital to speed analysis, as many formulas require a total throw distance: the distance from the pedestrian making first contact with the vehicle to his/her final rest (the horizontal distance). The investigator should also attempt to locate the area in which the body first made contact with the ground. This again may be utilized in the speed analysis.

Figure 8: Total throw distance

As the crash scene is being documented, the presence of body fluids at the crash site should also be noted. The investigator should also have pertinent data about the pedestrian such as height/weight, location of contact damage, and clothing information. In a pedestrian crash, it is important to document the "damage" (injuries) to the pedestrian just as you would document damage to a vehicle.

The reconstructionist must also determine the pedestrian's trajectory in each case. There are five pedestrian trajectories:

- wrap
- forward projection
- fender vault
- roof vault
- somersault

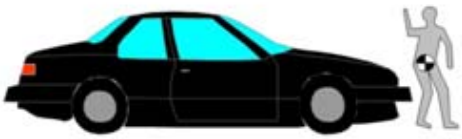


Figure 9: Wrap

The wrap and forward projection are the most common trajectories seen in pedestrian crashes. The least common is the somersault. This information may determine the formula the investigator can use in the speed analysis, as some formulas can only be applied in certain trajectories.

The vehicle size and type, as well as the pedestrian's size may assist in determining the trajectory. The pedestrian's center of gravity compared to the

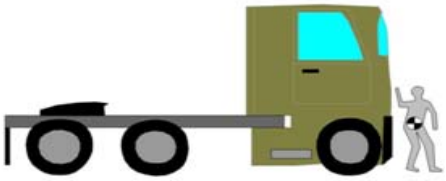


Figure 10: Forward projection

vehicle's leading edge may also assist in the determination of the trajectory. In a wrap trajectory, the pedestrian's center of gravity is normally higher and it tends to be lower in a forward projection.

John A. Searle derived two very useful formulas that can be used in most pedestrian crashes, as well as bicycle and motorcycle crashes. He derived a minimum and a maximum speed formula based on the total throw distance. Searle also assigned different friction values to pedestrians based on the type of surface they contacted after initial impact. These friction values included:

- .66 for asphalt (Searle & Searle 1983),
- .7 for dry roads (Searle, 1993) and
- .79 for grass (Searle & Searle 1983).

In terms of relating these pedestrian speeds to a crash, Searle & Searle (1983) found that a pedestrian acquired, on average, 77.5% of the vehicle's speed at impact.

Vehicle damage is as important to document in pedestrian crashes as in all motor vehicle crashes. The damage may be minor yet result in the death of the pedestrian. Published charts of vehicle damage in relation to speed offer a general summary of damage for wrap trajectories (Happer, Araszewski, Toor, Overgaard, & Johal, 2000). Care should be taking when using these charts to determine vehicle speed solely on vehicle damage. The vehicle size and shape may influence the damage, as may the size of the pedestrian. A child and an adult struck by the same type of vehicle will likely result in differing damage patterns. A child or shorter person may not wrap as far onto the hood as a taller person, thus resulting in different damage patterns and trajectories, although the vehicle may have been travelling at the same speed.

The vehicle must be painstakingly examined and all parts of the car where the pedestrian struck must be documented, including front to back, side to side, and height measurements. Each of the many pedestrian speed formulas has a different type of measurement and the investigator must be ready to supply the necessary data. Some of the points to consider are:

- Bumper height
- Leading edge height
- Highest point on the vehicle that was struck by the pedestrian

- Lateral travel distance across the vehicle

In 2010, Volvo introduced a pedestrian detection system with full auto brake. The system can detect if a pedestrian is in front of the vehicle, warns the driver, and then will automatically apply braking should the driver not respond to the audible alert. The braking is reported to be able to avoid a collision with a pedestrian at a speed up to 22 MPH. Should the vehicle be travelling at a greater speed, the braking would reduce the vehicle's speed as much as 22 MPH and hopefully reduce the severity of the crash.

Another innovation by Volvo is the Pedestrian Airbag Technology (currently only available in Europe). This airbag system works when the sensors on the front bumper register contact with a pedestrian. The airbag will deploy and cover 1/3 of the outer windshield and parts of the A pillar. The goal of the airbag is to minimize the contact of the pedestrian's head with the vehicle. When a pedestrian in struck by a vehicle, the front bumper is likely to be the area of first contact (also known as the leading edge). As the pedestrian wraps onto the front of the vehicle, which is still moving forward, the head will move rapidly, striking the windshield area. An airbag deployment may reduce head injuries, especially when the head is striking the ridged A pillar.

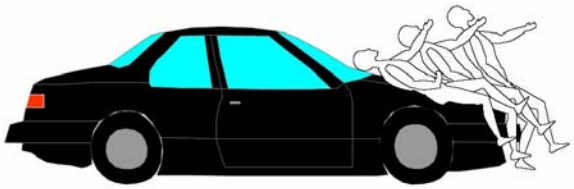


Figure 11: Pedestrian movement

It is not uncommon, as seen in the cases in this report, that there are no skid marks to assist the investigator in his/her speed analysis. The investigator should consider utilizing the Crash Data Retrieval (CDR) system when a supported vehicle is involved. Even in the event that the air bag(s) have not deployed, there may be valuable and useful information on the module to assist in the investigation. The frequency in which data will be available to the investigator will increase with the *United States Code of Federal Regulation Title 49 Part 563* issued 2006, amend 2008 effective September 2012 (see Appendix 1).

Another tool useful in reconstruction of pedestrian crashes is the Integrated Driver Response Research Software (I.DRR) developed by Jeffrey Muttart, a researcher at the

University of Massachusetts. This software employs a variety of statistical methods for combining extensive research data on driver response times across a multitude of situations and conditions. It provides quantitative and qualitative information that can be used to analyze the evidence and information collected in a specific case, allowing an investigator to compare and contrast that with specific and relevant studies. With an objective and methodical approach to assessing the case, the investigator can assist a prosecutor in determining whether to press charges and/or build a case based on how much the actual driver responses coincide or vary from the responses of drivers in similar situations.

I.DRR software can be used to evaluate driver response times in pathway intrusion crashes (which include most pedestrian crashes), cut-off related crashes, and cases where a lead vehicle is struck when stopped or slowing. It can provide assessments of pedestrian walking speeds, headlight illumination patterns, and pedestrian visibility distances based on clothing color and reflectivity, and research citations that may be helpful in a case. Members of the VMCIT used the I.DRR software to augment the reconstruction of several of the case studies in this report.

Injury Patterns

During the crash investigation, the investigating officer may consider speaking with the ME to gather additional facts. The ME may be able to provide valuable information, such as the measurements and direction of leg fractures. When compared to leading edge measurements for the vehicle, this information could be used to determine pre-impact braking, as well as the pedestrian's action(s) pre-crash. It is not uncommon in a pedestrian crash for the ME to only "view" the victim, rather than perform a full autopsy. However, the description of injuries from a view may still provide valuable information for the crash investigator, especially if it provides detail in the diagram of the external body. Pedestrian injuries do not only come from contact with the vehicle. The pedestrian will likely be injured when they contact the ground or other objects, and abrasions and fracture locations can be used to reconstruct some of the crash dynamics. Certain types of fractures and amputations are seen more frequently in higher speed

impacts, so more detail regarding injuries to the victim's body may give the investigator better evidence for determining what occurred.

Driver Factors

While in their vehicles, drivers are somewhat isolated from their surroundings, and their focus tends to be on navigating the paved terrain, watching for changes in the environment and for other vehicles that my affect their path of travel. However, any person operating a motor vehicle must be attentive to the areas in the periphery as well, where bicyclists and pedestrians may intrude into the path of travel. These vulnerable users may or may not legitimately access any given section of a roadway, but drivers should be cognizant of the need to be alert and share the road with them.

However, even at their most vigilant, drivers have little control over how much they can physically sense. In dark driving conditions, if lighting is insufficient, pedestrians may not be perceptible. Analysis of overhead lighting and headlights is valuable for determining whether or not a driver had the ability to detect a person standing or walking in or near the road. In daylight settings, even though there is plenty of light, drivers may become overloaded with sensory data. This is especially a factor when there is excessive visual clutter and/or multiple objects moving within the driver's visual field. Fixating on one object can create inattention blindness for other objects, resulting in missed cues and slower response times.

Actively engaging in distracting tasks like talking on a cell phone or texting, increase the likelihood that a driver will miss cues and respond more slowly. Despite the media attention, legislative and educational focus given to distracted driving, a recent Harris Interactive/Health Day poll revealed that 59% of adults admit to talking on non-hands free cell phones, and 37% text while driving. Smaller percentages of adults indicate that they have surfed the internet (13%) and watched videos (7%) while driving (Harris Interactive, 2011). While any distracting influence can lead to inattention blindness, tasks that require looking away from the roadway to view a device add to the problem by physically diverting the focal point of the visual field.

Other factors, such as driving under the influence of alcohol and/or drugs, may also negatively affect response times. Speeding will reduce the amount of time available to a driver to detect a hazard and attempt to avoid as crash.

Pedestrian Factors

Years of research have consistently identified the issue of pedestrian conspicuity as critical in crash causation and crash reduction. In order to identify, make decisions and respond to a pedestrian encroaching in their path of travel, drivers must first be able to detect them. As mentioned in several of the case studies, a variety of factors may decrease a person's detectability, affecting whether or not they can be seen and stand out sufficiently within their surroundings. In nighttime crashes, retroreflective apparel significantly improves the distance at which a pedestrian can be detected. Wearing retroreflective materials at the ankles and wrists provides visual feedback of bio-motion, allowing drivers to identify not only that they see "something" but that the object is moving in a manner similar to a human being, speeding up identification (Balk, Tyrrell, & Graving, 2009). Even in daylight situations, conspicuity is a factor. Pedestrians walking or running in urban areas compete with vehicles, signs, signals and other pedestrians for a driver's attention. If a pedestrian assumes that drivers are aware of them and will avoid them simply because they can be seen, they place themselves at risk. Actual perception does not always follow possible perception, and many drivers indicate that they never "saw" a pedestrian until the moment of impact.

In addition to inaccurately assessing their level of conspicuity, pedestrians may also inaccurately judge the distance and speed of oncoming vehicles with respect to the time they need to cross a roadway. Larger vehicles, for example, may appear to be travelling more slowly. Even though traffic signs and signals provide traffic control, drivers do not always comply and may not attend to their surroundings. Pedestrians must be cautious about making assumptions regarding oncoming traffic, even when they have right of way, and especially when they do not.

The pedestrian's condition and level of awareness play an important role in crash causation. Pedestrian distraction, alcohol and/or drug use and mental illness are common factors in many crashes. While highway safety advocates often stress the importance of

driving sober and resisting distractions, they have placed less emphasis on the condition of the pedestrian.

Each year, investigators respond to crashes in which a pedestrian had been lying in the road. In some of these cases, suicide is suspected but difficult to prove if the victim had not communicated an intent to take his or her life. In these and other cases, it is not unusual to find alcohol and/or drugs in the victim's system. Such impairment increases the likelihood that pedestrians will misjudge traffic conditions or their surroundings and place themselves in harm's way. Individuals who intend to consume alcohol may frequent local bars and restaurants, or local parties, believing that they are safe because they are not driving after drinking. However, walking home while impaired may be just as dangerous, and servers and hosts should ensure that their guests are sober enough to travel on foot as well as by motor vehicle.

While there has not been much attention given to substance-impaired pedestrians, concern about distracted walking is on the rise, especially in urban areas. The advent of the mobile devices for listening to music made it easier for those walking and jogging to tune out traffic, resulting in missed auditory cues that would have alerted them to approaching vehicles. As these devices became smaller and capable of storing a greater variety of customized recordings, they became commonplace on college campuses and in areas where foot traffic is heavy.

Simultaneously, cellular phone service grew. The mental and physical impairment that drivers experience when using a cell phone are replicated in pedestrian travel. Walking and talking takes attention off the surrounding environment. Auditory cues, which carry critical information to pedestrians, may be obscured by the earpiece and the conversation. While it may be possible for distracted pedestrians to see or hear potential hazards, they can fail to actually perceive and respond to them, as tragically exemplified in Case Study Number 4. The difficulties of texting while walking parallel those of texting while driving. The phone no longer blocks auditory input. Instead, it becomes the pedestrian's visual, mental, and motor focus, resulting in a significantly decreased level of environmental awareness, in addition to increases in walking errors (Lamberg & Muratori, 2011).

Educational and Enforcement Remedies

Education has long been a staple of safety advocates. Schools are often the first place people hear about pedestrian safety, and programs such as *Safe Routes to Schools and Bicycle Safety* (see http://www.nhtsa.gov/Pedestrians) have been effective in reducing the number of children injured or killed by motor vehicles. Significantly more pedestrian crashes involve adults. In light of the fact that most of these crashes are attributable largely to the pedestrians' actions, more attention will need to be directed to changing the way these individuals think and behave with regard to their movement on a roadway. Pedestrians generally need to become more sensitized to their lack of conspicuity, even when they feel that they are highly visible. Additionally, they need strategies for better judging vehicle speeds and closing times, as well as identifying safer crossing locations and times.

Pedestrian safety has been an area of focus within the U.S. Federal Highway Administration, and the agency began developing a Pedestrian Safety Campaign in 2003 (http://safety.fhwa.dot.gov/ped_bike/education/). The purpose of the campaign has three main elements: "(1) sensitize drivers to the fact that pedestrians are legitimate road users and should always be expected on or near the roadway, (2) educate pedestrians about minimizing risks to their safety, and (3) develop program materials to explain or enhance the operation of pedestrian facilities, such as crosswalks and pedestrian signals." The Pedestrian Safety Campaign is an outreach program that contains ready-made materials which can be used "as-is" or customized for a locality. A guide to implementing successful campaigns is included with multi-media resource materials, all available through the Campaign website. For communities with diverse populations, some of the materials are available in Spanish.

Education is not always sufficient to encourage safe practices. Enforcement of safety-related laws can be used to create awareness and motivate safer behaviors. Programs such as *Street Smart* (see http://www.bestreetsmart.net/index.php), which is operated in the Washington, D.C. area and includes parts of Maryland and Virginia, combines media campaigns to create awareness with enforcement "waves" that focus on all road users—drivers, bicyclists and pedestrians. The intent is to change behavior—and

thereby reduce fatalities and crashes—through increased awareness, education and visible enforcement.

Although some states have legislated bans on driving while using a cell phone or driving while texting, few have addressed the issue of pedestrian activities. Recently, however, a New Jersey town passed a ban on texting while walking. The ban allows officers to charge violators with jay walking and convictions carry an $85 fine. Holding pedestrians accountable for unsafe actions can be difficult and unpopular. However, allowing risky, illegal behaviors to occur unchecked provides an implicit sanction to the actions and may decrease pedestrians' perception of their vulnerability and need for caution.

Virginia has multiple laws that address the responsibilities of pedestrians and motor vehicle operators as they interact in and near roadways:

46.2-923	How and where pedestrians to cross highways
46.2-924	Drivers to stop for pedestrians; installation of certain signs; penalty
46.2-925	Pedestrian control signals
46.2-926	Pedestrians stepping into highway where they cannot be seen
46.2-927	Boarding or alighting from buses
46.2-928	Pedestrians not to use roadway except when necessary; keeping to left
46.2-929	Pedestrians soliciting rides
46.2-930	Loitering on bridges or highway rights-of-way
46.2-931	Localities may prohibit or regulate distribution of handbills, etc., solicitation of contributions...
46.2-932	Playing on highways; use of toy vehicle on highways, persons riding bicycles, electric personal ass...
46.2-932.1	Duty of driver approaching blind pedestrian; effect of failure of blind person to carry white cane ...
46.2-933	When vehicles to stop for pedestrian guided by dog or carrying white, red-tipped white, or metallic cane

ROADWAY FACTORS AND REMEDIES

Roadway characteristics can influence driver and pedestrian behaviors, and engineering changes, where possible and feasible, are often used to improve safety. The addition of overhead lighting may improve visibility in areas of high foot traffic and traffic signals can be timed to allow the pedestrian ample opportunity to traverse heavily travelled intersections.

More sophisticated devices, such as pedestrian hybrid beacons, provide additional cues to drivers approaching non-signalized intersections, alerting them to the presence of pedestrians in a crosswalk. Pedestrians activate the beacon by pressing a button. The beacon flashes yellow, and then displays a solid yellow signal before displaying a solid red to warn drivers to stop. Pedestrians can then cross safely. Pedestrian hybrid beacons can be costly to install and maintain, and they are not appropriate for all crossing situations. However, after three years of use, researchers found a 29% reduction in all crashes and a 69% reduction in pedestrian crashes in locations where they had been installed (Fitzpatrick, 2012).

Pedestrians travelling parallel to the roadway are vulnerable to vehicles that run across the edge line and onto the shoulders. However, safety researchers have identified effective engineering countermeasures (Bartlett, Graves, Petritsch, & Redmon, 2012). Separate sidewalks can help prevent as many as 88% of these types of collisions. On heavily travelled urban roadways, median crossing islands make pedestrians more visible to drivers. They also provide a break in the total crossing distance, allowing pedestrians to assess traffic conditions for each approach direction separately. Some median designs, such as a Danish Offset, alter the pedestrian's path of travel slightly so that they are looking toward oncoming traffic as they approach the second leg of a crossing (add diagram/picture). Adding and/or altering medians requires sufficient space and construction expenses, but they may reduce crashes by 39 to 78%.

Not all roadway changes are costly to implement or maintain: even pavement marking enhancements can be beneficial. For example, crosswalk markings provide guidance for pedestrians by defining and delineating the path to cross. When properly marked, the crosswalk lines are solid white lines and conform to the MUTCD. While transverse parallel lines are most commonly used to delineate crosswalks, researchers at the Texas Transportation Institute have found that pairs of bars placed perpendicular to a pedestrian's path of travel or continental markings (wider single bars placed equidistant apart) were more visible for longer distances to approaching drivers and improved safety at intersections (Fitzpatrick, 2012). An alternate way to mark crosswalks is using in-roadway warning lights that can be activated to warn motorists they are approaching a crosswalk, so that they will be more alert as they proceed. The installation of these lights

should be based on an engineering study or engineering judgment and is required to conform to the MUTCD (for more information, see Arnold, 2004). However, like pedestrian hybrid beacons, in-roadway warning lights can be costly to install and maintain.

Photo # 10: In-roadway warning lights

In cases where there are no marked crosswalks, such as Case Study Number 3, pedestrians receive less guidance about where to cross. A person in the vicinity of the bus stop may feel less vulnerable crossing at that mid-block location rather than exposing themselves to turning as well as through traffic at the nearby unmarked intersection. The VMCIT has discussed the issue of pedestrian safety at busy intersections without an "all red" signal phase in the timing sequence (see *VMCIT Report Number 205*).

CONCLUSIONS

Pedestrian fatalities comprised a small but consistent subset of motor vehicle deaths each year in the Commonwealth. Even though most occur in urban areas with heavier foot traffic, it is not uncommon to find pedestrian crashes in rural areas or on roadways that discourage pedestrian travel. Several deaths occur each year on the interstate, when drivers exit stopped vehicles. Although in some cases drivers are clearly at fault with regard to crash causation, pedestrians often place themselves in hazardous positions with respect to vehicular traffic. Research has consistently revealed that they overestimate their conspicuity, assuming that drivers can see them and that the situation is safe and/or that drivers will respond to their presence.

Pedestrian crashes are often a challenge to reconstruct, largely due to limited physical evidence. Investigators may have difficulty locating a clear area of impact and they may not have any evidence of braking to assist in determining a pre-impact speed. Careful documentation of the victim's injuries (and clothing) compared to vehicle measurements can be helpful in piecing together the crash dynamics. Additional technologies, such as the CDR system and the analytical tools available through I.DRR software, enable trained reconstructionists to perform a more thorough evaluation of the event.

Safety professionals have continuously worked to provide countermeasures that would reduce the number and severity of pedestrian crashes. Highway engineers have identified improvements in roadway design, signage and pavement markings to encourage safer behaviors for both pedestrians and drivers. The law enforcement community, especially those in areas with high pedestrian activity, worked with safety education groups to develop combination programs that motivate as well as educate all roadway users to travel safely and within the requirements of the law.

Members of the VMCIT have observed that the three types of roadway users—drivers, bicyclists and pedestrians—tend to have narrowed perspectives when they operate within a given mode. Additionally, many individuals harbor almost adversarial attitudes towards other roadway users. Drivers often express frustration when required to slow or stop for bicyclists and pedestrians. Bicyclists often express a sense of

vulnerability and frustration when sharing the road with motor vehicles, yet they convey irritation with having to share sidewalks with pedestrians. Pedestrians, in turn, are likely to express their sense of vulnerability with regard to both motor vehicles and bicycles, if they must navigate streets and walkways with those types of traffic. At some point, most people participate in two if not all three modes of travel, shifting their attitudes and frustrations as they change their frame of reference. If roadway users could shift from an "in the moment", adversarial perspective to one of empathy and respect for other roadway users, the underlying attitude change could support increased awareness, safer behaviors, and fewer crashes.

RECOMMENDATIONS

1. The Virginia Department of State Police (VSP) and local law enforcement agencies should continue to seek specialized training for officers involved in crash investigation and reconstruction. In addition to improving the process of determining fault and deciding if laws were violated, expert investigations provide better data to use in problem identification and development of effective countermeasures at the local, state and federal levels.

2. The Department of Motor Vehicles (DMV), the Virginia Department of Transportation (VDOT), VSP and other agencies or groups that focus on highway safety should continue to educate drivers, bicyclists and pedestrians about their rights and responsibilities with regard to other highway users.

a) Pedestrian awareness of conspicuity problems and driver response limitations is essential to decreasing the risks they take while walking and/or running on or near roadways.
b) Driver awareness of pedestrians' and bicyclists' assumptions of perceptibility can improve their alertness and expectations when travelling high pedestrian and bicycling areas, such as university campuses and urban locations.

3. The DMV, the Alcohol and Beverage Control Board and other agencies or groups that focus on highway safety should consider adding information on impaired pedestrian safety in their educational programs, including training for servers and hosts in establishments that sell alcohol, to ensure that their guests and customers are sober enough to travel on foot as well as by motor vehicle.

4. The Virginia Department of Transportation (VDOT) and/or the city public works department should consider making the following changes to the roads described in this report:

a) Case Number 1: No recommendations to VDOT.
b) Case Number 2: It is recommended that VDOT review the pavement markings and re-pave where necessary.
c) Case Number 3: It is recommended that VDOT install pedestrian crosswalk lines and signals at this intersection.
d) Case Number 4: It is recommended that the pavement and crosswalk markings be reviewed on these roads and remarked where necessary.

REFERENCES

Arnold, E.D. (2004). Final Report: Development of Guidelines for In-roadway Warning Lights. Virginia Transportation Research Council, Charlottesville, VA

Balk, S., Tyrrell, R. & Graving, J. (2009, May). Open-road studies of pedestrian conspicuity at night: the robustness of biological motion configurations. *19th Biennial Transportation Research Board Visibility Symposium*, Blacksburg, Virginia.

Bartlett, J., Graves, B., Petritsch, T. & Redmon, T. (2012, March/April). Proven countermeasures for pedestrian safety. *Public Roads (Publication Number FHWA-HRT-12-003.* U.S. Department of Transportation Federal Highway Administration, Washington, D.C. Retrieved April 10, 2012 from http://www.fhwa.dot.gov/publications/publicroads/12marapr/04.cfm

Eubanks, J. J. & Haight, W. R. (1992, August). Pedestrian Involved Traffic Collision Reconstruction Methodology, SAE Technical Paper Number 921591. *Future Transportation Technology Conference & Exposition*, Los Angeles, CA.

Fitzpatrick, K. (2012). Looking out for Pedestrians. *Texas Transportation Researcher 48 (1)*, pp. 6-7. Retrieved online June 11, 2012 at: http://tti.tamu.edu/2012/03/01/looking-out-for-pedestrians/

Fricke, L. B. (2010). *Traffic Crash Reconstruction 2nd Edition*, Northwestern University Center for Public Safety, Evanston, IL

Happer, A., Araszewski, M., Toor, A. Overgaard, R. & Johal, R. (2000) Comprehensive Analysis Method for Vehicle/Pedestrian Collisions, SAE Technical Paper Number 2000-01-0846. *Society of Automotive Engineers 2000 World Congress*, Detroit, MI

Harris Interactive (2011). Most drivers engage in “distracting” behaviors: Poll. Norwalk CN. Retrieved 6-11-2012 from: http://www.harrisinteractive.com/vault/HI-HealthDay-Distracted-Driving--2011-11-30.pdf

Lamberg, E. M. & Muratori, L. M. (2012, April) Cell phones change the way we walk, *Gait & Posture, 35 (4*), pp 688-690. Rretrieved May 29, 2012 from http://www.sciencedirect.com/science/article/pii/S0966636211008046

Muttart, J. & Romoser, M. (2009). Evaluating driver response and ability to avoid a crash at night. *Proceedings of the 1st Joint ITAI–EVU Conference*, Hinckley, UK.

Searle, J.A. (1993). The physics of throw distance in accident reconstruction. SAE Paper 930659. *Society of Automotive Engineers International Congress and Exposition*, Detroit, MI.

Searle, J.A & Searle, A. (1983). The trajectories of pedestrians, motorcycles, motorcyclists, etc. following a road accident, SAE Paper 831622. *Proceedings of Twenty-Seventh Stapp Car Crash Conference*, pp. 277-285

Virginia Department of Transportation (2010). *Average Daily Traffic Volumes With Vehicle Classification Data On Interstate, Arterial And Primary Routes*, Richmond, VA.

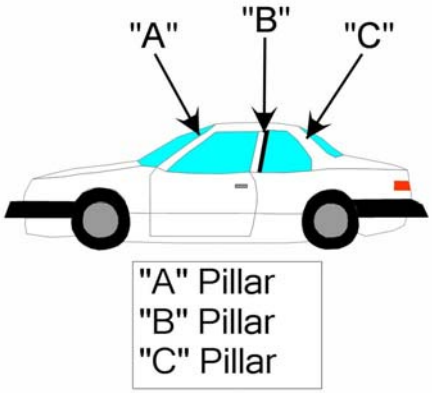
Wood, J.M., Tyrell, R.A. & Carberry, T.P. (2003). Pedestrian visibility at night: effects of pedestrian clothing, driver age, and headlamp beam setting. *2003 Annual Meeting of the Transportation Research Board*, Washington, D.C.

APPENDIX

DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
49 CFR Part 563
[Docket No. NHTSA-2006-25666]
RIN 2127-AI72
Event Data Recorders

SUMMARY: This final rule specifies uniform requirements for the accuracy, collection, storage, survivability, and retrievability of onboard motor vehicle crash event data in passenger cars and other light vehicles equipped with event data recorders (EDRs). This final rule responds to the growing practice in the motor vehicle industry of voluntarily installing EDRs in an increasing number of light vehicles. This final rule is intended to standardize the data obtained through EDRs so that such data may be put to the most effective future use and to ensure that EDR infrastructure develops in such a way as to speed medical assistance through providing a foundation for automatic crash notification (ACN). This final regulation: requires that the EDRs installed in light vehicles record a minimum set of specified data elements; standardizes the format in which those data are recorded; helps to ensure the crash survivability of an EDR and its data by requiring that the EDR function during and after the front and side vehicle crash tests specified in two Federal motor vehicle safety standards; and requires vehicle manufacturers to ensure the commercial availability of the tools necessary to enable crash investigators to retrieve data from the EDR. In addition, to ensure public awareness of EDRs, the regulation also requires vehicle manufacturers to include a standardized statement in the owner's manual indicating that the vehicle is equipped with an EDR and describing the functions and capabilities of EDRs.

This final rule for standardization of EDR data will ensure that EDRs record, in a readily usable manner, the data necessary for ACN, effective crash investigations, and analysis of safety equipment performance. Standardization of EDR data will facilitate development of ACN, e-911, and similar systems, which could lead to future safety enhancements. In addition, analysis of EDR data can contribute to safer vehicle designs and a better understanding of the circumstances and causation of crashes and injuries.

GLOSSARY

ADT	Average Daily Traffic
AE	Algorithm Enable
AASHTO	American Association State Highway and Transportation Officials
ASAP	Alcohol Safety Action Program
BAC	Blood Alcohol Concentration
CDL	Commercial Drivers License
CDR	Bosch Crash Data Retrieval System
DOH	Department of Health
DOT	Department of Transportation
DMV	Department of Motor Vehicles
DUI	Driving Under the Influence
EDR	Event Data Recorder
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
HOV	High Occupancy Vehicle
LED	Light Emitting Diode
ME	Medical Examiner
MPH	Miles Per Hour
MUCTD	Manual on Uniform Traffic Control Devices
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
OCME	Office of the Chief Medical Examiner
SAE	Society of Automotive Engineers
SUV	Sport Utility Vehicle
TRB	Transportation Research Board
USDOT	United States Department of Transportation
VCU	Virginia Commonwealth University
VSP	Virginia State Police
VDOT	Virginia Department of Transportation
VMCIT	Virginia Multi-disciplinary Crash Investigation Team
VWAPM	Virginia Work Area Protection Manual