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Pedestrian Safety and Mobility Aids for Crossings at Bus Stops

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Submitted by

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16. Abstract

New Jersey State law prohibits pedestrians from crossing between intersections (mid block) where a mid block crossing does not exist. However, enforcement of these regulations is not practical. Furthermore, difficulty in making this crossing maneuver discourages use of transit. The New Jersey Department of Transportation (NJDOT) and New Jersey Transit Corporation (NJ TRANSIT) recognize that solutions to alleviate this situation are few and that alternatives such as pedestrian overpasses are not feasible due to the relatively large expense. Therefore, NJDOT and NJ TRANSIT have initiated a project to investigate solutions that would benefit pedestrians and encourage mass transit ridership. Several measures are available for signalized intersections. However, unsignalized intersections and mid block crossings pose significantly more challenges in terms of safely accommodating pedestrian safety and mobility. The time critical need to access a bus stop location poses an additional challenge.

In order to properly develop criteria for identifying specific location deficiencies, the NJIT Project Team proposes a human centered approach for evaluating an array of creative solutions to address pedestrian crossing and access to bus stops along state highways. As the NJDOT maintains the state highway system, it is imperative that the potential solutions are acceptable to the NJDOT. Otherwise, it is likely that the solutions developed as part of the study, however seemingly functional, would not be implemented.

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SUMMARY

The New Jersey Department of Transportation (NJDOT) and New Jersey Transit Corporation (NJ TRANSIT) have initiated a project to investigate solutions that would benefit pedestrian accessibility to bus stop locations. Several measures have either been proposed or are under evaluation for enhancing pedestrian safety at signalized intersections. However, uncontrolled locations pose significantly more challenges in terms of safely accommodating pedestrians. Furthermore, the need for bus transit users to coordinate crossing movements with bus arrival times can often exacerbate these challenges.

This study seeks to identify and examine problems associated with safety and mobility for transit users accessing bus stops. Initial steps included a comprehensive review of current literature on the subject of pedestrian safety and the identification of potential candidate study sites. Once the sites were identified, numerous field observations were conducted. In addition, field surveys and laboratory studies were conducted to gain additional insight from the perspective of both transit users as well as highway motorists. By undertaking this approach, we have attempted to define the problem of pedestrian safety and mobility at bus stops and identify appropriate safety measures and mobility aids. Details of our research approach, findings, conclusions and recommendations are detailed in the respective sections of this report.

Literature Review

As a part of the research project, the research team conducted an in-depth literature review, which looks into the factors that contribute towards vehicle-pedestrian collisions. Traffic safety devices, which enhance the safety of pedestrians, were also reviewed. Significant variables that influence pedestrian collisions are high pedestrian volume, high traffic volumes, the number of lanes and the presence and type of median. Factors that help to explain high rates of motor vehicle-pedestrian collisions at pedestrian crossings have been derived as age, gender, time of day, vehicle movements and area types. Incidents of collisions are somewhat lower for older adults, but the fatality rate is higher compared to other age groups. Males accounted for approximately two-thirds of pedestrian related fatalities. Regarding time of the day, pedestrian collisions were highest between hours of 3 PM and 6 PM on Friday or Saturday and fatalities were greatest from 8 PM to midnight on weekends. With respect to vehicle traffic, through movement conflicts account for highest percentage of accidents (50 percent), followed by left turn (25 percent) followed by right turn conflicts and majority of the pedestrian fatalities occurred in urban areas (71 percent). Pedestrian safety devices are very important in helping to avoid vehicle-pedestrian collisions. The Manual on Uniform Traffic Control Devices (MUTCD) outlines specific requirements for the type and size of roadside traffic signs, pavement markings and traffic signal design. It is essential to use these pedestrian safety devices along with education and enforcement, but creation of friendlier pedestrian environments for the purpose of reducing vehicle speeds is also important. The different safety devices are classified into Regulatory signs, Warning signs, Pavement markings and Traffic signals. Educating the pedestrians about the different safety devices and signs is important. For example, the flashing “DON’T WALK” interval indicates that the crossing maneuver must be completed and that no new crossing movements may be initiated. Unfortunately, many pedestrians do not understand the meaning of this indication. It has been proven that symbolic walking pedestrian and upheld hand offers improved understanding over the flashing “WALK” and “DON’T WALK” signals. According to one study, the number of pedestrian accidents increases with the use of right-turn-on-red. On the other hand another study showed more pedestrian conflicts associated with right-turn-on-green than right-turn-on-red. Marked crosswalks are not recommended at multilane sites with an average annual daily traffic volume (AADT) greater than 12,000 (without raised median) or AADT greater than 15,000 with raised median that serve as pedestrian refuge areas. The number of pedestrian collisions increased at marked versus unmarked location on multilane highways with traffic volume exceeding an AADT of 10,000. No significant difference was found in the number of pedestrian collisions at marked versus unmarked location for two lane roadways with an AADT less than 10, 000. Marked crosswalks should also be avoided on high-speed streets where no traffic signal exists. Pedestrian push buttons are used where pedestrian activity is occasional and adequate opportunities do not exist for them to cross. Interestingly, some form of feedback if provided, can improve the effectiveness of the push buttons. For example, push buttons could be illuminated when the activation device is operational, thereby reassuring the pedestrians that the controller has received their signal call. Other safety devices include traffic calming devices (vertical deflections, horizontal shifts), medians, sidewalks and pedestrian overpasses and tunnels. One study shows that pedestrians tend to use an overpass only if walking time using the overpass versus an at-grade route is equal. As the ratio of time to use the overpass versus time to use the street increases slightly, the number of people using the overpass decreases significantly. Consequently, from the literature search and studies, it is proved essential that, there needs to be more concern towards pedestrian safety and mobility at signalized intersections. Appropriate design and proper implementation of apt safety control devices is an important step towards successively fulfilling this objective.

Site Selection

Early in the study, US Route 9 in Monmouth and Middlesex Counties was selected as the primary study corridor from which candidate sites would be chosen. This was principally due the corridor’s heavy transit usage and the roadway being a high volume principal multi-lane arterial, with a traversable median. Furthermore, the selected study section of US Route 9, having a traversable median, has a number of bus stops that are located at either stop street intersections or uncontrolled midblock locations, one of the principal criteria that was used for site selection. The overwhelming majority of bus stops on other multi-lane State highways, most of which have non-traversable median barriers, are located at signalized intersections.

Pedestrian crash data was for the study corridor to help identify potential candidate study locations. Data was collected for Years 1995, 1998, 1999 and 2000 for the entire stretch of US Route 9 Corridor extending from and including Freehold Township, Manalapan Township, Marlboro Township and Old Bridge Township. The total number of pedestrian crashes along the US Route 9 corridor, for the selected time frame and study limits totaled 26. While the research team agreed that the frequency of pedestrian-motor vehicle crashes should be an important criteria in selecting sites, many of the potential candidate sites that would have been considered using pedestrian crash data were either located at signalized intersections, such as Fairway Avenue and Taylors Mill Road or simply did not have an adequate amount of pedestrian use from which data could be collected and observations made. Ultimately, the selection of park and ride lots near Texas Road and Strickland Road was based on heavy pedestrian use and crossing behaviors.

Field Observations

The research team conducted a number of field observations both under favorable and inclement weather conditions. A summary of findings is provided below:

- The majority of bus transit users, after being discharged, would cross one direction of US Route 9, wait or walk toward their destination while in the median and then wait for a gap in traffic to cross the other direction of US Route 9. Several pedestrians were observed walking between cars, and in several instances, approaching vehicles were required to brake to allow pedestrians to cross the highway.

- Very few pedestrians were observed crossing US Route 9 at nearby traffic signals. Of the few that crossed at the traffic signals, none were observed pushing the pedestrian call button or properly following the pedestrian signal indications.

- Under inclement weather conditions, pedestrians crossed in a similar manner as indicated above. However, pedestrians were observed walking both in the left and right side shoulders most likely to avoid walking in the deep accumulated snow in the median and along the roadway.

Overall, we have found that while pedestrian features are designed in accordance with applicable standards they do not realistically go far enough to accommodate pedestrians. For example, pedestrian push buttons and pedestrian signal indications installed at key crossing locations are installed in accordance with the Manual on Uniform Traffic Control Devices. However, ***no one*** was observed using these devices in the manner in which they were intended.

On-Site Survey

A survey was prepared and administered at each study location in order to gain a better understanding of the conditions from the users as well as identify potential strategies for enhancing pedestrian safety. An excellent survey response was received. Relevant survey findings are summarized below:

- A large percentage of the survey respondents indicated that separate pedestrian phasing and crosswalks located more in line with the current walking path would encourage use of the traffic signals for crossing US Route 9.

- Survey respondents indicated that the presence of push buttons would encourage use of traffic signals for crossing US Route 9. This finding contradicts field observations, which revealed that none of the pedestrians activated the push buttons for crossing US Route 9.

- Written comments from the respondents indicated that there is a lack of proper illumination at bus stops at night and many expressed concern about the absence of sidewalks at the Texas Road location.

Laboratory Study

Several videos and photographs were taken at the study sites under different climatic conditions. The focus was on pedestrian crossing behavior and vehicle traffic. The videos were used for a laboratory experiment involving subjects to investigate the driver's perspective on their judgment about the risk (probability) level of unexpected pedestrians crossing the highway and traffic control devices that they think can help to increase the alertness about the potential hazards. Twelve subjects, who possess valid New Jersey driver's licenses, were recruited from NJIT. Comparing the content of the video clips and subjects' risk assessment scores, they gave higher risk scores to intersections and where there appeared to be stores and bus stops, compared to where there is no easy access to road for pedestrians and where there is less traffic congestion. Among the six traffic control devices that were provided as options, three of them were consistently chosen by subjects: the crosswalk marks, the traffic light and the pedestrian crossing sign. The findings also suggested that the presence of pedestrian crossing signs would increase driver alertness in areas where pedestrians may cross at any section of the highway.

Recommendations

Based on the results of the literature review, field observations and laboratory experiment, a number of short-terms and long-term recommendations have been developed and are listed below. These recommendations are elaborated upon in Section 6 of this report:

- Improve pedestrian accommodations such as sidewalks, more accessible push buttons and enhanced crosswalks.
- Install Advance Pedestrian Crossing signs on US Route 9.
- Provide user feedback devices on pedestrian activated signals.
- Consider modifications to signal timing to minimize vehicle-pedestrian conflicts at traffic signals.
- Investigate enhanced illumination.
- Educate transit users.
- Educate drivers.
- Consider relocation of bus stops.
- Further consider unwanted pedestrian crossing behavior when establishing bus stops and park and ride locations.

INTRODUCTION

Pedestrian safety is a serious concern both nationally and in New Jersey. According to the National Highway Traffic Safety Administration (NHTSA), nearly five thousand pedestrians are killed and nearly eight thousand injured annually as a result of pedestrian-motor vehicle collisions. While NHTSA statistics indicate that the annual number of pedestrian related fatalities has decreased nationally, New Jersey is experiencing a vastly different trend. Preliminary statistics show that 182 pedestrians were killed on New Jersey roads in 2002, the highest since 1996 when 183 pedestrians died in traffic crashes. Moreover, pedestrian fatalities in 2002 are also up a whopping 26 percent over the number of pedestrians killed in traffic crashes last year.

Not surprisingly, a number of agencies and professional organizations have examined problems and strategies for enhancing pedestrian safety and mobility. The Federal Highway Administration (FHWA) has published a number of documents providing information from past research on pedestrians, with a primary emphasis on pedestrian safety, addressing various issues like characteristics of pedestrian crashes, conflict analyses and hazard formulas, pedestrian safety programs, and countermeasures related to engineering and education.

Other initiatives are being undertaken at the State level. For example, due to the rise in pedestrian-motor vehicle collision rate in the State of Washington, Washington State Department of Transportation (WADOT), in collaboration with the Washington Traffic Safety Commission (WTSC) formed a Washington Quality Initiative (WQI) Pedestrian Safety Team to conduct analyses of pedestrian related collisions and identify ways to reduce these incidents. The team, comprised of city, county, and State representatives from transportation engineering and planning, enforcement, transit, and licensing, has developed recommendations to reduce pedestrian/motor vehicle collision rates. [(1)].

In its efforts to improve customer service, New Jersey Transit Corporation, Inc. (NJT), through New Jersey Department of Transportation (NJDOT) Office of Research and Technology, has initiated a study entitled _Pedestrian Safety and Mobility Aids for Access to Bus Stops_ to examine pedestrian safety and mobility issues related to bus transit stops.

The first phase of this study included a comprehensive literature review of research conducted or sponsored by transportation agencies and professional organizations. The second phase of the study consisted of selecting specific case study locations, identifying safety deficiencies and developing recommendations for implementing pedestrian safety and mobility measures.

LITERATURE REVIEW

The literature review addresses the following:

- What factors have or have not contributed to pedestrian related collisions?
- What criteria should be used in evaluating the effectiveness of treatments?
- What pedestrian safety measures have been implemented and what has been the outcome?

While the focus of our study examines conditions and measures to improve pedestrian safety at locations that are not controlled by traffic signals, signs or other traffic control devices, we have expanded the literature review to include pedestrian safety research at signalized intersections.

Contributing Factors

There have been a number of studies that examine contributing factors associated with pedestrian collisions. The US Department of Transportation and University Transportation Centers Program supported a study concentrating on the safety of pedestrian crossings in rural areas to discover and confirm factors that help explain high rates of motor vehicle-pedestrian collisions at pedestrian crossings. This study considers various environmental and exposure factors including pedestrian characteristics, population density, type of pedestrian crossing, traffic control used at the crossing, surrounding land use type, highway facility type, vehicle travel speed, vehicle volume and pedestrian volume. [(2)] A number of other research initiatives examine contributing factors associated with pedestrian collisions. A summary of results is provided below:

Age – A study sponsored by the American Automobile Association (AAA) found that incidents of collisions were somewhat lower for older adults (over 65) compared to other age groups. However, the number of fatalities was significantly higher compared to other age groups. None of the studies we found take into account a “walking-miles” based exposure rate.

Gender – The AAA study found that boys, ages 2-9, are twice as likely to be struck than girls in the same age category. The study found no statistical correlation between gender and pedestrian collisions for all other age categories. Data gathered by the National Highway Transportation Safety Administration (NHTSA) found that for all age categories, males accounted for approximately two-thirds of pedestrian related fatalities.

Time of Day – One study found that pedestrian incidents of pedestrian collisions were highest between the hours of 3 PM and 6 PM on a Friday or Saturday. The NHTSA study found similar results, except that fatalities were greatest on weekends between 8 PM and midnight.

Vehicle Movements – 15 to 20 percent of all motor vehicle fatalities include a pedestrian. One study found that through movement conflicts account for highest percentage of accidents (approximately 50 %), followed by left turn (approx 25%) followed by right turn conflicts. On freeways, 15% of the pedestrian accidents occur due to the driver driving off traveled way or out of control, 9% due to deceleration, 3% due to changing lanes and speeding and 1% during backing up. (3)

Area Type – According to the NHTSA the majority of pedestrian fatalities (71 %) occurred in urban areas. In another study that gathered data from across the United States, researchers found that the region of the country also influenced the number of pedestrian crashes. For example, the western region of the United States had a higher incidence of pedestrian crashes than other areas of the country.

Other Factors – According to the NHTSA, the majority of pedestrian fatalities occur at non-intersection locations, under normal weather conditions and at night. High pedestrian volume, high traffic volumes, the number of lanes and the presence and type of median were all significant variables that influence pedestrian collisions. One study found that approximately 2 percent of pedestrian collisions in urban areas are related to bus stops. In rural areas, this percentage increases slightly to 3 percent. This study also found that speeds tend to be higher in suburban areas due to distance between the stops and the traffic volume. (4) Physical features, including signs, traffic signals and pavement markings, and their impact on pedestrian collisions are discussed under the section entitled "Pedestrian Safety Measures".

Evaluation Criteria

Transportation professionals have a vast array of acceptable and measurable methods to evaluate locations identified as "problematic". For example, vehicle collision rates can provide meaningful insight to specific intersection deficiencies such as inadequate sight distance and lack of advance signing. Excessive vehicle queue lengths may be indicative of poor signal timing. Traffic volume counts can be analyzed using mathematical models to determine average vehicle delay or average speed.

A number of accepted strategies and measures for vehicular operations have been developed and are an integral part in determining measures of effectiveness. For the transportation industry, The Highway Capacity Manual (HCM) is the standard for determining operational measures of effectiveness or "Level of Service". Level of Service (LOS) is based on an alphanumeric scale ranging from A to F, with "A" representing optimal operations and "F" representing breakdown conditions. Level of Service (LOS) measures vary with roadway operation type. For example, average vehicle delay is used to measure traffic signal LOS; vehicle density is used to measure freeway operations.

Previous versions of the HCM largely focus on highway operations. However, the current HCM adds modules to evaluate LOS for pedestrian crossing movements. Still, the total number of pedestrian injuries and fatalities over some period of time, typically per year, were found to be the most common evaluation criteria for determining the effectiveness of treatments. We found no "exposure-based" rates related to pedestrian collisions. Hence, no firm conclusions can be made regarding the decline in pedestrian collisions that may be associated with a decline in pedestrian activity. However, a number of studies have been conducted which have both expected and surprising results.

Pedestrian Safety Devices

Design, location and installation of both vehicular and pedestrian traffic control devices on public roadways are largely dictated by the USDOT *Manual on Uniform Traffic Control Devices* (MUTCD). The MUTCD outlines specific requirements for the type and size of roadside traffic signs, pavement markings, and traffic signal design. A brief description of devices prescribed by the MUTCD along with other innovative measures and their results are discussed.

Regulatory Signs

The MUTCD states, "...regulatory signs shall be used to inform road users of selected traffic laws or regulations and indicate the applicability of the legal requirements." In short, motorists and pedestrians are required to comply with the messages conveyed by these signs and violators are subject to fines and increased insurance premiums.

Regulatory signs have distinct characteristics prescribed by the MUTCD. Typically, regulatory signs are square or rectangular shaped and typically consist of a white background with black lettering or symbols. Stop and Yield signs have red backgrounds with white letters and symbols and are further defined by their unique shape. Regulatory signs are also retroreflective, enhancing their visibility under nighttime and other low-ambient light conditions. The MUTCD also has strict guidelines as to the placement and application of regulatory signs. Design and installation requirements are based on several factors including visibility and the need for road users to react.

Regulatory signs control both vehicular and pedestrian movements. Some examples of pedestrian related regulatory signs and their corresponding MUTCD designation include the following:

- Cross Only at Crosswalks (R9-2)
- Pedestrians Prohibited (R9-3a)
- Use Crosswalk (R9-3b)
- Pedestrian Crosswalk (R9-8)
- Pedestrian Traffic Signal Signs (R10-1)

Specific sizes, shapes, color schemes and application are contained in the MUTCD.

Although the requirements have been established for a variety of applications, there is some latitude in terms of the actual layout and installation. For instance, in an attempt to improve pedestrian safety, three types of devices that have been used in conjunction with marked crosswalks were evaluated: an overhead crosswalk sign in Seattle, Washington; pedestrian safety cones (which read, "State Law: Yield to Pedestrians in Crosswalk in Your Half of Road") in New York State and in Portland, Oregon; and pedestrian-activated overhead signs (which read, "Stop for Pedestrians in Crosswalk") in Tucson, Arizona. The signs were used under varying traffic and roadway conditions.

The effects of these three treatments on pedestrian and motorist behavior were evaluated. The variables of interest were whether pedestrians had the benefit of motorists yielding to them; whether pedestrians had to run, hesitate, or abort their crossing; and whether pedestrians crossed in the crosswalk. The New York cones and Seattle signs were effective in increasing the numbers of pedestrians who had the benefit of motorists yielding to them. At one location in Tucson, the overhead sign increased motorist yielding to pedestrians. The signs in Seattle and Tucson were effective in reducing the number of persons who had to run, hesitate, or abort their crossing. None of the treatments had a clear effect on whether people crossed in the crosswalk. By themselves, these devices cannot ensure that motorists will slow down and yield to pedestrians. It is essential to use these and other devices along with education and enforcement, but creation of friendlier pedestrian environments (e.g., by means of implementing geometric improvements) for the purpose of reducing vehicle speeds may be more important. [5]

Warning Signs

Warning signs are principally intended to advise motorists. Similar to regulatory signs, specific size, color scheme and layout is prescribed by the MUTCD. In their application as pedestrian safety measures, Warning Signs are intended to advise motorists of potential pedestrian activity. The MUTCD also encourages conservative use of signs. Overuse of signs reduces their effectiveness and often fails to serve the purpose of modifying driver behavior. Unnecessary signs also provide obstruction to pedestrians and bicyclists. [6]

One section of the MUTCD is dedicated specifically for school areas. Signs for the safety and mobility of pedestrians that are especially applicable for safety and access to bus stops on State highways include *Advance Pedestrian* (W11-2) and *Pedestrian Crossing* (W11-2A) signs. Advance pedestrian crossing signs are used to warn motorists of possible pedestrian conflicts. These signs are placed at locations where pedestrians may not be expected to cross or at locations where volume of pedestrians crossing the street is high. The MUTCD recommends a minimum size of 30”x 30” for such signs. Pedestrian crossing signs are located immediately adjacent to the crossing point. This sign is similar to the Advance Pedestrian Crossing Sign except for the presence of two parallel lines that are intended to represent the crosswalk. The advance warning sign must precede Pedestrian Crossing signs.

Pavement Markings
Pavement markings are intended to provide additional guidance and information to motorists and pedestrians and serve both regulatory and warning functions. Again, the MUTCD provides specific design criteria, including width, length and color, and application for pavement markings. Longitudinal pavement markings, installed in the direction of traffic flow, include continuous and intermittent lines for lane designation. Transverse applications (perpendicular to traffic flow) include crosswalks and stop lines. Pavement markings can also alert drivers through non-visual means. For example, "rumble strips", a series of relatively thick lines installed perpendicular to traffic flow, can simulate traversing an irregular pavement surface, providing both audible and tactile responses for motorists.

Statutory crosswalks exist at all intersections and pedestrians are permitted to cross from corner to corner parallel to traffic flow, whether crosswalk lines exist or not. Under certain circumstances, "midblock" crossings, crosswalks located between intersections, may be established. Midblock crossings must be legally established and must have appropriate signs and pavement markings installed in accordance with the MUTCD.

Several studies have been undertaken to evaluate the effectiveness of crosswalks, both at intersections and midblock locations. All of the studies reviewed use a comparative total number of pedestrian collisions with and without certain devices. Intuitively, one may expect installation of crosswalks to be associated with fewer pedestrian collisions. However, several studies have revealed somewhat contradictory safety results regarding the usage of marked-unmarked crosswalks. One study examined 400 intersection locations in San Diego, California and found the number of accidents were HIGHER at marked crosswalks than unmarked crosswalks. Another study reached similar conclusions at unsignalized intersections, where a higher accident frequency was found for locations with marked crosswalks versus no crosswalks.

However, in a study sponsored by the Federal Highway Administration (FHWA), it was found that drivers tend to reduce their speed as they approach a pedestrian in a crosswalk. This study also found that that more pedestrians use the crosswalk after the markings have been installed. No changes were observed in driver yielding or pedestrian assertiveness, as well. Overall, the study concluded that marking pedestrian crosswalks at relatively low-speed, low-volume, unsignalized intersections was a desirable practice. (2)

Other studies were conducted to examine the effects of traffic volume, speed and the presence of medians. The following summarizes the results of these studies:

- The number of pedestrian collisions INCREASED at marked versus unmarked location on multilane highways with traffic volumes exceeding an Average Annual Daily Traffic Volume (AADT) of 10,000.

- There is no significant difference in the number of pedestrian collisions at marked versus unmarked location for two lane roadways with an AADT less than 10,000.

- There is no significant difference in the number of pedestrian collisions at marked versus unmarked locations on multilane roads with an AADT less than 12,000.

- The number of pedestrian collisions is HIGHER at marked versus unmarked locations on multilane roads with an AADT GREATER THAN 12,000 AND with no raised median.

- The number of pedestrian collisions is HIGHER at marked versus unmarked locations on multilane roads with an AADT GREATER THAN 15,000 AND with a raised median.

- Researchers hypothesize that marked crosswalks provide pedestrians with a greater level of comfort and hence pedestrians may be willing to take greater risks crossing at a marked location. This also leads researchers to conclude that marked crosswalks alone may not be adequate in alerting motorists or affecting their response to pedestrians entering the roadway to cross. Although a similar FHWA study had differing results, the conclusions were similar.

A summary of research recommendations applicable to application of crosswalks is provided below:

- Marked crosswalks alone are not recommended at multilane sites with an AADT greater than 12,000 (without raised median) or ADT greater than 15000 with raised median that serve as pedestrian refuge areas.

- Do not install crosswalks alone where travel speeds exceed 40 MPH.

- Two lane road with an AADT less than 12000 no positive or negative effect.

- Do not install crosswalks alone on three lane roads with an AADT greater than 12,000.

- Marked crosswalks should be installed in combination with other treatments like curb extensions, raised crossing islands, traffic signals, enhanced overhead lighting, traffic-calming measures, etc. [(4)]

- Marked crosswalks should be avoided on high-speed streets where no traffic signal exists. High-visibility crosswalks are suggested for locations where greater motorist information is considered beneficial and where pedestrians may not be expected to cross or where pedestrian-crossing volume is high. [(7)] Some cities in California have implemented intelligent road stud (IRS) technology on pedestrian crossings. The IRS system uses a standard power connection or alternative solar panel, microprocessor, battery and a set of in-road surface studs that are fitted with ultra-bright light emitting diodes (LEDs). The LEDs are activated by either traditional push buttons or by microwave- activated automated pedestrian detectors. [8]

- Crosswalks marked with raised buttons or reflectors are generally not recommended. Pedestrians may trip on the raised pavement markers. [7]

Traffic Signals

Traffic signals use dynamic and responsive light sequences to assign rights-of-way to both vehicular and pedestrian movements. Traffic signal design guidelines, application and warrants for installation are prescribed by the MUTCD and also like regulatory signs, traffic signals are enforceable measures for regulating the flow of traffic. While traffic signals are predominantly installed to address safety and operational issues associated with vehicular traffic, there are specific guidelines for accommodating pedestrians. Furthermore, traffic signals provide an opportunity to provide special pedestrian phasing sequences.

Although only a small percentage of new traffic signals in the United States have been installed principally to accommodate pedestrians, the MUTCD contains provisions for installation based on the number of pedestrian crossing movements. As per Warrant 3, a traffic signal may be warranted when the pedestrian volume crossing the major street at an intersection or midblock location during an average day is either

- 100 or more for each of any four hours, or
- 190 or more during any one hour.

These volume requirements can be reduced by as much as 50 percent when the predominant crossing speed is less than 3.5 feet per second. There should be less than 60 gaps per hour in the traffic stream of enough length for pedestrians to cross during the same period.

The current MUTCD includes several revisions to prior versions for pedestrian control. For example, The “WALK” and “DON’T WALK” word indications have been replaced by symbols. Walk indicates that pedestrians may enter the roadway to begin their crossing maneuver. MUTCD requires the walk interval to extend 4 to 7 seconds. The “FLASHING DON’T WALK” interval indicates that the crossing maneuver must be completed, and that no new crossing movements may be initiated. Steady “DON’T WALK” prohibits any crossing activity from occurring. For pedestrians, WALK, FLASHING DON’T WALK and steady DON’T WALK are somewhat analogous, respectively, to green, yellow and red indications for motorists.

Unfortunately, many pedestrians do not understand the meaning of the pedestrian signals and indication, especially the flashing DON’T WALK. [9] As part of the behavioral analysis of a variety of intersections in Washington D.C., San Francisco and Oakland, California, observations were made of observance of pedestrian signals at six intersections. Based on four intersections with pedestrian signals displaying a flashing “WALK” indication (550 pedestrians) and two intersections having steady “WALK” indications (139 pedestrians), no difference appears from this analysis between flashing and steady “WALK” signals in terms of pedestrian usage of the cycle. It was found that the vast majority of users pay little, if any, attention to the pedestrian signal. This study also demonstrated that symbolic walking pedestrian and upheld hand offers improved understanding over the “FLASHING WALK” and “DON’T WALK” signals. [(10)]

Modern traffic signals respond to vehicles through a number of innovative technologies, including loop detectors installed in the pavement and sensing devices installed on signal mast arms. In most cases, traffic signals detect pedestrians through manually activated devices or pedestrian push buttons, which are typically mounted traffic signal poles. In general, pedestrian push buttons are used where pedestrian activity is occasional and adequate opportunities do not exist for them to cross. It has been suggested that the use and effectiveness of push buttons could be greatly improved if some form of feedback were provided when the push-button is activated. For example, push buttons could be illuminated when the activation device is operational, thereby reassuring the pedestrians that the controller has received their signal call.

In most jurisdictions, motorists are allowed to turn right when faced with a red indication, but only after yielding to conflicting pedestrians and vehicles. The MUTCD permits the use of No Turn on Red signs at signalized intersections under a number of conditions, including the existence of pedestrian conflicts. However, the issue regarding the effectiveness of the use of No Turn on Red is highly controversial. A study by Zador indicates that the number of pedestrian collisions increases with the use of right-turn-on-red. On the other hand, studies by the American Association of State Highway and Transportation Officials and McGee do not agree with these results. A study by Zegeer also shows more pedestrian conflicts associated with right-turn-on-green than with right-turn-on-red.

Other Devices

In addition to conventional signs, pavement markings and traffic signals prescribed by the MUTCD, a number of other devices and measures have been implemented and investigated. A brief description and research evaluation summary is provided below.

Traffic Calming devices - Traffic Calming is defined as “the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users. Four basic types of traffic calming measures have been adopted by the Institute of Transportation Engineers (ITE) which include: *Vertical deflections, horizontal shifts*, and *reductions in roadway width* are intended to reduce speed and enhance the street environment for non-motorists; *Closures* (diagonal diverters, half closures, full closures, and median barriers) are intended to reduce cut-through traffic by obstructing traffic movements in one or more directions. Before and after evaluations have generally shown reductions in travel speed and the number of accidents.

Medians – Several types of median barriers exist including non-traversable "Jersey" barrier, curbed islands with a grass or other type of traversable median, and center areas delineated with pavement markings (i.e. two way center left turn lanes). A study for Federal Highway administration in 1993 has revealed the fact that streets with raised medians, in both CBD and suburban areas have lower pedestrian crash rates compared to streets with painted two-way left turn lane or undivided streets. [(11)] Pedestrian barriers are provided to prevent pedestrians from crossing streets at undesirable points and direct them to alternate crossings. Such barriers are installed at locations with high volumes of high-speed right turning vehicles as well as at high-speed midblock locations or high-volume arterial streets where crossing at midblock is much more dangerous than crossing at a nearby intersection. In general, lower accident rates were found to be associated with raised medians. Non-traversable barrier medians were found to be the principle reason pedestrians use intersections. However, it was found that in some cases, pedestrians walk along the median barrier to reach the intersection, creating a potentially hazardous condition. Painted medians including, two way center left turn lanes were found to provide no significant safety benefits. Barrier system, however, by itself poses an additional fixed-object hazard and may lead to motorist injury accidents and property damage. Also barrier system installation may require high capital investment and regular maintenance. Hence careful engineering analyses of need and cost-effectiveness are required before installing barrier systems. [(12)]

Lighting – Studies have found that illumination of pedestrian activity areas significantly reduced pedestrian related collisions.

Pedestrian overpass – Under conditions where it is not deemed feasible to accommodate pedestrians using at-grade solutions, some agencies have turned to construction of pedestrian overpasses and subways. Studies have been conducted to evaluate the use these measures. One study compared the time required to use pedestrian overpasses versus crossing the street. It was found that where the pedestrian travel times were equal, pedestrians favored use of the overpass. However, as the ratio of time to use the overpass versus time to use street increased slightly, the number of pedestrians using the overpass decreased significantly. Where the ratio of travel time to use the overpass over travel times associated with not using the overpass met or exceeded 1.5, NO pedestrians were observed to use pedestrian overpasses. The study also found that pedestrian subways are generally used less frequently than pedestrian overpasses.

Sidewalk – The presence of sidewalk was found to have a significant impact on pedestrian safety. Several studies have concluded that pedestrian collisions were highest where no sidewalks exist and the lowest where sidewalk exists on both sides of the roadway.

RESEARCH APPROACH

Site Selection

A research study team was assembled to provide input on the site selection and the overall direction of the project. The team consisted of the two Co-Principal Investigators from NJIT as well as the following representatives:

- Nancy Ciaruffoli, NJDOT Research
- Kevin Conover, NJDOT, Safety Programs
- Elise Bremer-Nei, NJDOT Office of Bicycle and Pedestrian Programs
- Paul Spiegel, NJ TRANSIT
- Jerome Lutin, NJ TRANSIT

Several meetings were held with the research team to discuss the overall project approach as well as develop an initial set of criteria for selecting “problematic” sites. Based on the results of the literature review, we found that the number of accidents over a given time period (typically annually) was the primary criteria for determining whether a crossing location is problematic.

Since there are a number of initiatives underway to improve pedestrian safety and mobility at signalized intersections, the study team first decided to narrow the number of potential locations by considering the type of crossing. We chose to focus the study on locations that are either between intersections (midblock) or coincident with unsignalized street intersections. We also decided to select study locations on multilane State highways along which bus stops are located. Since the study requires extensive user feedback, the locations needed to be heavily used.

In summary, the bus stop locations selected for the study would need to meet the following criteria:

1. Be located along multilane State highways.
2. Experience heavy bus transit rider use.
3. Be located at either midblock or unsignalized intersections.

In order to minimize the number of independent variables that could influence the study results, it was also necessary that the locations have similar characteristics in terms of traffic volume and environmental surroundings. Hence, we considered locations along a single corridor. While a number of corridors were initially considered for study, NJTransit team representatives indicated that many of the corridors that could potentially be considered had Jersey barrier installed in the median with bus stops designated at signalized intersections and would be inconsistent with criteria number 3 listed above. Choosing different corridors also posed experimental problems, as other study elements would be introduced in the evaluation of different pedestrian safety measures and treatments.

The US Route 9 Corridor is reportedly one of the most heavily used bus transit corridors in New Jersey. Several bus transit lines, including the NJTRANSIT 139 line provide express service between the many suburban communities along US Route 9 in Monmouth and Middlesex Counties and the Port Authority Bus Terminal in New York City. US Route 9 runs north-south. In Middlesex and Monmouth Counties, where bus transit service is heaviest, US Route 9 consists of two lanes and a shoulder in each direction divided by a grass median (See figure 1). The roadway is posted at 50 MPH along much of its length. Access is limited to right turn in and right turn out with left turn access provided at signalized jughandle locations.

The US Route 9 Corridor has been the focus of several bus transit studies. The Monmouth County Planning Board conducted an extensive inventory of pedestrian and transit facilities as well as roadway features. Parsons Brinckerhoff Inc. conducted a separate investigation of pedestrian access along selected sections of US Route 9. Due to the Corridor's heavy use as a key bus transit corridor and focus of other non-related transit studies, the team selected US Route 9 in Monmouth and Middlesex Counties as the study corridor for this project.

Figure 1. US Route 9. Two lanes with shoulder in each direction divided by grass median.

Once US Route 9 was selected as the corridor from which the study sites were to be selected, the research team conducted preliminary field investigations. Initial investigations were undertaken to identify potential study sites. The first screening involved a "drive-by" assessment to determine whether the location actually fit our study site selection criteria. Four initial locations were identified (See figure 2):

- Sandburg Drive.
- Texas Road.
- Strickland Road.
- CR 516.

Additional field investigations were conducted to determine pedestrian use of each bus stop location (See figure 3). We also studied each location for unique or unconventional crossing behavior. Locations where safety enhancements are already being proposed and/or implemented were eliminated from consideration. Based on the results of our field investigations, Strickland Road and Texas Road were selected as the final study locations.

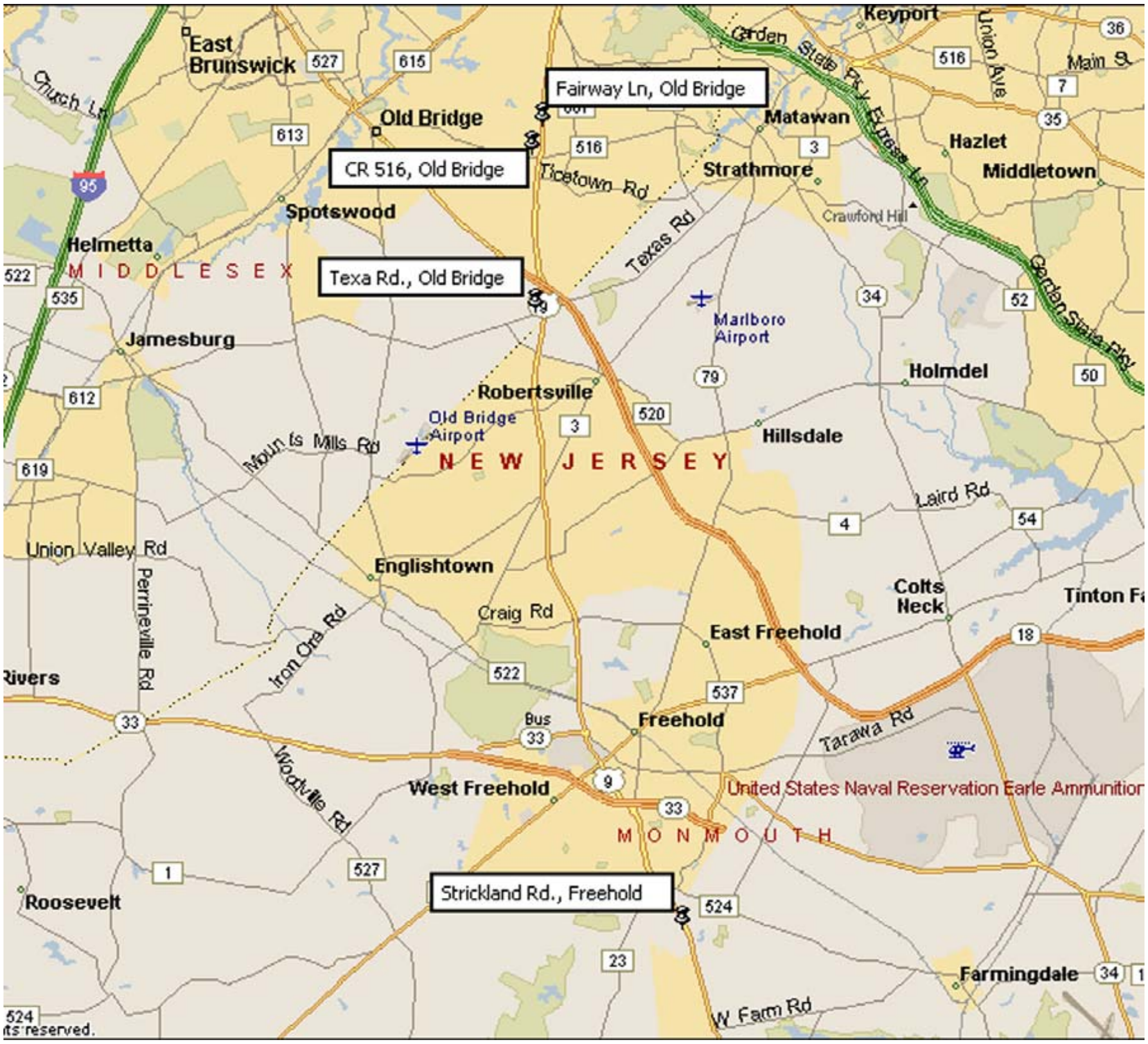


Figure 2. Map of study corridor.

Photographs were taken at each of the selected study sites. For Texas Road and Strickland Road, video recordings were also taken to document pedestrian crossing behavior both under favorable weather and roadway conditions and under snowy conditions. Videos were taken on the day nearly 8 inches of snow had fallen at the study locations. While the travel portion of the roadway was cleared of snow at the time the videos were taken, we noted that some of the pedestrian walkways were obstructed. It was under these conditions that we recorded images of pedestrian crossing behavior.

Sandburg Drive

Texas Road

Strickland Road

CR 516

Figure 3. Potential study locations.

As a follow-up to our field investigations, we also reviewed pedestrian related collisions that occurred along US Route 9 in Monmouth and Middlesex Counties over the past three-year period. The Collision Diagram and Accident Summary are contained in appendix A. We found that a number of serious pedestrian related accidents occurred at the intersection at Fairway Lane in Old Bridge Township (See figure 4). Hence this location was added to our list of study sites only for conducting driver evaluation for measures to enhance pedestrian safety and mobility. Due to the observed lack of use and probable survey participation, the team decided not to administer the survey/questionnaire at Fairway Lane. However, an evaluation from the driver's perspective was conducted for this location.

Figure 4. Intersection at Fairway Lane in Old Bridge.

Descriptions of each study location and observations of pedestrian crossing behaviors under clear and inclement weather conditions are discussed in the Findings section of the report.

Onsite Survey

A survey was prepared and administered at each study location in order to gain a better understanding of the conditions from the users as well as to identify potential strategies for enhancing pedestrian safety. The survey was administered on site and approximately one-half of the respondents were able to complete the survey while waiting for the bus. Transit riders were given the option of completing the survey and then mailing it back to NJIT.

Driver's Perspective Laboratory Study

A laboratory experiment was conducted for investigating driver's perspective on their judgment about risk (probability) level of unexpected pedestrians crossing the highway and traffic control devices that they think can help to increase alertness about the potential hazards.

The laboratory experiment used a XGA computer projector to display video clips to the subject. Quick Time Movie Player® 5.0 was used to deliver the video clips. The resolution of the video was 720 lines by 480 lines. Fifteen video clips were produced from digital video recording on the road. A SONY PD-100A digital camcorder was used to record the driver's view on US Route 9 in both directions within the study area. Adobe Premiere® 5.1 software was used to process the original videotape. MPEG video compression was applied to reduce the file size in order to be played on the computer displays. Subjects used a mouse to control the video display. A Pentium 4 personal computer was used to display the video and to record subjects' responses.

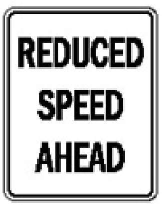
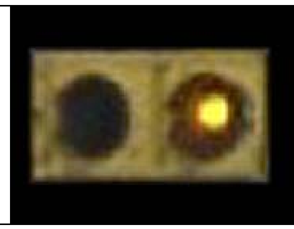
		
Crosswalk marks	Fence	Pedestrian crossing sign
		
Reduced speed ahead sign	Flashing yellow lights	Traffic lights

Figure 5. Pictures of traffic control devices for subjects' selection

Twelve subjects were recruited from NJIT campus to participate in the experiment. There were 8 males and 4 females, ranging from 23 to 60 years of age, with a mean age of 35.2 years (standard deviation = 13.5 years old). All subjects possessed a valid New Jersey driver's license. Their driving experience was between 3 and 43 years with a mean of 13.9 years (SD = 15.2 years). Out of twelve subjects, only one had ever experienced a reportable car crash.

Subjects were given written experiment instructions and a consent form prior to the experiment. The written experiment instructions described the objective and procedure of the task to be performed by the subject. Subjects first filled out a subject demographic data sheet, followed by reviewing response selections displayed on the screen. An experimenter was present to answer subjects' questions. Subjects were instructed to start playing the first video clip by clicking a play button using a mouse. A five-point scale (1: very low, 2: low, 3: moderate, 4: high, 5: very high) was used to record subjects' perception about potential hazards of unexpected pedestrians crossing the section of the highway shown in the video. Subjects were allowed to replay the video clip if necessary. After they checked the risk level of the highway section, subjects were asked to replay the video and concentrate on traffic control devices that they thought would increase their alertness about the potential hazards. Six control devices were displayed for selection, namely *crosswalk marks on the road*, *6-foot fence*, *pedestrian crossing* sign, *reduced speed ahead* sign, *yellow flashing lights*, standard *traffic light*. Pictures of the above traffic control devices were displayed for subjects to consider their choices of effective warnings (see figure 5).

FINDINGS

The research results include a summary of our field observations, which are discussed below for each study location as well as the observations from onsite survey and laboratory drivers' perspective laboratory study. The survey results are discussed for both locations collectively.

Field Observations

<u>Texas Road</u>

Bus stops are located within close proximity of the Texas Road and US Route 9 intersection (see figures 6 and 7). On the northbound side of US Route 9, an existing shopping center parking area serves as a park and ride lot. A bus shelter is provided approximately 500 feet south of Texas Road and a bus pull off is provided on the northbound US Route 9 shoulder. For the southbound direction, the bus pulls off the traveled way onto the existing shoulder approximately 200 feet south of Texas Road. No shelter is provided for this direction. The northbound direction experiences the heaviest use during the morning hours.

Figure 6. Texas Road location

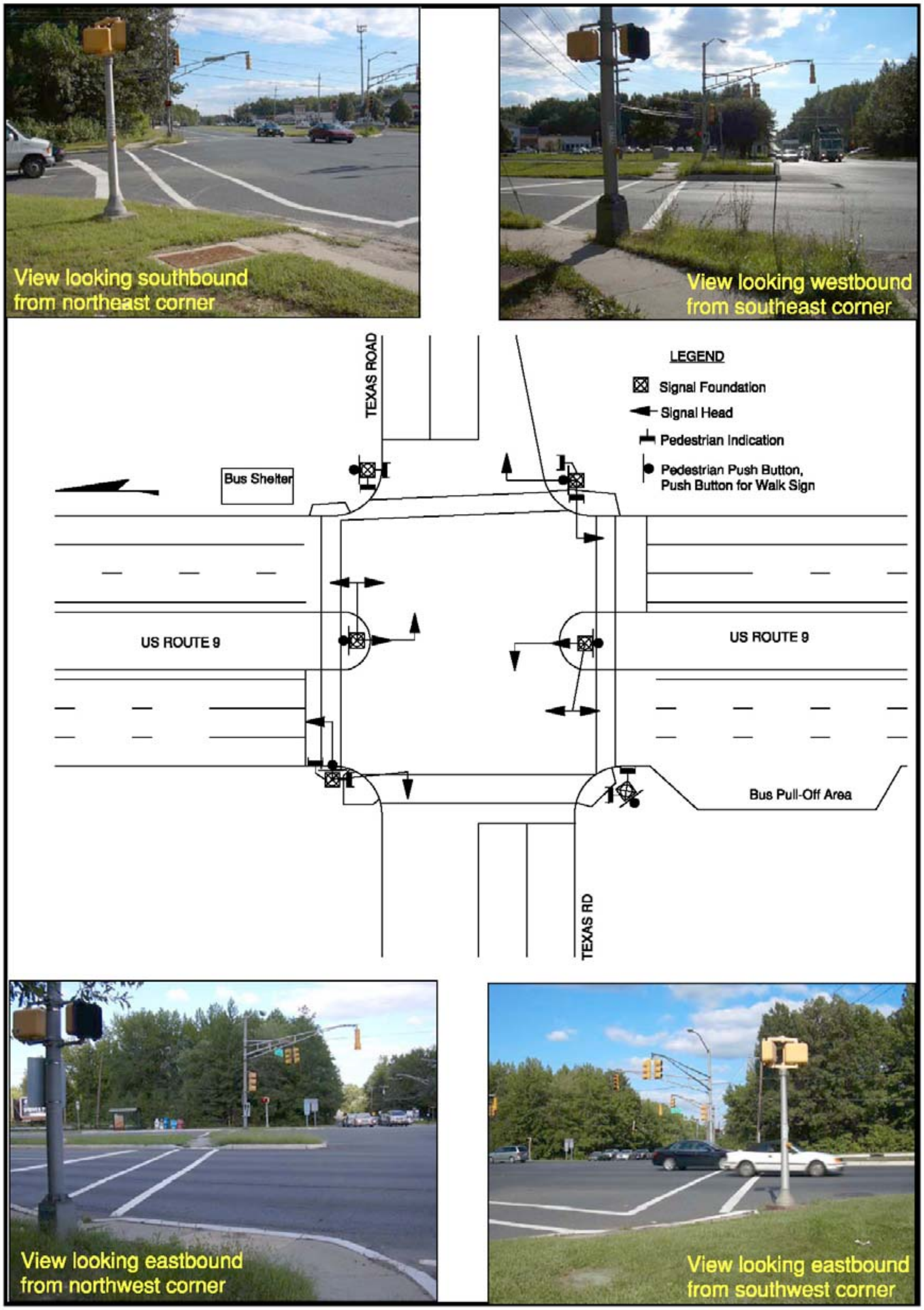


Figure 7. Intersection of Texas Road and US Route 9

During our field observations, no pedestrians were observed to be crossing US Route 9 during this time period to access the bus stop. Some pedestrians crossed US Route 9 to purchase goods at the shopping center located on the opposite side of US Route 9; however, the predominant number of bus transit users did not cross US Route 9 to access the bus stop. In the evening, this pattern is reversed. Most bus transit users were discharged at the southbound location and then crossed US Route 9 to access the park and ride lot on the northbound side. It was during this time, the evening peak commuter hours, that pedestrian activity related to bus stop access was greatest. Observed pedestrian paths and behaviors are depicted in figure 8 and are noted below:

- The majority of bus transit users, after being discharged, would walk in front of the bus and after waiting for a gap in traffic would cross the southbound direction of US Route 9. They would then either wait in the median or walk in the median towards the park and ride lot and wait for a gap in traffic to cross the northbound direction of US Route 9. Several pedestrians were observed walking between cars, and in several instances, approaching vehicles were required to brake to allow pedestrians to cross the highway.

- Very few pedestrians were observed crossing US Route 9 at the Texas Road traffic signal. Of these pedestrians, none were observed pushing the pedestrian call button or properly following the pedestrian signal indications.

- Under inclement weather conditions, pedestrians crossed in a similar manner as indicated above. However, pedestrians were observed walking both in the left and right side shoulders most likely to avoid walking in the deep accumulated snow in the median and along side of the roadway.

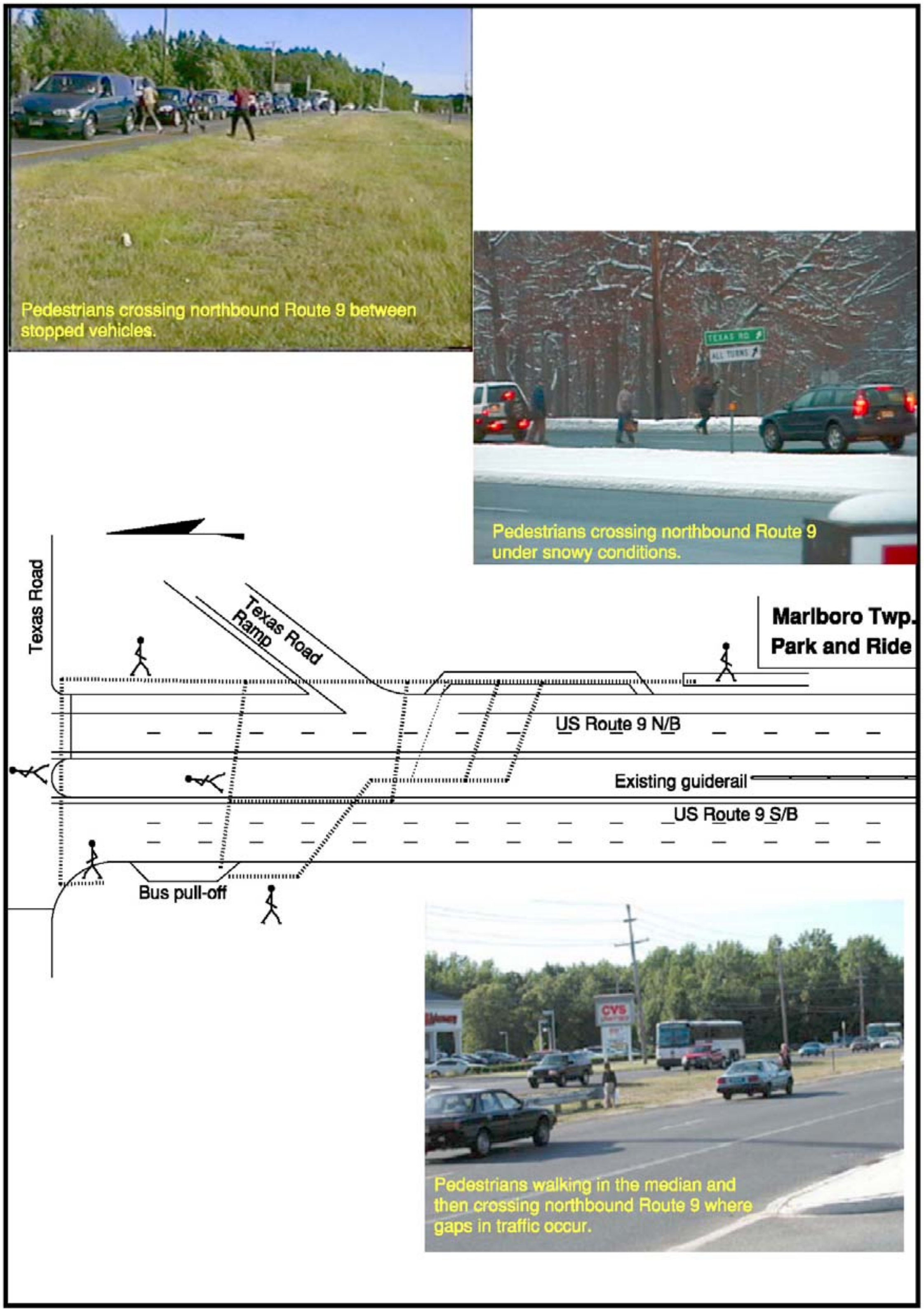


Figure 8. Observed Pedestrian Behaviors at US Route 9 and Texas Road

Strickland Road

The Strickland Road location has a large park and ride facility with several bus shelters and a large bus pull off area which can accommodate several attending buses at once. These facilities are located on the northbound US Route 9 side. A single bus shelter is provided in the southbound US Route 9 direction and the existing shoulder provides the bus pull off area. (See figures 9 and 10)

Bus commuter travel patterns are very similar to the Texas Road location: flow is predominant in the northbound direction during the morning commuter hours and then reverses, becoming heaviest in the southbound direction during evening commuter hours. As such, US Route 9 at this location experiences a large number of pedestrian crossing movements during the evening commuter hours.

Figure 9. Strickland Road Location

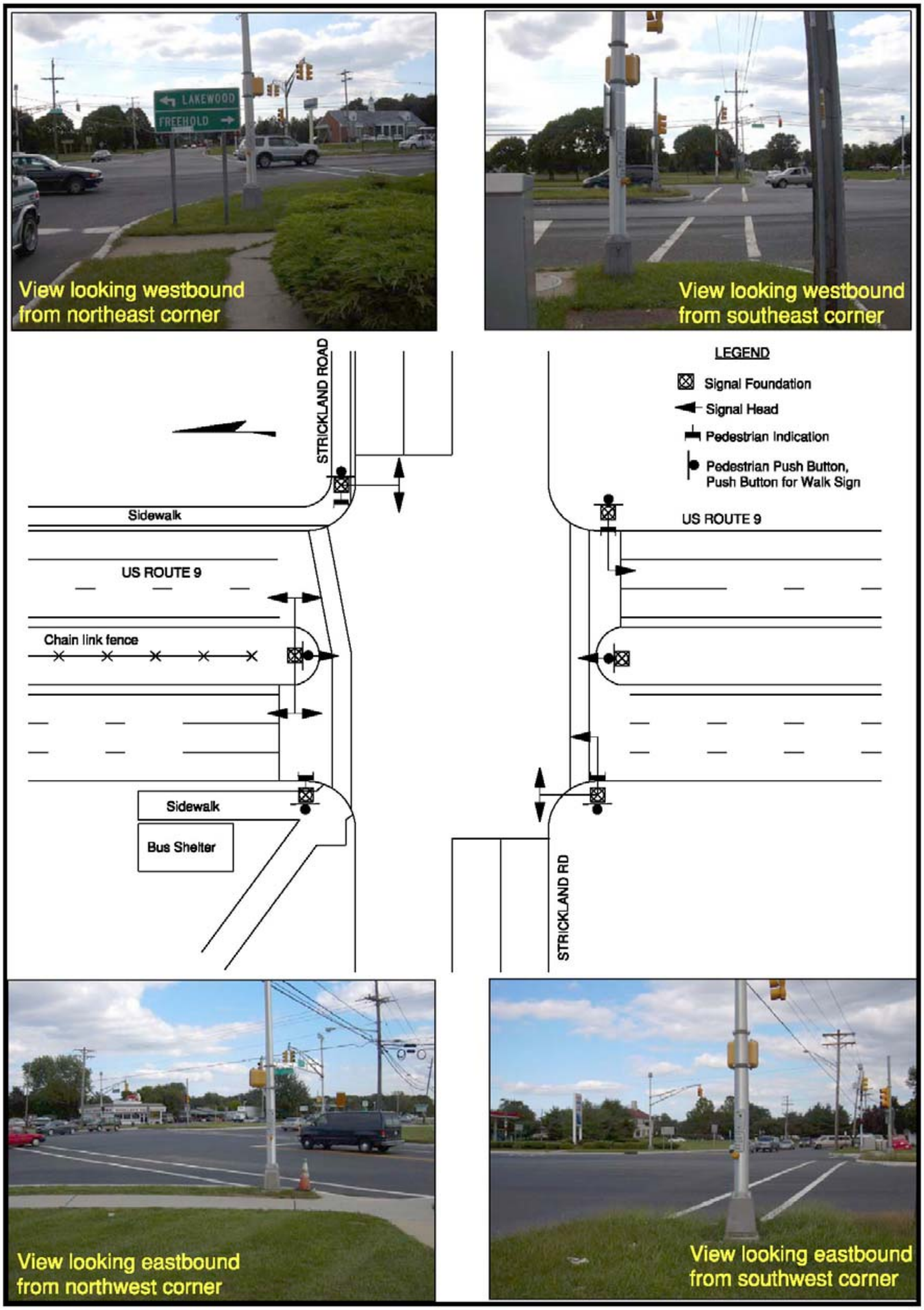


Figure 10. Intersection of US Route 9 and Strickland Road

However, there are several features that distinguish Strickland Road from the Texas Road location. Unlike Texas Road, the southbound bus stop is located much closer to the Strickland Road traffic signal, approximately 50 feet, and a high chain link fence is installed in the median (See figure 11). While these conditions would seemingly induce pedestrians to cross at the traffic signal, the majority of pedestrians crossed US Route 9 at locations not coincident with the traffic signal. Of the few pedestrians crossing US Route 9 near the intersection, none completed their crossing maneuvers within the crosswalk, nor did they activate the pedestrian push buttons. Moreover, they did not use the “WALK” and “DO NOT WALK” indications to guide their crossing maneuvers. In fact, many pedestrians crossing US Route 9 were observed walking along the fence in the median and then using gaps in traffic flow to cross US Route 9.

Crossing behaviors under inclement weather conditions were similar to those at the Texas Road location. Pedestrians would cross the median near the intersection where the snow was packed down and then would wait for a gap in traffic flow and make their crossing maneuver. Another similarity observed was that, most pedestrians walked along the shoulder to access the park and ride lot.

A summary of observed pedestrian crossing behaviors at this location is depicted in Figure 11.

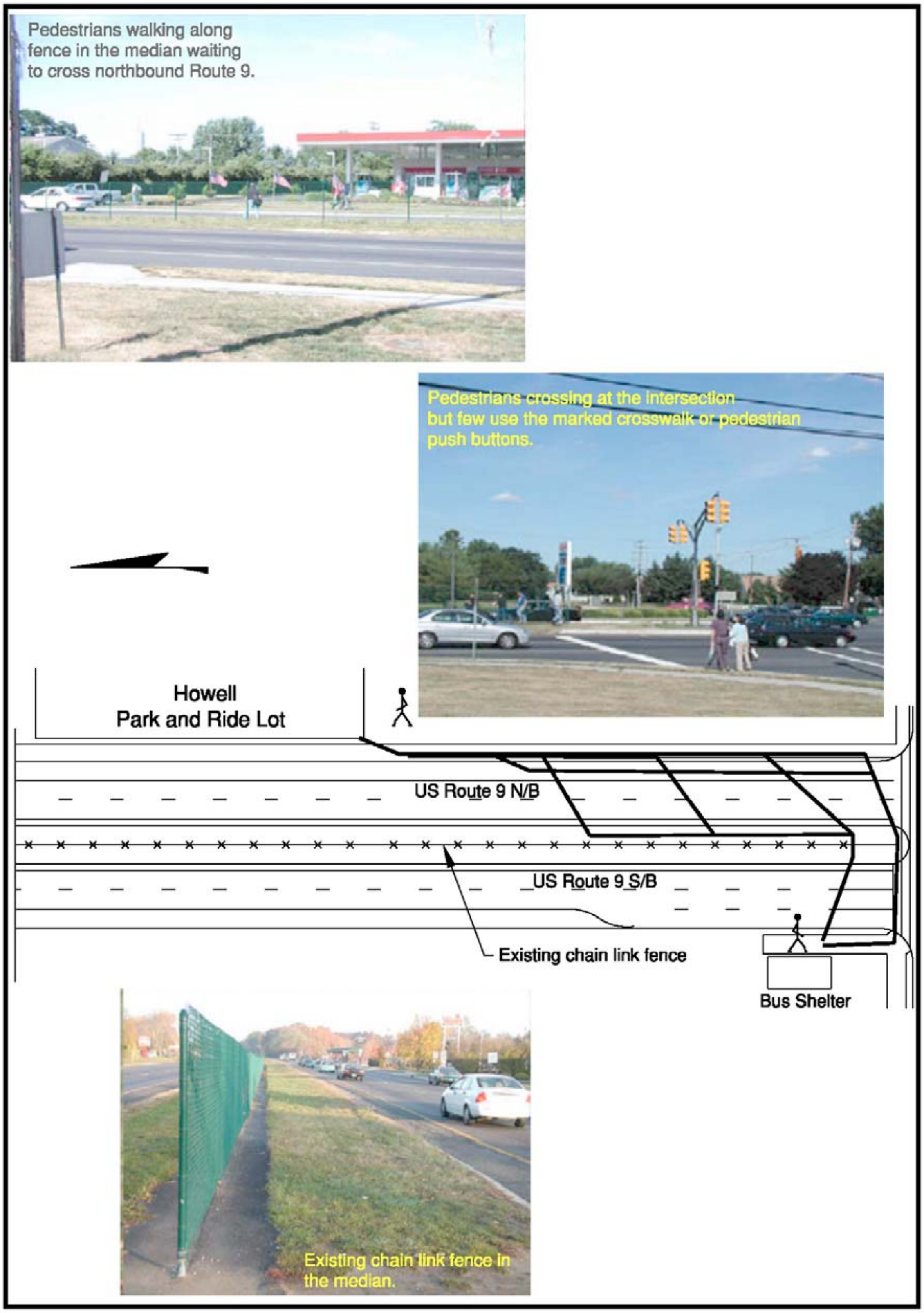


Figure 11. Observed Pedestrian Behaviors at US Route 9 and Strickland Road

On-Site Survey

Of the surveys given out for mail back, we received an approximate 95 percent response rate. Administering the survey on site also provided a valuable opportunity to speak with the transit users and gain feedback from them. A copy of the survey is provided in appendix B.

Of the total 75 surveys completed, 31 were from the Strickland Road location and 42 were from the Texas Road location. Two of the respondents did not indicate from which location they boarded the bus. Surveys were administered at the two study locations during the peak morning commuter period hours. Survey questionnaires were handed out at the Texas Road location between 6 AM and 8 AM on Thursday, April 3. Surveys at Strickland Road were handed out between 6 AM and 8 AM on Friday, April 4.

The survey consisted of two major parts. The first part requested information about the subject, such as age, gender, how long he/she has been traveling by bus, frequency and purpose of travel and by which means they get to the bus stop. The second part consisted of three basic sections of questions. The first section consisted of eight questions and was intended to gain an understanding of the general behavior and user perspective. The second section consisted of six questions providing an opportunity for respondents to indicate what measures they believe would improve safety for crossing US Route 9. The final section consisted of five questions asking respondents what additional measures would encourage them to cross US Route 9 at the nearby Texas Road traffic signal. Each question consisted of a statement to which respondents were given a choice to agree, disagree or be neutral. The survey also provided an opportunity for survey participants to provide written comments.

Table 1 shows summary of the summary results. An overview of the survey results is provided below:

Age: In order to avoid neglecting the effects of age on the style of crossing, attitude and safety knowledge, subjects were grouped into the following five age categories: 17 or less, 18 to 30, 31 to 50, 51 to 65 and above 65. Of the 75 respondents of the survey, seven people were between 18 to 30 years of age, fifty-four were aged between 31 to 50, twelve in the 51 to 65 range and one person above 65. None of the respondents were 17 years of age or less. One respondent did not indicate the age.

Gender: There were twenty-five females and fifty men who participated in the survey.

Experience: Respondents were asked how long they have been using the bus. Four subjects have been using the bus since less than six months; 9 subjects have been using the bus six months to one year; 19 subjects have been using the bus one to three years; and 42 have been using the bus for over three years. One person did not provide any information regarding this.

Frequency of Travel: The frequency of travel of the passengers was divided into three; less frequent users who use the bus less than one day per week, another group of people who take the bus 1 to 4 days per week and the more frequent users who commute 5 or more days per week by bus. All of the respondents fell into two frequency categories: 61 use the bus five or more days a week and 14 use the bus 1 to 4 days a week.

Purpose of trip: Respondents were asked to identify the purpose of their trip. The vast majority, seventy, use the bus for commuting purposes. Three responded in the “other” category, and two respondents did not indicate trip purpose.

Means of getting to the bus stop: Respondents were asked to indicate how they get to the bus stop location. The majority, sixty-eight, drive to the parking lot and walk. Five respondents indicated that they are dropped off and one person walks from home. One person did not provide a response to this question.

Some of the participants were unable to respond to all of the questions in the second and third parts of the survey. For these sections, we set a benchmark of answering 18 of the 20 questions. Consequently, the analysis considered the responses of 60 out of 75 respondents. However, all of the written comments were considered.

Table 1. Summary of survey results.

NO.	QUESTION	AGREE Number (%)	NEUTRAL Number (%)	DISAGREE Number (%)	TOTAL Number (%)
First Section					
1	Concerned about crossing Route 9	45(75%)	5(8%)	10(17%)	60 (100%)
2	Cross at traffic signal rather than between signals	42(70%)	7(12%)	11(18%)	60 (100%)
3	Concerned about being ticketed - crossing at traffic signal	19(32%)	25(41%)	16(27%)	60 (100%)
4	Cross Route 9 at the traffic signal if the bus stops there	45(75%)	7(12%)	8(13%)	60 (100%)
5	Understand the working of pedestrian push button	42(70%)	8(13%)	10(17%)	60 (100%)
6	Hesitating to cross Route 9 at traffic signal - turning vehicles conflicting path	40(67%)	8(13%)	12(20%)	60 (100%)
7	Not crossing at traffic signal – takes too much time	29(48%)	17(29%)	14(23%)	60 (100%)
8	Use gaps in traffic - not pedestrian/signal indications	27(45%)	22(37%)	11(18%)	60 (100%)
Second Section *The following would help the pedestrians to cross Route 9*					
9a	Warning signs indicating presence of pedestrians	43(72%)	10(16%)	7(12%)	60 (100%)
9b	Presence of police officer	23(38%)	19(32%)	18(30%)	60 (100%)
9c	Fence in median – forces to cross at traffic signal	26(43%)	18(30%)	16(27%)	60 (100%)
9d	More visible crosswalks at traffic signal	43(73%)	5(8%)	11(19%)	59 (100%)
9e	Dropped off closer to traffic signal	39(65%)	9(15%)	12(20%)	60 (100%)
9f	Dropped off in the median	21(37%)	21(37%)	15(26%)	57 (100%)
Third Section *The pedestrian would prefer to cross at the traffic signal if the following are present*					
10a	Pedestrian push buttons & Signal heads	35(58%)	5(9%)	20(33%)	60 (100%)
10b	Pedestrian push buttons in the median	30(50%)	9(15%)	21(35%)	60 (100%)
10c	Push buttons that activate flashing warning lights for oncoming traffic	42(71%)	7(12%)	10(17%)	59 (100%)
10d	High visible crosswalk stripping	42(70%)	3(5%)	15(25%)	60 (100%)
10e	Separate signal phase-all vehicle traffic stop for pedestrians	49(82%)	6(10%)	5(8%)	60 (100%)
10f	Crosswalks more in line with where the subject actually crosses at intersection	49(82%)	2(3%)	9(15%)	60 (100%)

Driver's Perspective Laboratory Study

The twelve subjects reported their judgment of the highway sections shown on 15 video clips. Risk levels among the 12 subjects on the 15 video scenarios was between 1.9 and 3.5. There is a strong correlation between the perceived risk level and the number of traffic control devices suggested. The Pearson correlation coefficient was 0.73 ($p<.01$) between the two. Comparing the content of the video clips and subjects' risk assessment scores, subjects give higher risk scores to intersections and where there appeared to be stores and bus stops, as compared to where there is less congestion or no easy access to the road by pedestrians.

Among the six traffic control devices, three of them were consistently chosen among subjects, namely the crosswalk marks, the traffic light, and the pedestrian crossing sign. The other three devices were only chosen at a much lower frequency among subjects. An interesting finding was observed from the three top choices from subjects to alert the potential hazards. Crosswalk marks and traffic lights were present in six out of 15 video clips but no pedestrian crossing sign was seen in the 15 clips. The equivalent frequency of subjects chose the pedestrian crossing sign compared to the crosswalk marks and traffic lights. This suggests that the presence of pedestrian crossing signs will increase driver alertness in areas where pedestrians may cross at any section of the highway. The results of the laboratory experiment are shown in table 2. Subjects reported their perceived risk level (1: lowest, 5: highest) on each of the 15 video clips, as well as perceived usefulness of cues for pedestrian crossing at roadways.

Table 2. Results of Laboratory Experiment

Video Clip	Avg. Risk Value	Perceived usefulness of cues for pedestrian crossing at roadways (% of total subjects)					
		Crosswalk Marks	Fence	Ped-xing Warning Sign	Reduced Speed Sign	Flashing Yellow Lights	Traffic Lights
1	2.8	50	17	33	25	0	58
2	2.9	75	0	58	8	8	58
3	2.6	17	67	42	25	17	17
4	3.4	75	8	67	17	0	75
5	1.9	17	25	8	17	17	0
6	2.5	33	17	33	17	8	42
7	3.0	42	17	33	25	0	42
8	2.4	75	0	25	8	0	83
9	2.8	8	17	33	33	25	25
10	2.9	25	17	25	33	8	33
11	3.5	50	0	83	17	25	42
12	2.4	25	8	42	17	8	33
13	1.9	25	25	25	8	8	25
14	2.9	50	0	42	17	17	58
15	2.8	75	0	75	17	0	83
Mean	**2.7**	**43**	**14**	**42**	**19**	**9**	**45**
Std. dev.	***0.5***	***24***	***17***	***21***	***8***	***9***	***24***

CONCLUSIONS

There were a number of interesting findings based on the results of our field investigations and survey. It is also apparent that users are very concerned with their ability to safely cross US Route 9. Paradoxically, a limited number of safety measures have been implemented at both locations, yet none of the measures appear to have achieved their intended use. For example, a high chain link fence is installed in the median at the Strickland Road location in an attempt to discourage crossing movements directly across from the established bus shelter location approximately 500 feet north of the traffic signal at Strickland Road and US Route 9. However, the vast majority of pedestrians were observed walking along the fence in the median and then crossing Route 9 when a gap in traffic flow exists. At the Texas Road location, very few pedestrians were observed crossing at the traffic signal.

A large percentage of survey respondents indicated that additional measures would encourage use of the traffic signal for crossing US Route 9. These measures included separate pedestrian phasing and crosswalks located more in line with the current walking path. However, an exclusive pedestrian phase may have serious impacts to traffic operations on US Route 9 and relocation of crosswalk to better align with the actual walking path would require reconstruction of signal indications and may substantially increase vehicle clearance intervals and hence impair traffic operations on US Route 9.

While respondents indicate that enhanced pedestrian push buttons would encourage use of traffic signals for crossing US Route 9, our field observations revealed that none of the pedestrians activated the existing push buttons at each location. Furthermore, those crossing US Route 9 at Strickland Road, for example, paid no heed to the "WALK"-"DON'T WALK" indications.

As indicated in the survey, the majority of transit users drive to the bus stop location. Therefore, the proximity of the bus pick up and drop off area are critical in determining pedestrian crossing behavior. For both locations, however, pedestrians are required to go out of their way in order to walk from the bus drop off to the parking area. Furthermore, once at the traffic signal, pedestrians must contend with vehicles turning at the intersection, as indicated by 67 percent of the respondents. It is not surprising, therefore, that crossing movements are not made at the traffic signal and when they are, are made improperly.

Survey respondents also provided a number of written comments. Several commented that there is a lack of adequate illumination at the bus stops at night. Also, several indicated concerns regarding the absence of sidewalks at the Texas Road location.

The laboratory study indicated that there was a higher risk of pedestrians crossing at intersections and where there appeared to be stores and bus stops, compared to where there is no easy access to road for pedestrians and where there is less traffic congestion. From the experiment, it can also be concluded that subjects preferred the presence of marked crosswalks, traffic lights and pedestrian crossing signs in areas where there was a potential of unexpected pedestrian crossing at any section of the highway.

These conclusions have provided the basis for several recommendations concerning pedestrian accessibility and safety at bus stop locations. However, a proper compromise has to be reached which will enhance pedestrian safety without creating excessive congestion and vehicle delays

RECOMMENDATIONS

The recommendations have been categorized into both short term and long term measures, and include recommended actions to be undertaken by both the New Jersey Department of Transportation and New Jersey Transit Corporation. The short-term measures consist primarily of improvements that would encourage crossing movements to be made at the signalized intersections closest to the bus stop locations. And while the recommendations are based on our investigations at the two specific study locations, they could be applied at a number of crossing locations throughout the State. It should be noted that the conditions on US Route 9 in Monmouth and Middlesex Counties are somewhat unique that bus stops are frequently located between signalized intersection locations. Throughout the remainder of the State highway system, bus stops have been located adjacent to signalized intersections. Furthermore, most of the highway segments which may have met our study requirements have Jersey barrier medians instead of a wide grassy median that exists along US Route 9 in Monmouth and Middlesex Counties.

If we are to encourage pedestrians to cross at signalized locations, it is imperative that measures be implemented that would improve pedestrian safety and accessibility at these intersections. While the traffic signals appear to be operating properly and are designed in accordance with mandated standards, very few pedestrians appear to actually be using the traffic signals in the manner in which they are intended. This may be a result of several conditions that are brought out in our survey:

- Conflicts with vehicle turning movements
- Lack of sidewalks and other pedestrian accommodations
- Circuitous route in getting to park and ride lot destination
- Circuitous route to reach the pedestrian push button
- Lack of knowledge as to how the pedestrian push button works
- Difficulty in locating and accessing pedestrian push buttons

At the Texas Road location, a non-traversable fence has been installed in the median. While this may discourage transit users from crossing southbound US Route 9 at improper locations, it certainly does not discourage improper crossing movements on the northbound US Route 9 side. In actuality, the bus drop off point appears to be more of a critical determinant in pedestrian crossing locations. It is questionable then, whether installing fence in the median is an effective measure.

Recommended long-term measures are programmatic and policy focused. Since these recommendations seek to encourage use of traffic signals for completing crossing maneuvers, it is imperative that the traffic signals and pedestrian accommodations be implemented first and given high priority. Recommended long-term measures will be discussed in further detail later in this section.

Short Term Recommendations:

The following short-term recommendations have been developed through the results of our survey, investigations and literature review.

- ***Improve pedestrian accommodations such as sidewalks, more accessible push buttons and enhanced crosswalks at Texas Road and US Route 9***. Many of the respondents indicated concerns over the lack of sidewalks linking the crossing at the intersection of Texas Road with the park and ride lot facility on the northbound side of US Route 9. Furthermore, transit users indicated a concern regarding the near-side jughandle ramp on the northbound side.
- ***Install Advance Pedestrian Crossing signs on US Route 9***. Both the laboratory experiment and on-site survey indicated that Advance Pedestrian Crossing signs would be effective in making drivers aware of pedestrian crossing movements. Although such an application is not in accordance with the MUTCD, the majority of respondents indicated that some form of advance pedestrian signage would improve their safety.
- ***Provide user feedback devices on pedestrian activated signals.*** Transit users reported that they were not certain a pedestrian call was activated after they pushed the pedestrian push button. Some type of device installed in conjunction with the existing pedestrian push button would help users verify that the push button were in fact operational.
- ***Consider modifications to signal timing to minimize vehicle-pedestrian conflicts at traffic signals***. NJDOT should consider installation of exclusive pedestrian phases or signal phasing that minimizes turning vehicle movement conflicts. Changes to the signal operation would need to balance with the overall operation of US Route 9. However, as pedestrians are legitimate users of the highway system, full consideration cannot be given only to the movement of vehicles. In addition, NJDOT should consider installation of signs telling drivers that when they are turning they are required to yield to pedestrians.
- ***Further investigate enhanced illumination***. Several of the survey respondents who use the Route 9 and Texas Road bus stop indicated that lighting is inadequate. The matter should be investigated further to determine the adequacy of lighting at this location.

Long Term Recommendations:

The following recommendations should only be considered upon implementation of the short-term recommendations listed above. Long-term recommendations include the following:

- ***Education of transit users.*** It is recommended that efforts to develop an advertising and education campaign to encourage comprehensive program be initiated through a comprehensive advertising campaign. "Cross at the green and not in between" could possibly be a slogan. These initiatives could be led by

NJTransit and could begin with installation of poster inside the buses. Pedestrians should also be instructed that they could be ticketed for crossing at unauthorized midblock locations.

- ***Educate drivers***. Current driver education programs should be enhanced and new programs initiated to highlight pedestrian safety. Such programs could include emphasis on Yield to Pedestrian regulations, driver responsibility and liability as well as education on hazardous pedestrian behaviors.
- ***Consider relocation of bus stops***. While NJ TRANSIT undertakes a number of efforts including coordination with local and State officials in establishing bus stop locations and park and ride lots, a greater emphasis should be placed on encouraging greater use of traffic signals to make the crossing maneuvers. For example, the existing bus stop location at Texas Road drops off passengers south of the Texas Road traffic signal. Relocating the bus stop north of the intersection would encourage use of the traffic signal, as it would be more in line with the walking path. Similarly, the bus drop off location at Strickland Road discourages pedestrians from using the traffic signal. As noted in our literature review, extending the route length pedestrians must travel strongly discourages them from crossing at a designated location, even if the location has no conflicts with traffic, such as an overpass or underpass.

Implementation of the above recommendations will require a high level of coordination with State, county and local officials. Furthermore, local municipalities should encourage and support maintenance of existing sidewalk and construction of new sidewalks along paths that promote use of traffic signals.

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APPENDIX A

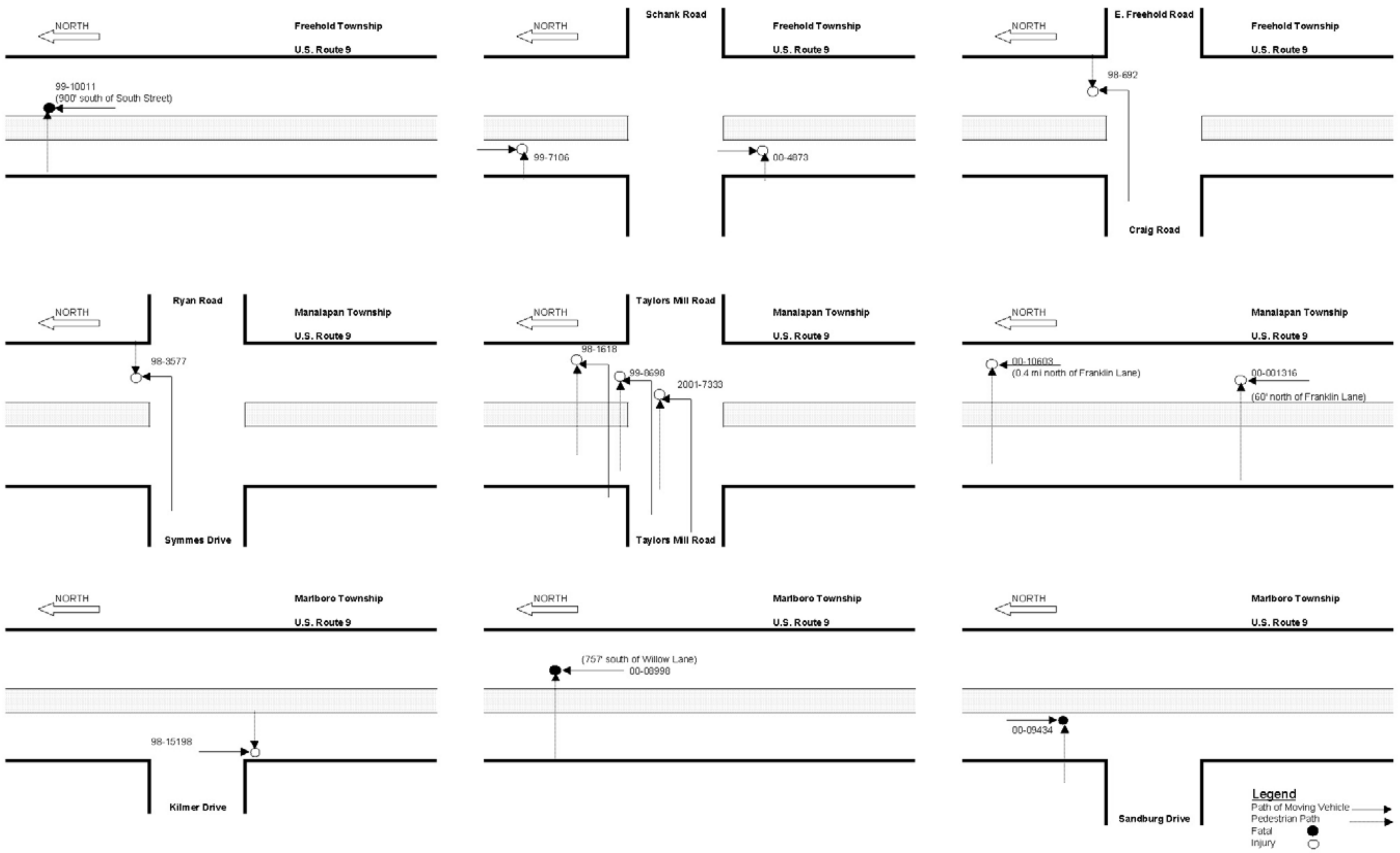
Accident Summary and Collision Diagram

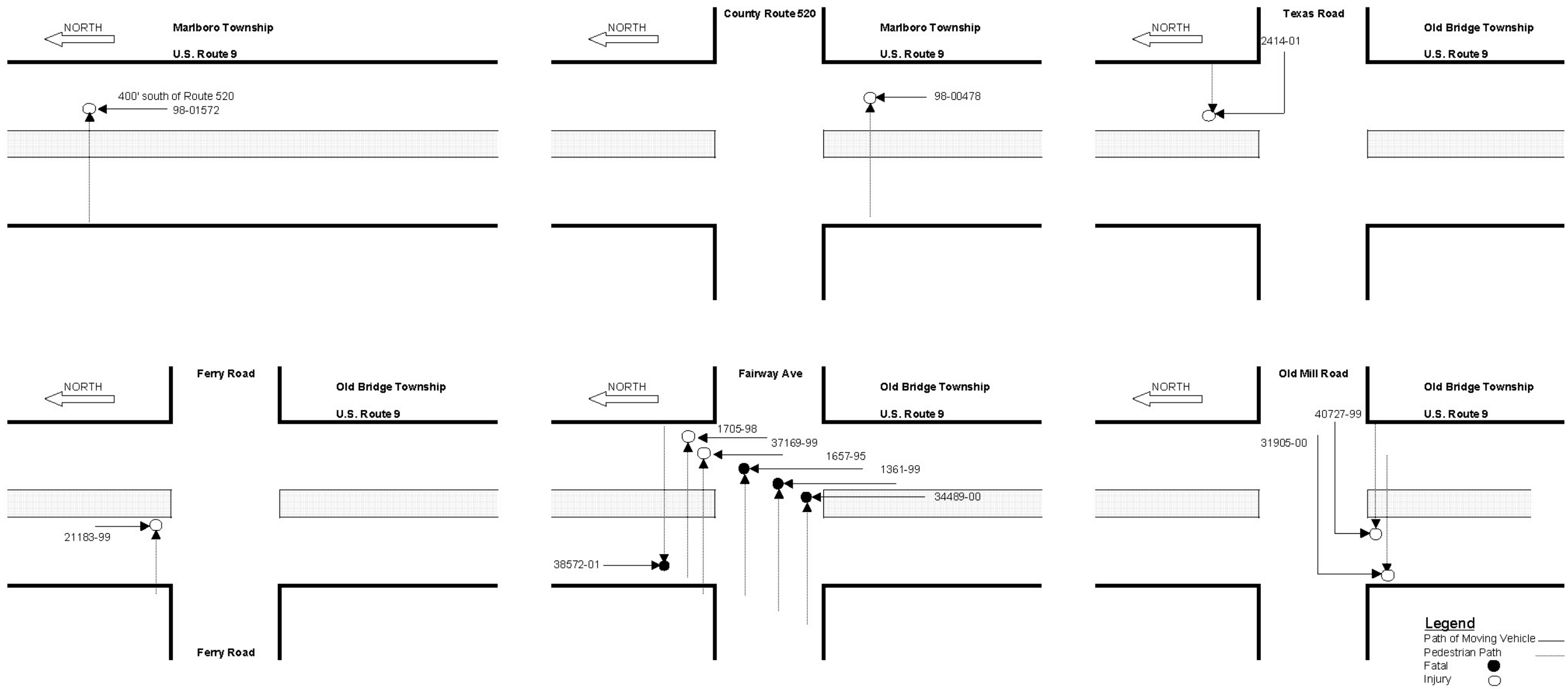
Project 2001-22 Pedestrian Safety and Mobility Aids for Bus Stops

Route U.S 9 Pedestrian Accident Summary

ID	Case No.	Date		Day	Time	Night/Day	Weather/Road Conditions	Bus (Stop) Involved?	Straight/ Right Turn/ Left Turn	Intersection	Severity	Case Description	Listed Causes
1	00 09434	6/18/2000	Int of Rt 9 (S side of intersection) & Sanburg Dr.	Sun	23:11	N	Rainy/Wet	Yes	S	Yes	FATAL	43 yr f driver hit 49 yr f ped (xing Rt 9). Raining, Dark, Ped wore dark clothes. Fatal	visibility at dark/weather, ped unsafe behavior
2	1657-95	1/19/1995	Int of Rt 9 (N side of intersection) & Fairway Lane	Thur	10:52	D	Rainy/Wet	Yes	S	Yes	FATAL	21 yr f driver hit 40 yr f ped (xing Rt 9 at n of Fairway Ln from w to e) at the int. when Rt. 9 light was green. Ped wore dark clothes. Fatal	visibility at dark, ped unsafe behavior
3	1705-98	6/1/1998	Int of Rt 9 (N side of intersection) & Fairway Lane	Mon	22:49	N	Clear/Dry	?	S	Yes	INJURY	22 yr m driver hit 45 yr m ped (xing Rt 9 at n of Fairway Ln from e to w) at the int. when Rt. 9 light was green. Injury	visibility at dark, ped unsafe behavior
4	1361-99	3/3/1999	Int of Rt 9 (N side of intersection) & Fairway Lane	Wed	20:18	N	Clear/Dry	?	S	Yes	FATAL	21 yr m driver hit 36 yr m ped (xing Rt 9 at n of Fairway Ln from e to w) at the int. at the int. when Rt. 9 light was green. Fatal	visibility at dark, ped unsafe behavior
5	37169-99	11/10/1999	Int of Rt 9 (N side of intersection) & Fairway Lane	Wed	21:39	N	Clear/Dry	?	S	Yes	INJURY	22 yr m driver hit 47 yr m ped (xing Rt 9 at n of Fairway Ln from w to e) at the int. when Rt. 9 light was green. Injury	visibility at dark, ped unsafe behavior
6	34489-00	10/18/2000	Int of Rt 9 (N side of intersection) & Fairway Lane	Wed	0:43	N	Rainy/Wet	?	S	Yes	FATAL	35 yr m ped hit by car 1 (46 yr m driver) (xing Rt 9 at n of Fairway Ln) at the int. when Rt. 9 light was green. four more cars hit ped. Fatal	visibility at dark, ped unsafe behavior
7	38572-01	10/21/2001	Rt 9 150 ft S of Fairway Lane	Sun	2:40	N	Clear/Dry	?	S	No	FATAL	Hit and run driver hit m ped (xing Rt 9 at ? bound Fairway Ln) at the int. when Rt. 9 light was green. Fatal	visibility at dark, ped unsafe behavior
8	98-1618	2/5/1998	Int of Rt 9 & Taylor Mills Rd (car turning left onto Rt 9 N)	Thur	11:05	D	Rainy/Wet	Yes	LT	Yes	INJURY	30 yr m driver hit 55 m ped when the car turning left onto Rt 9 N	veh #1 agressive left turn then tried to avoid veh #2 straight, reaction time
9	99-8698c	7/2/1999	Int of Rt 9 (N side of intersection) & Taylor Mills Rd (car turning left onto Rt 9 N)	Fri	16:43	D	Clear/Dry	?	LT	Yes	INJURY	44 yr f driver hit 31 yr f ped when the car turning left onto Rt 9 N	Ped unsafe behavior, reaction time
10	2001-7333	6/4/2001	Int of Rt 9 (N side of intersection) & Taylor Mills Rd (car turning left onto Rt 9 N)	Mon	15:58	D	Clear/Dry	?	LT	Yes	INJURY	46 yr f driver hit 33 yr m ped when the car turning left onto Rt 9 N	veh #1 agressive left turn, reaction time
11	2414-01	1/23/2001	Int of Rt 9 & Texas Rd	Tues	6:12	N	Clear/Dry	Yes (go to bus stop	RT	Yes	INJURY	39 yr m driver hit 55 yr f ped (walking on Rt N) when the car turing right onto Rt 9 N	Snow forced ped walking on the highway, driver did not see ped
12	00-08998	6/11/2000	Rt 9 757 ft S ofWillow Ln	Sun	16:15	D	Clear/Dry	?	S	No	FATAL	53 yr m driver hit 57 m ped. Fatal	
13	40727-99	12/13/1999	Int of Rt 9 & Old Mill Rd	Mon	18:51	N	Rainy/Wet	Yes	LT	Yes	INJURY	50 yr m driver hit 51 yr m ped (xing Rt 9) when the car turning left onto Rt 9 S. Injury	visibility at dark?
14	31905-00	9/27/2000	Int of Rt 9 & Old Mill Rd	Wed	17:04	D	Clear/Dry	Yes	LT	Yes	INJURY	74 yr f driver hit 46 m ped (xing Rt 9 at s of Old Mill Rd from w to e) at the int. (center ln) when the car turning left onto Rt 9 S. Injury	visibility due to excessive sun glare
15	98-01572	2/7/1998	Rt 9 392 ft S of Rt 520	Sat	3:43	N	Clear/Dry	?	S	No	INJURY	33 yr m driver hit 21 yr m ped. Fatal	?
16	98-00478	1/12/1998	Int of Rt 9 & Rt 520	Mon	20:20	N	Clear/Dry	Yes	S	Yes	INJURY	Hit and run driver hit 38 yr f ped (xing Rt 9 at s of Rt 520) at the int when the car going straight on Rt 9 N. Injury	veh #1 suddenly moved from outer to inner lane, reaction time
17	17006-00	5/24/2000	Int of Rt 9 & H?rtles Ln	Wed	15:21	D	Clear/Dry	?	S	Yes	INJURY	Appears that a worker was struck placing construction equipment. This was not plotted.	?
18	98-15198	11/3/1998	Int of Rt 9 & Kilmer Dr	Tues	12:48	D	Clear/Dry	?	RT	Yes	INJURY	85 yr m driver hit 11 yr m ped (xing Rt 9) at the int when the car was turning right on to Union Hill Rd. Ped had roller skates on. Injury	ped unsafe behavior, reaction time
19	43-98	1/14/1998	Int of Rt 9 & East Freehold Rd	Wed	20:13	N	Clear/Dry	Yes	LT	Yes	INJURY	20 yr m driver hit 52 yr f ped (xing Rt 9 from w to e) at the int when the car turning left onto Rt 9 N from Craig Rd on green light. Ped wore dark clothes. Injury	no clear right of way for ped, visibility hampered due to tinted windows, reaction time
20	21183-99	6/28/1999	Int of Rt 9 & Ferry Rd	Mon	22:02	N	Clear/Dry	?	S	Yes	INJURY	61 yr f driver hit 19 yr m ped (xing Rt 9 from w to e) at the int in left lane.	ped unsafe behavior, vehicle driver tried to pass at yellow light
21	00-10603	8/1/2000	Rt 9 0.4 mile N of Franklin Ln	Tues	21:13	N	Clear/Dry	?	S	No	INJURY	46 yr m driver hit 31 yr m ped. Injury	?
22	99-00131c	1/4/1999	Rt 9 600 ft N of Franklin Ln	Mon	0:21	N	Clear/Dry	?	S	No	INJURY	20 yr m driver hit 40 yr f ped (xing Rt 9). Injury	ped unsafe behavior?
23	98-3577	3/9/1998	Int of Rt 9 & Ryan Rd	Thur	19:41	N	Rainy/Wet	?	LT	Yes	INJURY	53 yr f driver hit 45 yr f ped (xing Rt 9) at the int when the car was turning left on to Rt 9 N. Ped wore dark clothes. Injury	visibility at dark, ped unsafe behavior
24	00-4873	9/6/2000	Rt 9 100 ft S of Schanck rd	Wed	13:30	D	Clear/Dry	Yes (go to bus stop	S	No	INJURY	42 yr m driver hit 37 yr m ped. Injury	careless driving, tried to change lane when realized that his lane ended but could not do so on time due to traffice on other lane, ped walked on the road?
25	99-7106	5/20/1999	Rt 9 0.5 miles N of Schanck Rd	Thur	22:06	N	Clear/Dry	Yes	S	No	INJURY	62 yr m driver hit 24 yr m ped (xing Rt 9 from w to e), ped wore dark clothes, area of collison poorly lit. Injury	ped unsafe behavior, not crossing in crosswalk or intersection
26	99-10001	7/11/1999	Int of Rt 9 & South St (Rt 79)	Sun	22:16	N	Clear/Dry	?	S	No	FATAL	29 yr m driver hit 35 yr m ped (xing Rt 9 from w to e), when car going at 50 mph. Fatal	ped unsafe behavior, not crossing in crosswalk or intersection

Project 2001-22
Pedestrain Safety and Mobility Aids for Bus Stops




NORTH
Marlboro Township
U.S. Route 9
400' south of Route 520
98-01572
NORTH
County Route 520
Marlboro Township
U.S. Route 9
98-00478
NORTH
Texas Road
Old Bridge Township
U.S. Route 9
2414-01
NORTH
Ferry Road
Old Bridge Township
U.S. Route 9
21183-99
Ferry Road
NORTH
Fairway Ave
Old Bridge Township
U.S. Route 9
1705-98
37169-99
1657-95
1361-99
34489-00
38572-01
NORTH
Old Mill Road
Old Bridge Township
U.S. Route 9
40727-99
31905-00
Legend
Path of Moving Vehicle
Pedestrian Path
Fatal
Injury

APPENDIX B

Survey

NJDOT Research Project 2001-22 Pedestrian Safety and Mobility Aids for Access to Bus Stops

Survey Location:____

PART I. CUSTOMER INFORMATION (Please check the corresponding box.)

1. Age:	☐ 17 or less	☐ 18-30	☐ 31-50	☐ 51-65	☐ over 65
2. Gender:	☐ Male	☐ Female			
3. I've been using the bus:	☐ less than 6 months	☐ 6 months to 1 year	☐ 1 -3 years	☐ over 3 years	
4. I ride the bus:	☐ less than 1 day per week	☐ 1 to 4 days per week	☐ 5 or more days per week		
5. Generally, my trip purpose is for:	☐ work	☐ shopping	☐ meeting/ appointment	☐ other	
6. Generally, I get to the bus stop by:	☐ Driving to the lot and then walking	☐ Walking from home	☐ Being dropped off		

PART II. EXPERIENCE AND OPINIONS: (Please check the corresponding box)

	Agree	**Neutral**	**Disagree**
1. I am concerned and/or feel anxious about crossing Route 9 under current conditions.	☐	☐	☐
2. I prefer to cross at the traffic signal rather than between signals.	☐	☐	☐
3. I am concerned that I will be ticketed for not crossing at the traffic signal.	☐	☐	☐
4. I would cross Route 9 at the traffic signal if that were where the bus let me off.	☐	☐	☐
5. I understand how pedestrian push buttons work and cross only when they indicate I should walk.	☐	☐	☐
6. I hesitate to cross Route 9 at the traffic signal because turning vehicles conflict with my path	☐	☐	☐

7. I do not cross at the traffic signal because it takes too much time.	☐	☐	☐
8. I prefer to use gaps in traffic rather than pedestrian/signal indications to cross Route 9	☐	☐	☐

9. The following would help me cross Route 9:	**Agree**	**Neutral**	**Disagree**
(a) Warning signs on Route 9 indicating the presence of pedestrians.	☐	☐	☐
(b) Having police officer or crossing guard assistance.	☐	☐	☐
(c) Fence or other physical barrier in the median forcing me to cross at the traffic signal.	☐	☐	☐
(d) More visible crosswalks at the traffic signal.	☐	☐	☐
(e) Being dropped off closer to the traffic signal.	☐	☐	☐
(f) Being dropped off in the median.	☐	☐	☐

10. I would choose to cross at the traffic signal if the following were in place:	**Agree**	**Neutral**	**Disagree**
(a) Pedestrian push buttons and signal heads with walk/don’t walk indications.	☐	☐	☐
(b) Pedestrian push buttons in the median.	☐	☐	☐
(c) Pedestrian push buttons that activate flashing warning signs for oncoming traffic.	☐	☐	☐
(d) High visible crosswalk striping.	☐	☐	☐
(e) A separate signal phase, where all vehicle traffic must stop for pedestrians.	☐	☐	☐
(f) Crosswalks that are more in line with where I actually cross at the intersection.	☐	☐	☐

Other Comments: ____

____

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