Human Factors Assessment of Pedestrian Roadway Crossing Behavior

PUBLICATION NO. FHWA-HRT-13-098

JANUARY 2014

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

FOREWORD

More than half of pedestrian fatalities occur at unmarked locations away from intersections. However, little research has been conducted to understand why pedestrians cross roadways at unmarked locations. As a result, this study sought to better understand the environmental influences on both where and when pedestrians elect to cross the road. This report examines more than 70,000 pedestrian crossings at 20 different locations. The circumstances of those crossings (pedestrians yielding to vehicles, vehicles yielding to pedestrians, and evasive actions) were documented and analyzed. A model using environmental factors as inputs is provided to predict where (marked crosswalk intersection or outside the marked crosswalk) pedestrians will cross the road.

This report may be of interest to roadway designers, traffic engineers, and researchers who are concerned with the safety of pedestrian crossings at unmarked locations.

Monique Evans
Director, Office of Safety
Research and Development

TECHNICAL DOCUMENTATION PAGE

<table>
<tr><td>1. Report No.
FHWA-HRT-13-098</td><td>2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Human Factors Assessment of Pedestrian Roadway Crossing Behavior</td><td colspan="2">5. Report Date
January 2014</td></tr>
<tr><td colspan="2">6. Performing Organization Code:</td></tr>
<tr><td colspan="2">7. Author(s)
Stacy A. Balk, Mary Anne Bertola, Jim Shurbutt, and Ann Do</td><td colspan="2">8. Performing Organization Report No.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
SAIC
6300 Georgetown Pike
McLean, VA 22101-2296</td><td colspan="2">10. Work Unit No.
TRAIS</td></tr>
<tr><td colspan="2">11. Contract or Grant No.</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
Federal Highway Administration
1200 New Jersey Ave. S.E.
Washington, DC 20590-9898</td><td colspan="2">13. Type of Report and Period Covered</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="4">15. Supplementary Notes
The Contracting Officer's Representative (COR) was C.Y. David Yang.</td></tr>
<tr><td colspan="4">16. Abstract
Pedestrian–vehicle crashes are both common and deadly. The majority of pedestrian fatalities occur outside marked intersection crosswalks. The influences of pedestrian and environmental factors on crossing location choice were examined. A literature review covering factors intrinsic to pedestrians is provided. In addition, pedestrian crossings at 20 different locations were recorded and analyzed. The vast majority of crossings (89 percent of the total observed) took place in the marked intersection crosswalks. Drivers are likely to yield to pedestrians. However, while drivers are more likely to yield to pedestrians in the marked crosswalk, pedestrians and vehicles are equally as likely to yield to one another outside the marked crosswalk. The data also suggest that measures that reduce the perceived affordances to cross the roadway (e.g., flowerbeds that separate the sidewalk from the roadway) also reduce the proportion of crossings outside the marked crosswalks. It also appears that pedestrians cross when perceived control of the crossing is greatest. Measures to increase perceived control have the potential to increase (e.g., visible countdown clocks) or decrease (e.g., large medians) crossings in the marked crosswalk. A model to predict pedestrian crossing location is provided. The model uses various environmental variables as predicting factors and was shown to successfully predict an average of 90 percent of the crossings.</td></tr>
<tr><td colspan="2">17. Key Words
Pedestrian, crosswalk, midblock crossings, safety, human factors assessment</td><td colspan="2">18. Distribution Statement
No restrictions. This document is available to the public through NTIS: National Technical Information Service 5301 Shawnee Road, Alexandria, VA 22312</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. of Pages
218</td><td>22. Price</td></tr>
</table>

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Pedestrian–vehicle crashes are both common and deadly. In 2010, 13 percent of all fatal crashes involved pedestrians.(1) Of these, 68.1 percent occurred outside intersections. As a result of the large proportion of pedestrian fatalities that occur at non-intersection locations, it is important to investigate the causal factors of these collisions. Despite the large proportion of crashes, little research has investigated the reasons pedestrians cross roadways at unmarked locations.

As a result, the present study sought to better understand the environmental influences on both where and when pedestrians elect to cross the road. The circumstances surrounding when and where more than 70,000 crossings took place were recorded and analyzed. A model to predict crossing behaviors was created. These data have the potential to guide roadway design. Furthermore, this approach may aid in the selection and location of pedestrian crossing interventions (e.g., new pedestrian activation crossing beacons), ultimately increasing pedestrian safety in shared use environments.

Pedestrian roadway crossings were coded at 20 different locations in the Washington, DC, metropolitan area. Each location was one block in length and was flanked by two marked crosswalks at intersections. Crossings were recorded within one marked, light-controlled crosswalk and the roadway between it and the next marked crossing (but not within the far crossing). Pedestrian crossings were coded for several different factors:

A. Location. Within the marked crosswalk, or not.

B. Traffic status. Walk or don’t walk sign illuminated.

C. Yielding. Pedestrians yielding to vehicles or vehicles yielding to pedestrians in the roadway.

D. Evasive Actions. Any evasive movement made by a vehicle or pedestrian to avoid collision (e.g., running or abrupt braking).

Stable components of each location were also recorded:

1. Distance between the marked crosswalks.

2. Average annual daily traffic volume (AADT).

3. Street directionality (one- or two-way).

4. Physical barriers in or along the roadway that might prevent pedestrians from easily crossing between the roadway and sidewalk.

5. Presence and location of bus stops.

6. Number of potential pedestrian trip originators/destinations.

7. Availability of street parking.

8. Presence of a center turn lane.
9. Presence of a right turn only turning lane
10. Length of the walk light phase.
11. Length of the don't walk light phase.
12. Width of the roadway/pedestrian crossing.
13. Presence and type of median (e.g., raised concrete or painted asphalt).
14. Presence of a T-intersection between the two marked crosswalks.
15. Traffic control device of the second crosswalk (i.e., traffic signal, stop sign, or none).
16. Pace at which pedestrians are required to travel to complete a crossing entirely during the walk light phase.

Data were used to create a model to predict where pedestrians are likely to cross the road (marked intersection crosswalk or non-intersection). The accuracy of the model ranged from 80 to 95 percent based on location. The model correctly predicted a mean of 90 percent of crossings. Overall, the model was successful in predicting whether pedestrians would cross in marked crosswalks at intersections or outside a marked crossing.

A mean of 13.89 percent of pedestrian crossings took place at unmarked non-intersection locations. Given the disproportionate percentage of fatalities that take place outside marked intersections, this number may be a bit surprising. However, these data suggest that some locations are more prone to have more unmarked non-intersection crossings than others. This was indeed the case here. Non-intersection crossings ranged from 3.02 to 36.55 percent.

The location with 36.55 percent of the crossings that took place at a non-intersection was different from many of the other locations in very specific ways. A wide, grassy median separates traffic directionality. This median allows pedestrians to cross one road segment, wait on the median for a gap in traffic, and complete the second portion of the crossing. In addition, the juxtaposition of a Metro (subway) train station and a surrounding neighborhood is such that the most direct route (in terms of absolute distance) between the two areas involves crossing outside the marked intersection. Given that some might consider traveling through the marked crosswalks to be out of the way, many may increase their perceived control of the crossing by using the median and cross midblock.

Environmental factors were also examined in terms of their influence on crossing behaviors. For example, a significant relationship between the width of the crossing and the percentage of pedestrians who crossed entirely during the walk signal light phase at each location was found. In other words, the longer the distance that pedestrians were required to travel to cross the road, the more likely they were to cross entirely during the walk phase of the light cycle. Interestingly, a significant relationship between crossing entirely during the don't walk signal phase and traffic directionality was found—pedestrians were more likely to cross during the don't walk phase on one-way streets than on two-way streets.

Not surprisingly, when physical barriers that might prevent pedestrians from easily crossing between the roadway and sidewalk were present, pedestrians were less likely to cross the roadway at unmarked non-intersection areas. Thus it appears that even small barriers, such as flower planters, reduce the perceived affordances to cross the roadway.

Overall, only .98 percent of crossings involved pedestrians yielding to vehicles. Not surprisingly, a significantly greater percentage of crossings in non-intersections involved pedestrian yielding than in marked crosswalks.

Overall, 8.93 percent of crossings involved a vehicle yielding to a pedestrian. A significantly greater percentage of crossings in the marked intersection involved vehicle yielding than crossings in the unmarked non-intersection areas. This discrepancy is largely attributable to turning vehicles yielding to pedestrians crossing in the marked crossings during the walk phase.

Within the marked intersections, a significantly greater percentage of crossings involved vehicle yielding than pedestrian yielding. However, outside the marked pedestrian crossing, pedestrians and vehicles were equally likely to yield to avoid collision.

It is recommended that in new, redesigned, or problematic environments an evaluation of the environmental features should be made to determine where pedestrian crossings are likely. The developed model was successful in predicting an average of 90 percent of the pedestrian crossings. Areas that have a high predicted likelihood of unmarked non-intersection crossings could be proactively targeted to modify the crossing affordances of the environment—leading pedestrians to cross at marked intersections. Presumably this would reduce the number of pedestrians crossing midblock. A combined effort of pedestrian education and shared road use planning would hopefully reduce pedestrian injuries and fatalities and ultimately increase roadway safety.

INTRODUCTION

Vehicle collisions with pedestrians are both common and deadly. In 2009, 12.1 percent (a number that has remained relatively consistent since 2000, ranging from 12.1 percent to 12.9 percent) of roadway fatalities in the United States were pedestrians.[1] The problem is even graver elsewhere in the world. For example, 67 percent of roadway fatalities in Hong Kong, 51 percent in Ethiopia, and 50 percent in Romania are pedestrians.[2] It has been estimated that approximately 400,000 pedestrian fatalities occur globally each year.[3] Further, the World Health Organization estimates that roadway crashes will become the third leading cause of years of life lost by 2020. (Years of life lost is a measure quantifying premature mortality.)[4]

An examination of pedestrian fatalities in the United States reveals that most occur at non-intersection locations.[1] As a result, it is important both to be able to determine where these collisions are likely to occur and to understand what measures can be taken to improve safety. The present study focuses on the former. In other words, this study focuses on determining what factors, both pedestrian and environmental, influence potentially dangerous non-intersection crossing behavior. It is hoped that this information might be used to increase the proportion of safe pedestrian crossing behaviors.

During the daytime in the United States, about 1,500 pedestrian fatalities occur in urban environments each year (based on an analysis of Fatality Analysis Reporting System (FARS) data for 1994–2009).[1] Of these, about 64 percent occur on the roadway in non-intersection locations, while only about 30 percent occur in intersections or are intersection related.

Figure 1 illustrates this relationship. It should be noted that the number of non-intersection and intersection/intersection-related fatalities do not equate to the total number of daytime fatalities. This is because areas such as driveways, exit ramps, and rail grade crossings were excluded from both the intersection/intersection-related and non-intersection categories. (These areas were excluded from analyses because they result in special circumstances that are distinctly different from traditional non-intersection crossing.) In addition, rural environments, interstates, expressways, and unknown roadway types were excluded from the non-intersection and intersection/intersection-related categories. These areas were excluded from analyses because of the focus of the current study. This study focuses on urban areas where pedestrian populations are the densest. Furthermore, these urban areas have the greatest likelihood of crossing treatment safety enhancements (e.g., pedestrian hybrid beacon). In addition, as a result of the perceptual complexities involved with nighttime pedestrian collisions, the present study focuses only on those occurring during daylight hours.

As a result of the large proportion of pedestrian fatalities that occur at non-intersection locations, it is important to investigate the causal factors of these collisions. It is probable that some of these collisions result from pedestrians traveling along the roadway. However, it is likely that the majority result from pedestrians crossing the roadway. Despite the large proportion of crashes involving pedestrians crossing roadways at unmarked locations, little research has investigated the reasons.

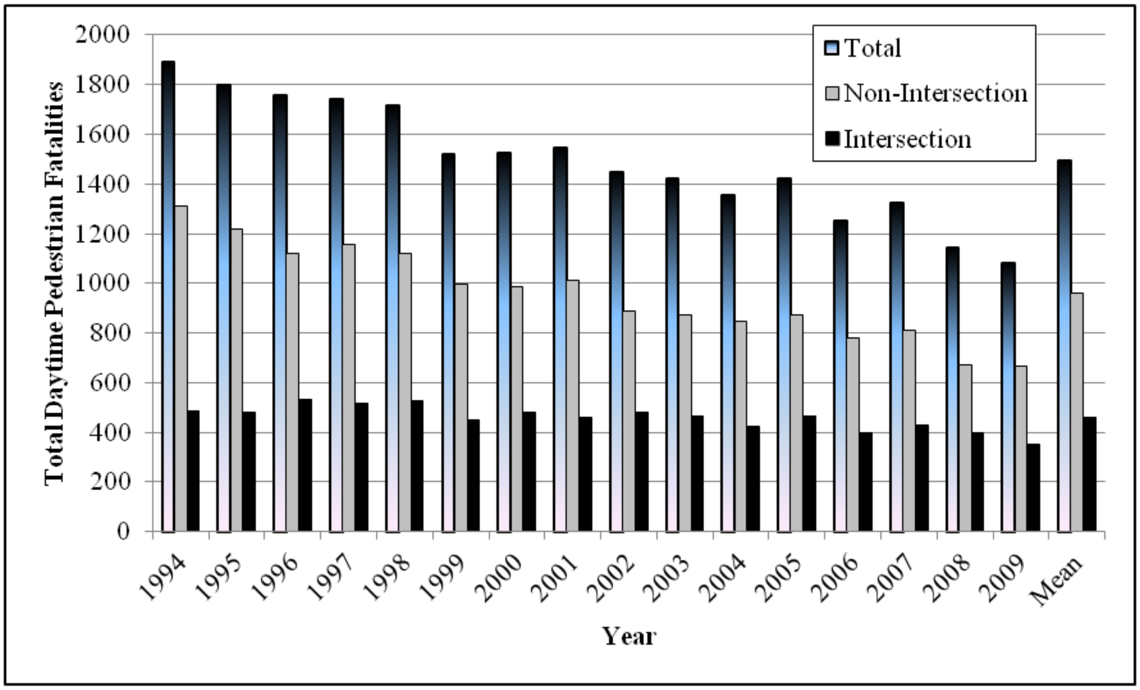


Figure 1. Graph. Total number of pedestrian fatalities, number of urban intersection/ intersection-related fatalities, and number of urban non-intersection fatalities in daytime environments by year.

It has been shown that pedestrians who cross away from crosswalks are more likely to be trapped in the middle of the street than those who cross at the crosswalk.(5) Furthermore, pedestrians who cross at crosswalks are more likely to yield to vehicles than those who cross away from crosswalks.(5) This is especially important to safety. If pedestrians take measures to increase their safety, they are less likely to be involved in pedestrian–vehicle collisions.

In many areas, pedestrian markings and signalization can be implemented to attempt to increase safety as pedestrians cross midblock. However, it is obvious that some areas simply do not feasibly (or realistically) allow for the addition of marked pedestrian crossings (e.g., rural and gridlock-prone roads).

The Federal Highway Administration (FHWA) has multiple current projects investigating the performance of several different pedestrian crossing treatments. These projects include identifying the optimal number and combination of rectangular rapid flashing beacons and circular rapid flashing beacons, as well as examining the effect of varying characteristics, such as flash pattern/sequence, intensity, size, shape, and positioning.

No matter the situation, it is important to understand what types of factors influence pedestrians to cross at unmarked locations. Roadway designs and environmental factors have the ability to both promote and hinder opportunities to cross at unmarked and midblock locations. For example, a concrete lane divider severely reduces the ability to quickly and safely cross a roadway. Yet, some areas appear to encourage people to cross at unmarked locations. Pedestrians may elect to cross the road for many reasons. This report focuses on two of these factors—those intrinsic to pedestrians and those of the roadway environment itself.

PEDESTRIAN FACTORS

It is obvious that pedestrians, in most cases, attempt to select the fastest and most direct route from their origin to their preferred destination. However, route planning must take into account the features of the traveling environment, physical abilities, some level of risk (real or perceived), among other factors. For example, suppose that Route A is .5 miles in length and that Route B is 1 mi in length. While Route A is shorter in absolute distance, it includes two steep hill segments, and Route B is flat. Given these environmental characteristics, a young and physically fit pedestrian would likely select Route A. However, an older adult with a physical impairment might select Route B for its terrain advantages.

It is improbable that people use complex decisionmaking processes to determine which route to walk to reach a specific location. Rather, pedestrians are likely to plan a general route and rely on other factors to make smaller in-route choices, such as where to cross the roadway. For example, one person may "always" cross at a specific location, and for this reason, he or she will rely on habit and cross there again on subsequent trips. Another pedestrian may have mobility issues and will cross at the most accessible location. It is probable that pedestrians rely on a set of heuristics or tendencies when selecting when and where to cross the roadway. Here, the study team explores some of the intrinsic pedestrian characteristics that can influence route choice and crossing behaviors.

Gender

Overall, males are more likely to be involved in vehicle crashes than females.(6) This trend remains consistent with pedestrian fatalities. In 2009, the male pedestrian fatality rate was 1.86 per 100,000, compared with .82 per 100,000 females. In total, 69 percent of the pedestrian fatalities were male. This gender difference is consistent across all age groups.(7)

This evidence suggests that gender plays a role in pedestrian crossing decisions to some degree. This idea is further supported in a recent study by Holland and Hill.(8) The authors presented participants with a variety of potentially dangerous crossing scenarios. In each of the scenarios, women reported perceiving more risk than their male counterparts. Furthermore, the females were less likely to indicate an intention to cross the roadway. Taken together, these data suggest that, in general, males and females view and act on potential safety hazards in the roadway environment differently. These gender differences might prove useful in targeting interventions and education toward different groups.

Age

Age also plays a role in pedestrian–vehicle collisions. In 2009, pedestrians 65 and older had the highest rate of fatalities, 1.96 per 100,000. Moreover, older adults constituted 19 percent of all pedestrian fatalities.(7) On the opposite end of the spectrum, pedestrians 15 years and younger accounted for 25 percent of all pedestrian injuries and 7 percent of pedestrian fatalities in 2009.(7)

Many factors could result in these age-related fatality trends. One possibility is that younger and older pedestrians make riskier road-crossing choices. However, multiple studies have shown that when participants are presented with potentially dangerous crossing scenarios, older adults are less likely to indicate that they would be likely to attempt the crossing.[8,9,10] Thus, it appears, at least in regard to intention to cross the road, older adults are not necessarily making more risky choices. In fact, this suggests just the opposite. One can logically draw the conclusion that those who are less likely to engage in risky crossing behaviors are also less likely to be involved in pedestrian–vehicle collisions.

If older adults are less inclined than younger adults to intend to make risky crossings, then other factors must contribute to their large proportion of the total pedestrian fatalities. This appears to be the case. While older adults constitute 19 percent of all pedestrian fatalities, they only make up 8.5 percent of the total injuries.[7] These data imply that older adults are less likely to be struck by a vehicle. However, when an older adult is involved in this type of collision, it is more likely to result in a fatality.

It has been suggested, for example in Barton and Morrongiello, that children have not fully developed the cognitive reasoning skills to cross the street safely.[11] It is certainly a possibility that children make riskier crossing decisions. It is also likely that smaller children are more difficult to see from the drivers' perspective. This condition makes it more difficult for a driver to proactively avoid collision with this special group of pedestrians.

Age differences in pedestrian injury and fatality rates may help to direct educational interventions to increase safe crossing behaviors. Further, age-related differences may help engineers to target different interventions for different age groups. For example, sidewalk markings outside elementary schools may lead children to walk to pedestrian-activated crosswalks. In addition, crosswalk activation buttons could be lowered to child level or made visually more attractive to push. Longer protected crossings could also be employed near senior citizen communities.

Alcohol

Alcohol plays a significant role in pedestrian fatalities. In 2009, it was reported that 48 percent of crashes resulting in a pedestrian fatality involved alcohol. When focusing on drivers involved in these collisions, about 13 percent had a blood alcohol concentration (BAC) of .08 percent by volume or greater. This is compared with 35 percent of pedestrians. Further, both the driver and the pedestrian had BAC levels of .08 percent by volume or higher in 6 percent of the fatal crashes.[7]

Self-Identity

Self-identity as a safe or careful pedestrian has been shown to be correlated with roadway crossing behavior. For example, Holland, Hill, and Cooke asked pedestrians to make decisions on whether or not they would cross the roadway in various situations.[10] It was found that pedestrians who had high self-identities as careful pedestrians selected fewer gaps in which they would cross the roadway at non-signalized crossing locations. Similarly, Evans and Norman presented pedestrians with a set of potentially hazardous road crossing behaviors. Those people who identified themselves as "safe pedestrians" were less likely to state that they would cross the roadway in such a manner.[9] A similar study with adolescents also found that those who rated themselves as safe pedestrians reported that they were less inclined to cross at a potentially risky location.[12]

If people who identify themselves as cautious accept fewer gaps to cross the roadway, then it is ideal to further understand what factors influence this self-identity. Holland, Hill, and Cooke found that people who had previously been involved in a roadway collision viewed themselves as more willing to take a risk.[10] Contrarily, those with mobility impairments and older adults rated themselves as more cautious. Furthermore, it was found that the biggest predictor of a self-identity as a careful or safe pedestrian was age (even when accounting for factors such as experience and mobility). This suggests that older adults take fewer risks when crossing the roadway than do younger pedestrians. Furthermore, this helps to explain the age-related discrepancy in the number of collisions with younger persons than older persons. Beyond this, if it is known that older adults are pedestrians who take fewer risks, then efforts to improve roadway safety might be better directed at younger foot travelers.

The results of these studies suggest that people who consider themselves to be careful/safe pedestrians are more aware of the potential hazards involved in crossing the roadway. As a result, these people may be less likely to employ potentially risky road-crossing choices. Along similar lines, it may be reasonable to assume that increases in perceived roadway dangers (either via environmental changes or educational interventions) will lead to fewer crossings at unmarked roadway locations.

Perceived Control

In addition to the aforementioned factors, Evans and Norman found that perceived control influenced pedestrians' intentions to cross the roadway.[12] (Perceived behavioral control is a component of the Theory of Planned Behavior, a widely used theory of safety- and health-related behaviors.[13]) Participants were presented with three scenarios: crossing during a gap in traffic of a multilane roadway to get to a vehicle after a shopping trip, crossing at signalized pedestrian crossing during the don't walk phase to get to the dry cleaners before closing, and crossing a residential roadway to meet a friend. For each of the scenarios, it was probable that those participants who perceived having more behavioral control (as assessed by a planned behavior questionnaire) of the situation would indicate that they would cross the roadway.

Evans and Norman also attempted to apply the Theory of Planned Behavior to adolescent intentions to cross the roadway.[12] Middle school aged children were presented with a potentially dangerous road-crossing scenario. Much like the researchers' previously mentioned findings, perceived behavioral control was the strongest predictor of expressed intention to cross the roadway.[9] In both studies, perceived control of the situation is the greatest predictor of pedestrians' planned intent to cross the roadway. This suggests that if pedestrians' perceptions of the ability to cross the roadway at unsafe areas are decreased, then overall pedestrian safety may increase.

ENVIRONMENTAL FACTORS

Many factors contribute to whether people attempt to cross the roadway at a specific location at a specific time. However, features of the roadway environment have been largely ignored when examining these causal factors. Here the study team discusses foot travel in three components: trip originators, destinations or attractions, and affordances.

Trip Originators

Trip originators are areas where pedestrians begin trips. Some originators tend to generate more trips than others. For example, a house generates a finite number of trips. However, other originators generate countless pedestrian trips. Some of these high trip generating sources are places such as shopping malls, Metro/subway stations, and bus stops. These high trip originators require special attention with regard to pedestrian flow. One can easily imagine how pedestrian travel patterns might differ between a bus stop placed in the middle of a block and a bus stop placed at the corner of an intersection.

Trip Destinations

Trip destinations are end points of pedestrian trips, whether they are final destinations or attractions (e.g., coffee shop) en route. Often, destinations are also trip originators. Take the example of a shopping center. Many people may consider the shopping center the completion of their trip, that is, their destination. However, when people leave this locale, the shopping center becomes the trip originator. As a result, designers must attend to both how pedestrians enter and exit such locations.

Affordances

It is obvious from the pedestrian fatality data that simple risk perception is not an adequate source of determining whether or not one should cross the roadway at a given location at a given time. If risk perceptions were adequate, pedestrians would not take such potentially harmful actions. Instead, it is likely that people rely on action-oriented perceptions of affordances.

An affordance refers to the qualities (real or perceived) of the environment (or object).[14] These qualities/properties determine how the environment/object can be used. For example, a chair of sufficient size and stability affords sitting or climbing upon. Along similar lines, a gap in traffic of sufficient distance may afford crossing of the roadway. Affordances are egocentric. This means that a chair that affords sitting to a child may not afford sitting for an adult. Similarly, a gap in traffic may afford crossing for an able-bodied young adult but not for an older adult with mobility impairment. It is very important to note that although these qualities of the environment are directly perceived, they may or may not be real. As a result, the affordances of an environment can lead a person to take an incorrect or unsafe action. For example, imagine an elongated door handle with the word “push” above it. A user will likely directly perceive that the door handle appears to afford pulling and will attempt to pull the door open. This is an “incorrect” action in the sense that the door must be pushed to open.

When they act upon perceived affordances, people generally produce a behavior that is adequate, this is, unless the affordance leads the user to perform an unsafe action. According to this perspective, behavior is goal-driven (e.g., I want to cross the street) rather than avoidance-driven (e.g., I don’t want to be struck by that car). This results in generally adequate choices (e.g., I can cross the roadway now). Of course, irregular outside influences have the potential to increase the salience of avoidance-driven choices (e.g., seeing a police officer during a known target jaywalking enforcement zone).

Perceived affordances are, of course, not the same as actual safety. People often incorrectly perceive an action to be safe, when indeed, it is not. For example, as Tyrrell, Wood, and Carberry found, at night, pedestrians frequently overestimate the distance at which drivers are able to see them.(15) These perceptions can lead pedestrians to take unsafe actions. As such, it is important to consider affordances when designing an environment. This includes affordances that influence safety, aesthetics, and functionality. Take, for example, Norman's classic teapot example. Norman describes a teapot that has the handle and the spout on the same side of the pot.(16) While the design is aesthetically pleasing, the pot is not functional, and could actually pose quite a burn hazard. This example can easily be applied to the roadway and pedestrian travel area. While it may be desirable to make pedestrian pathways pleasing to the eye, this should not be the top priority when designing roadway environments. Instead, pathways should be developed to increase the ability of pedestrians to safely (and quickly) move from an originator to a destination. In reaching this goal, aesthetically pleasing environmental furniture could be used. For example, attractive shrubbery might be placed along a curb to dissuade people from crossing midblock (by reducing the roadway crossing affordance). Ultimately, roadway environments should maximize the roadway-crossing safety while not inhibiting pedestrian or vehicle travel.

If one is able to design an area that maximizes the affordances related to safe pedestrian crossing behaviors (and minimizes those that increase more hazardous crossing), pedestrians should be more likely to make safe crossings. Furthermore, this should reduce the need for hazard, or warning signs. If a better understanding of pedestrian crossing affordances is gained, modifications can be made to increase pedestrian safety, including the implementation of marked crossings (in optimal locations that encourage use) or midblock crossing inhibitors (encouraging pedestrians to cross at marked intersection crossings), while not inhibiting pedestrian travel. Further, if pedestrian crossing schemas can be identified, possible educational interventions can be developed.

An iterative process is presented here that explored the factors surrounding pedestrian crossings at 20 different intersections in the Washington, DC, metropolitan area. Data were collected in three separate phases. Each phase is discussed separately. A combined summary of each of the phases is presented later. The influences of environmental factors on pedestrian crossing locations are discussed. The individual relationships of these factors and where (i.e., intersection or non-intersection) and how (e.g., walk, run, etc.) pedestrians cross the road are examined. In addition, models are provided to predict where pedestrians are likely to cross given a set of roadway environmental factors. The ability to readily predict problematic unmarked crossing locations before crashes occur could be useful in the proactive deployment of mitigation strategies. These may include educational interventions or engineering countermeasures, which have been shown to be effective (e.g., Pelican, Puffin, and Zebra crossings, or refuge islands).(17)

PEDESTRIAN CROSSING BEHAVIORS: PHASE 1

To assess pedestrian crossing behaviors, eight different locations in Washington, DC, were selected. Pedestrian crossings were video recorded and later coded at each of the locations. The following section describes this process as well as where pedestrians are likely to cross the roadway at each of these locations. Later, these results are compared with more data that were collected in phases 2 and 3.

DATA COLLECTION LOCATIONS

Eight different locations in Washington, DC, were selected as areas in which data would be collected. Each area must have met several requirements to be included. These requirements were the following:

- The area must be captured by a District of Columbia Department of Transportation (DDOT) traffic management/closed-circuit television (CCTV) camera. This provided the opportunity to record video feed directly from the cameras.
- Each camera must be positioned at an intersection that clearly captures a marked intersection crosswalk in the foreground.
- Each camera must capture a second marked crosswalk. This ensured that all crossings between two marked intersections could be captured.
- Each camera must capture enough traffic light information to determine walk/don’t walk phases at the intersection crosswalk in the foreground.

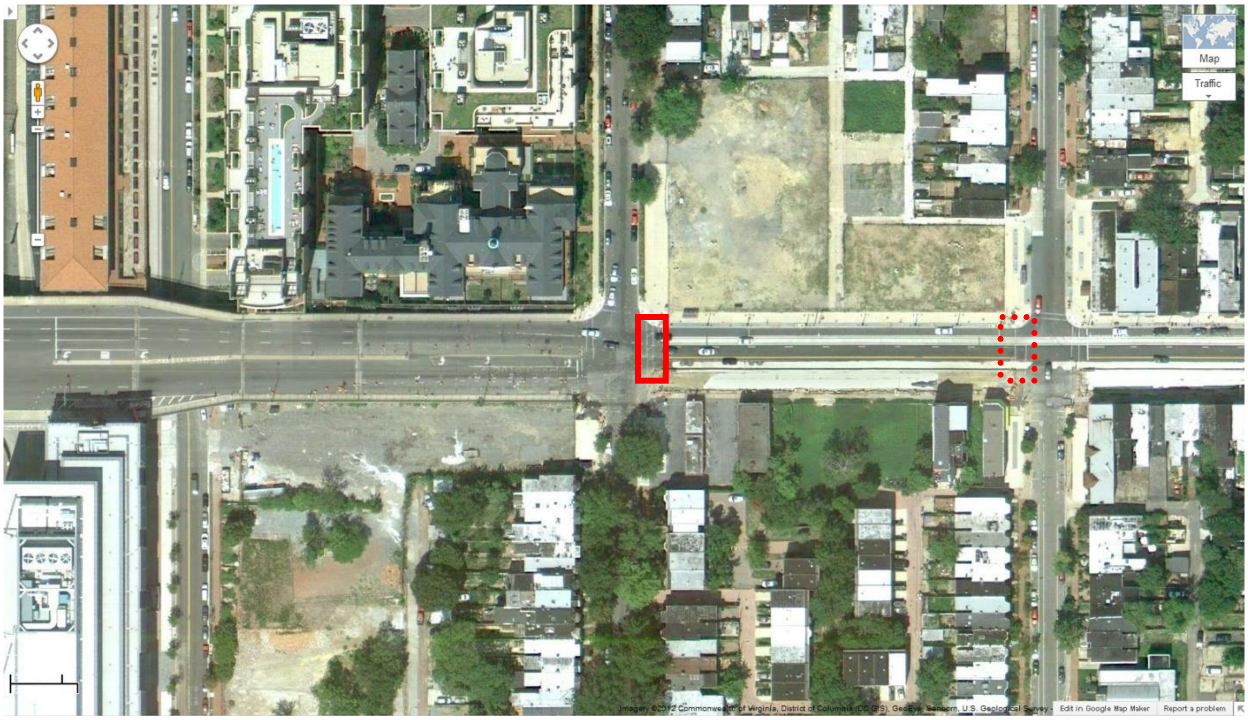
Other roadway characteristics were not considered when selecting data collection areas. It is possible that factors such as the number of lanes and directionality (one versus two lanes) influence pedestrian crossing behaviors. As a result, these factors were not intentionally included or excluded when selecting data collection areas. Rather, it was hoped that the influence of these factors would present itself in the data.

Video feed was recorded from each of the eight cameras from 8:30 a.m. to 5:00 p.m. and from 8:00 p.m. to 11:00 p.m. Eastern Standard Time on February 9, 2012. Following this first day of recording, all cameras recorded from 7:00 a.m. to 5:00 p.m. and from 8:00 p.m. to 11:00 p.m. Eastern Standard Time, beginning February 10, 2012, and ending February 22, 2012.

The following section describes each of the eight data collection locations, which are labeled in no particular order.

Location 1

The first data collection area is located at the intersection of 3rd Street Northeast and H Street Northeast in Washington, DC. Figure 2 is an aerial view of this data collection area. Third Street Northeast runs north/south and is located in the center of the image. H Street Northeast runs east/west and is also located in the center of the image. The solid red rectangle highlights the intersection of 3rd Street Northeast and H Street Northeast. The dotted red rectangle highlights the intersection of 4th Street Northeast and H Street. The DDOT camera was positioned on the southwest corner of the 3rd and H intersection facing east (see figure 3). As a result, pedestrians making north/south crossings on H Street between 3rd Street and 4th Street were captured. The distance from 3rd Street and 4th Street is approximately 352 ft. Figure 3 shows marked crossings are present at both 3rd Street Northeast (solid red line) and 4th Street Northeast (dotted red line). The AADT in this area is 15.8 (expressed in thousands and rounded to the nearest 100).[18]



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 2. Photo. Aerial view of Location 1.[19]

The neighborhood around this location contains both residential buildings and businesses. (It is located only a few blocks from Union Station.) However, few businesses/offices along H Street might attract pedestrian traffic. Along the entire block on north side of H Street, a large construction project was underway throughout data collection. The result of this construction has two relevant impacts on the present study. First, there are nearly no trip originators or destinations on this side of the block for persons other than worksite employees. Second, a barrier was placed between the sidewalk just outside the construction and the roadway. A break in the barrier near the 3rd and H intersection allows pedestrians to enter and exit a nearby bus stop. The southeast corner of this intersection has both a liquor store and a Capital Bikeshare™ station. (Capital Bike Share is a local subscription-based bicycle sharing program that allows users to pick up and drop off bicycles at more than 140 different Washington, DC, metropolitan area locations.) No other notable trip originators or destinations are located on the south side of H Street.

Figure 3. Photo. Still image captured from the Location 1 camera.

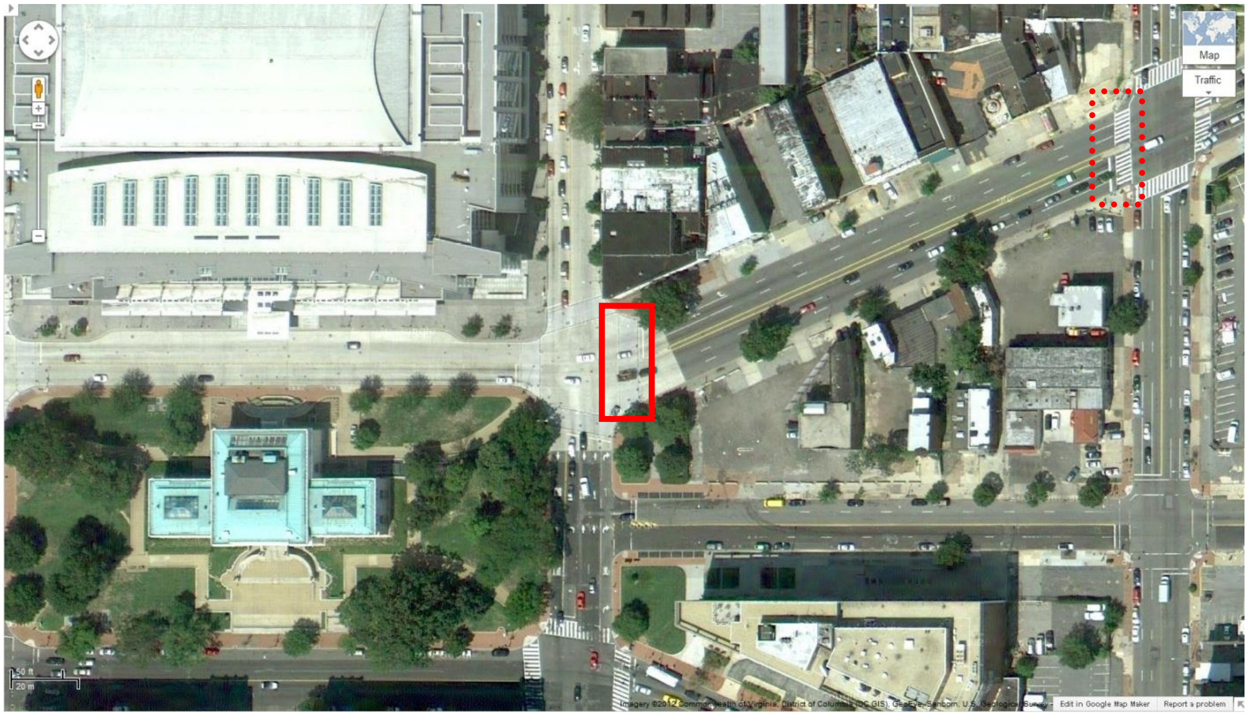
The northern portion of the relevant block of H Street Northeast (i.e., vehicles traveling from east to west) provides two lanes of through traffic and an additional partial lane near the western end of the block. This third lane functions primarily as an area for buses to stop to pick up passengers. As vehicles continue to travel west (behind the view of the camera), the three lanes continue and two additional bus stops are present. The southern portion of the relevant block of H Street Northeast (i.e., vehicles traveling from west to east) provides two lanes of travel and a third parking lane. Just west of the relevant intersection, two through lanes and a right turn only lane are present. A bus stop is located just before the intersection.

The marked intersection of interest at 3rd and H Streets (as highlighted by the solid rectangular box in figure 3 is 61 ft long (curb to curb). The walk phase is illuminated for 20 s, and the don't walk phase is illuminated for 69 s. Figure 4 illustrates what a pedestrian might see as he or she attempts to cross from the north side of H Street Northeast to the south side of the street along 3rd Street Northeast. The image shows a pedestrian waiting to cross to the north side of the street and looking for oncoming traffic.

Figure 4. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the north side of H Street Northeast to the south side of the street along 3rd Street Northeast.

Location 2

The second data collection area is located at the intersection of 7th Street Northwest and New York Avenue Northwest in Washington, DC. Figure 5 is an aerial view of this data collection area. Seventh Street Northwest runs north/south and is located in the center of the image. New York Avenue runs northeast/southwest and is also located near the center of the image. The solid red rectangle highlights the intersection of 7th Street Northwest and New York Avenue Northwest. The dotted red rectangle highlights the intersection of 6th Street Northwest and New York Avenue Northwest. The DDOT camera was positioned on the southwest corner of the 7th and Mt. Vernon Place intersection facing east (see figure 6). (Note that because New York Avenue is a "diagonal" street, it meets Mt. Vernon Place at Mount Vernon Square as can be seen in figure 5.) As a result, pedestrians making north/south crossings on New York Avenue between 7th Street and 6th Street were captured. The distance between 7th Street and 6th Street is approximately 530 ft. Figure 6 shows marked crossings are present at both 7th Street Northwest (solid red rectangle) and 6th Street Northwest (dotted red rectangle). The AADT in this area is 24.2 (expressed in thousands and rounded to the nearest 100).[18]



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 5. Photo. Aerial view of Location 2.[20]

The neighborhood surrounding Location 2 contains both residential buildings and businesses. The two largest attractions in the vicinity are Mount Vernon Square and the Walter E. Washington Convention Center. Along the south side of New York Avenue are two smaller pay parking lots. In addition, several older buildings (some vacant) are not likely to be substantial trip originators or destinations. Along the north side of New York Avenue, several buildings under construction are not likely to serve as trip originators or destinations for persons other than worksite employees. There is also a smaller pay parking lot, a vehicle service station, vacant buildings, and a business that functions primarily during evening hours. As a result, there are few trip originators or destinations along this side of the roadway.

Figure 6. Photo. Still image captured from the Location 2 camera.

The northern portion of the relevant block of New York Avenue Northwest (i.e., with vehicles traveling from east to west) provides two lanes of through traffic. An additional third lane is present that provides metered parking and a right turn only lane toward the western end of the block. As vehicles continue to travel west (behind the view of the camera), the two travel lanes continue. The southern portion of the relevant block of New York Avenue Northwest (i.e., with vehicles traveling from west to east) provides two lanes of travel and a third parking lane. Just west of the relevant intersection, two through lanes are present. There is also a small "soft" median (i.e., a small area in the roadway that is not raised/protected by concrete) between the eastbound and westbound travel lanes of New York Avenue. Also of relevance, the rightmost lane traveling northbound on 7th Street Northwest is right turn only. That is, there is a dedicated lane of traffic turning onto New York Avenue.

The marked intersection of 7th Street and New York Avenue of interest (as highlighted by the solid rectangular box in figure 6) is 81 ft 3 inches long (curb to curb). The walk phase is illuminated for 46 s, and the don't walk phase is illuminated for 55 s. Figure 7 illustrates what a pedestrian might see as he or she attempts to cross from the north side of New York Avenue Northwest to the south side of the street along 7th Street Northwest. The traffic traveling northbound (closest to the crosswalk) is waiting for the pedestrians to clear before completing a right turn.

Figure 7. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the north side of New York Avenue Northwest to the south side of the street along 7th Street Northwest.

Location 3

The third data collection area is located at the intersection of 7th Street Northwest and Rhode Island Avenue Northwest in Washington, DC. An aerial view of this data collection area can be seen in figure 8. Seventh Street Northwest runs north/south and is located in the center of the image. New York Avenue runs northeast/southwest and is also located near the center of the image. The solid red rectangle highlights the intersection of 7th Street Northwest and Rhode Island Avenue Northwest. The dotted red rectangle highlights the intersection of 6th Street Northwest and Rhode Island Avenue Northwest. The DDOT camera was positioned on the northwest corner of the 7th and Rhode Island intersection facing east (see figure 9). As a result, pedestrians making north/south crossings on Rhode Island Avenue between 7th and 6th Streets were captured. The distance between 7th Street and 6th Street is approximately 550 ft. Figure 9 shows marked crossings are present at both 7th Street Northwest (solid red rectangle) and 6th Street Northwest (dotted red rectangle). The AADT in this area is 26.3 (expressed in thousands and rounded to the nearest 100).[18]

In addition, Marion Street Northwest runs north/south between 6th and 7th Streets. Marion Street is located to the south of Rhode Island Avenue. Northbound Marion Street traffic must turn (either right or left) when it meets Rhode Island. This intersection does not contain a marked pedestrian crossing. The distance between 7th Street and Marion Street is approximately 277 ft.

Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 8. Photo. Aerial view of Location 3. Northwest between 7th and 6th Streets Northwest.(21)

The neighborhood surrounding Location 3 consists of mostly residential buildings and a few small businesses. Along the south side of Rhode Island Avenue, west of Marion Street, a residential building complex fills the entire block. The south side of Rhode Island Avenue (east of Marion Street) comprises a small grassy area. Along the north side of Rhode Island Avenue, to the west of Marion Street, is a vacant lot. Directly north of the Rhode Island Avenue and Marion Street intersection is construction of a new housing complex. A barrier was placed between the sidewalk and the roadway in front of this construction area. However, there are notable gaps in the barrier blocks. The remaining portion of the northeastern section of Rhode Island Avenue consists of houses. Other trip originators or destinations include a convenience store on the southwestern corner of the intersection of 7th Street Northwest and Rhode Island Northwest. A public library is also located directly west of the intersection. In addition, a Metro station (Shaw-Howard) is located on the northwestern adjacent block (behind the camera).

Figure 9. Photo. Still image captured from the Location 3 camera.

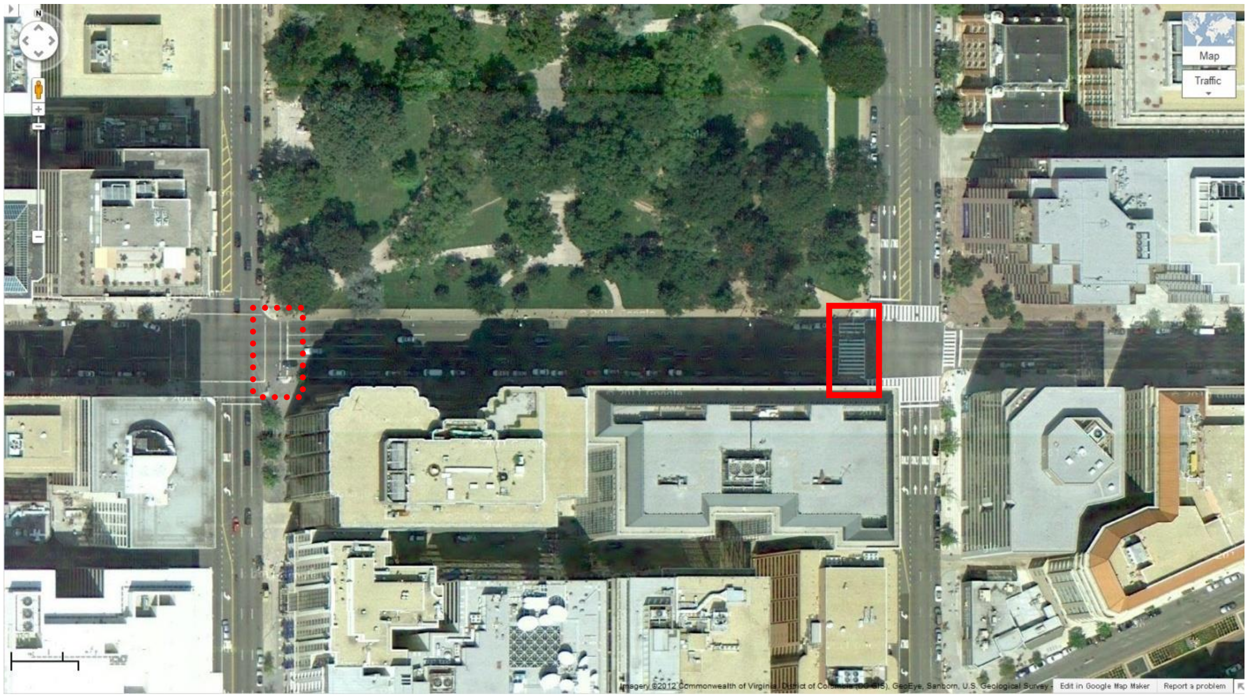
The northern portion of the relevant block of Rhode Island Avenue Northwest (i.e., vehicles traveling from east to west) provides three lanes of through traffic. An additional third left turn only lane is present just east of the intersection, and there is a split to the right so that drivers can travel westbound on R Street Northwest. As vehicles continue to travel west (behind the view of the camera), the three travel lanes continue. The southern portion of the relevant block of New York Avenue Northwest (i.e., vehicles traveling from west to east) provides three lanes of travel continued from the roadway west of the intersection. A bus stop is located just to the east of the intersection. A concrete median is present between the eastbound and westbound lanes of traffic. This median is also present to the east of Marion Street Northwest.

The marked intersection of 7th Street and Rhode Island Avenue of interest (as highlighted by the solid rectangular box in figure 9) is 48 ft 3 inches long (median refuge to curb). The walk phase is illuminated for 46 s, and the don't walk phase is illuminated for 71 s. The median between the eastbound and westbound traffic is 7 ft wide. Figure 10 illustrates what a pedestrian might see as he or she attempts to cross from the north side of Rhode Island Avenue Northwest to the south side of the street along 7th Street Northwest.

Figure 10. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the north side of Rhode Island Avenue Northwest to the south side of the street along 7th Street Northwest.

Location 4

The fourth data collection area is located at the intersection of 13th Street Northwest and I (eye) Street Northwest in Washington, DC. An aerial view of this data collection area can be seen in Figure 11. Thirteenth Street Northwest runs north/south and is located toward the right of the image. Traffic travels east/west on I Street Northwest and is located near the center of the image. The solid red rectangle highlights the intersection of 13th Street Northwest and I Street Northwest. The dotted red rectangle highlights the intersection of 14th Street Northwest and I Street Northwest. The DDOT camera was positioned on the northeast corner of the 13th and I intersection facing west (see figure 11). As a result, pedestrians making north/south crossings on I Street between 13th and 14th Streets were captured. The distance between 13th Street and 14th Street is approximately 565 ft. Figure 12 shows marked crossings are present at both 13th Street Northwest (solid red line) and 14th Street Northwest (dotted red line). The AADT in this area is 11.3 (expressed in thousands and rounded to the nearest 100).[18]



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 11. Photo. Aerial view of Location 4.(22)

The neighborhood surrounding Location 4 consists of mostly businesses. Along the south side of I Street Northwest, there are two large office buildings. They contain a variety of businesses, including restaurants, automatic teller machines (ATM), and a staffing solutions/temporary employment center. The entire north side of the relevant I Street block is bordered by Franklin Park.

Figure 12. Photo. Still image captured from the Location 4 camera.

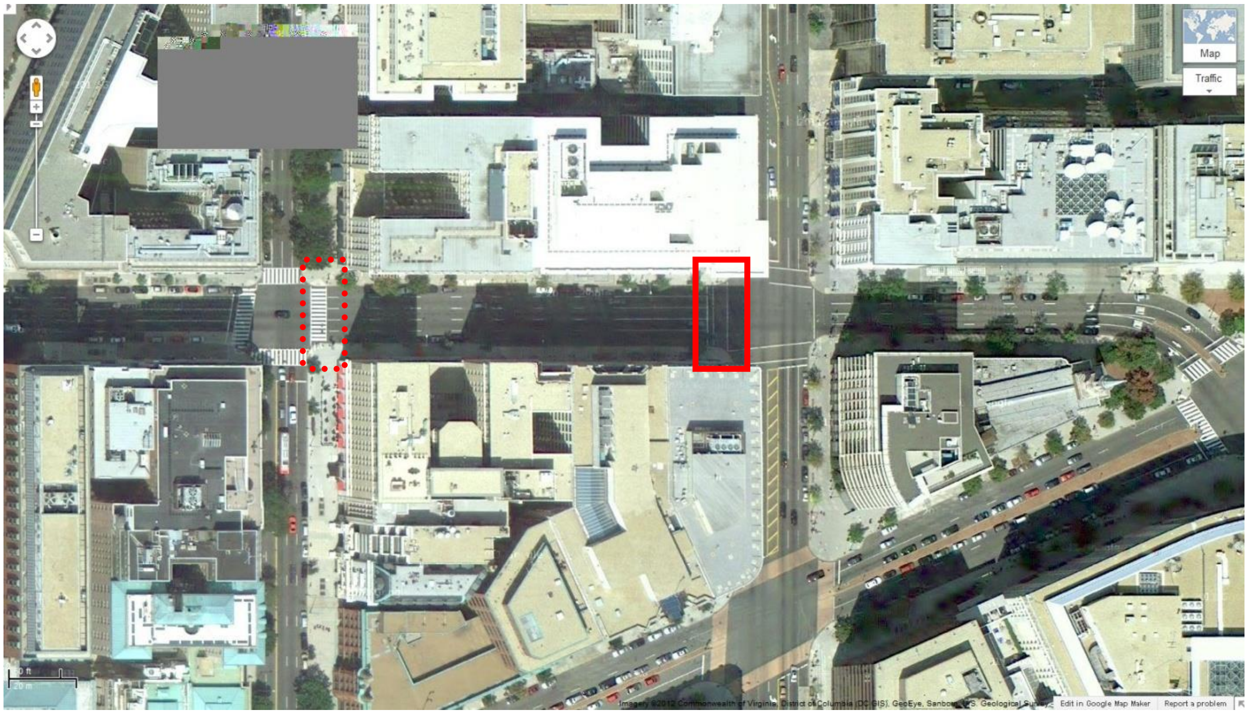
I Street Northwest is a one-way street with traffic flowing from east to west. To the east of the relevant 13th Street intersection, vehicles travel in two through lanes along I Street. Parking is available on both the north and south sides of the roadway. As traffic moves west to the data collection zone between 13th and 14th Streets, a third travel lane becomes available. Parking is also available on the south side of I street. A bus lane with multiple stops is present on the north side of I Street. The bus lane continues to the block west of 14th Street as parking space.

The marked intersection of 13th Street and I Street of interest (as highlighted by the solid rectangular box in figure 12 is 54 ft 5 inches long (curb to curb). The walk phase is illuminated for 32 s, and the don't walk phase is illuminated for 45 s. Figure 13 shows the view of the crossing of I Street Northwest at 13th Street Northwest from the southeast corner of the intersection.

Figure 13. Photo. Image of the westernmost crossing of I Street Northwest at 13th Street Northwest. The photo is taken from the southwestern corner of the intersection.

Location 5

The fifth data collection area is located at 14th Street Northwest and H Street Northwest in Washington, DC. An aerial view of this data collection area can be seen in figure 14. Fourteenth Street Northwest runs north/south and is located toward the right of the image. H Street Northwest travels east/west and is located near the center of the image. The solid red rectangle highlights the intersection of 14th Street Northwest and H Street Northwest. The dotted red rectangle highlights the intersection of 15th Street Northwest and H Street. The DDOT camera was positioned on the southeast corner of the 14th and H intersection facing west (see figure 15). As a result, pedestrians making north/south crossings on H Street between 14th and 15th Streets were captured. The distance between 14th Street and 15th Street is approximately 391 ft. Figure 15 shows marked crossings are present at both 14th Street Northwest (solid red line) and 15th Street Northwest (dotted red line). The AADT in this area is 15.1 (expressed in thousands and rounded to the nearest 100).(18)



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 14. Photo. Aerial view of Location 5.(23)

The neighborhood surrounding Location 5 consists of mostly businesses. Along the south side of H Street Northwest, there are several large buildings. These buildings contain a variety of businesses, including restaurants, offices, and a public parking garage. The north side of H Street is also made up of office buildings. These buildings contain the city center offices, an engraving shop, a men's clothing shop, a hair salon, a mobile telephone store, and a parking garage.

Figure 15. Photo. Still image captured from the Location 5 camera.

H Street Northwest is a one-way street with traffic flowing from west to east. H Street between 15th and 14th Streets contains three travel lanes and parking both to the north and south. As vehicles approach the 14th Street intersection, the parking along the north side of H Street becomes a left turn only lane, and the parking along the south side of H Street becomes a right turn only lane. As traffic continues past this intersection traveling east, there are three travel lanes and a parking lane on the north side of H Street.

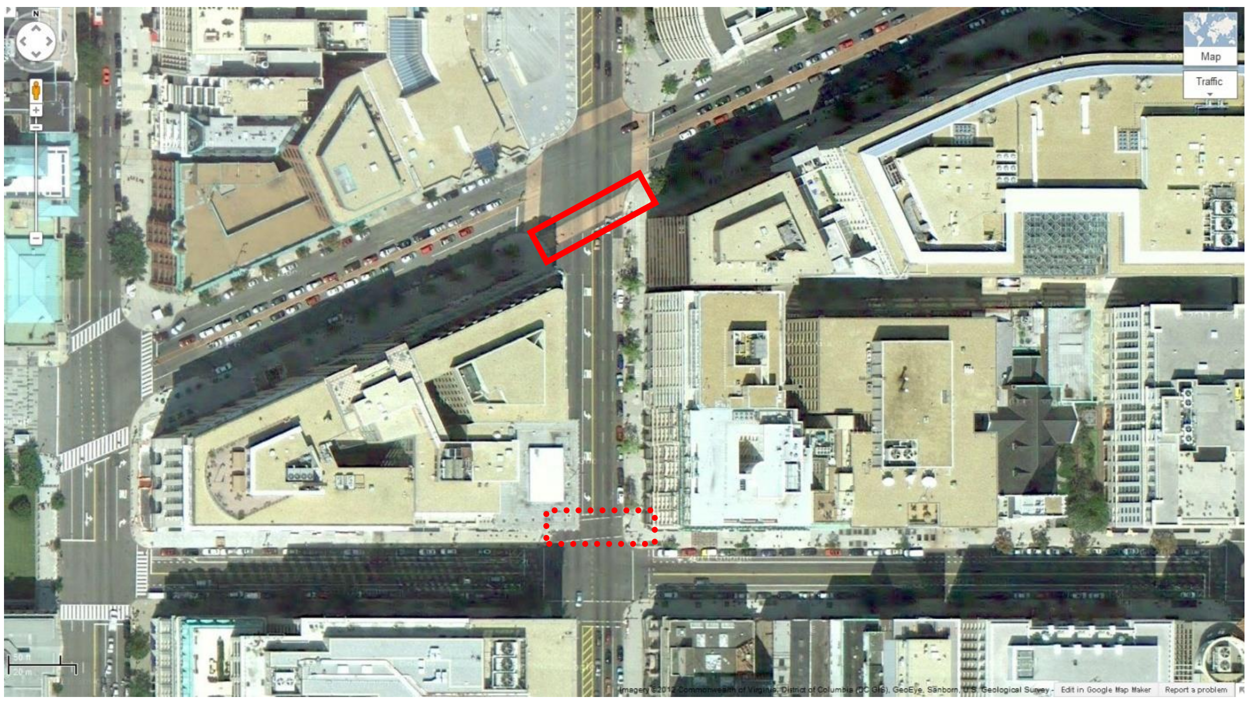
The marked intersection of 14th Street and H Street of interest (as highlighted by the solid rectangular box in figure 15) is 61 ft long (curb to curb). The walk phase is illuminated for 53 s, and the don't walk phase is illuminated for 50 s.

Figure 16 illustrates what a pedestrian might see as he or she attempts to cross from the south side of H Street Northwest to the north side of the street along 14th Street Northwest.

Figure 16. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the south side of H Street Northwest to the north side of the street along 14th Street Northwest.

Location 6

The sixth data collection area is located at 14th Street Northwest and New York Avenue Northwest in Washington, DC. An aerial view of this data collection area can be seen in figure 17. Fourteenth Street Northwest runs north/south and is located toward the center of the image. New York Avenue Northwest travels northeast/southwest and is located near the center/top of the image. The solid red rectangle highlights the intersection of 14th Street Northwest and New York Avenue Northwest. The dotted red rectangle highlights the intersection of 14th Street Northwest and G Street Northwest. The DDOT camera was positioned on the northeast corner of the 14th and New York intersection facing south (see figure 18). As a result, pedestrians making east/west crossings on 14th Street between New York Avenue and G Street were captured. The distance between New York Avenue and G Street is approximately 294 ft. Figure 18 shows marked crossings are present at both New York Avenue Northwest (solid red line) and G Street Northwest (dotted red line) along 14th Street Northwest. The AADT was not available for this specific block. However, the AADT for 14th Street Northwest on the block north of New York Avenue is 27.2 (expressed in thousands and rounded to the nearest 100).[18] In addition, the AADT for 14th Street Northwest two blocks south of New York Avenue is 35.7 (expressed in thousands and rounded to the nearest 100).[18] This suggests that the AADT for this block is in the middle 30s range. (An AADT of 31.5 was used for analysis purposes.)



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 17. Photo. Aerial view of Location 6.[24]

The neighborhood surrounding Location 6 consists of mostly businesses. The west side of 14th Street contains a restaurant serving primarily sandwiches, a mobile telephone repair shop, a fitness center, a parking garage, and office space. The east side of 14th Street contains a major pharmacy chain store, a bank, a shoe store, a café/restaurant, and office space.

Figure 18. Photo. Still image captured from the Location 6 camera.

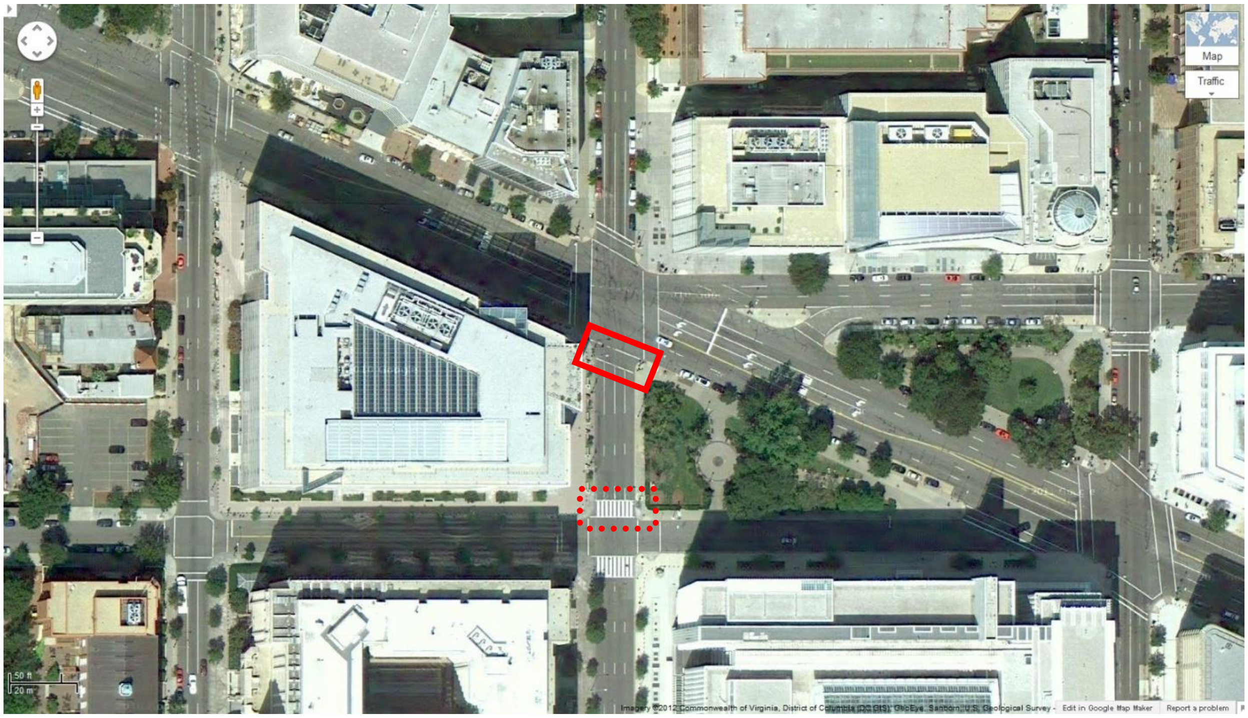
Fourteenth Street Northwest is a two-way street with traffic flowing north/south. There are three northbound travel lanes. A bus stop is located in the far right northbound lane near the intersection of 14th and New York. There are three southbound travel lanes, and an additional left turn lane that spans the entire block. A bus stop is located in the far right southbound lane near the intersection of 14th and G Streets.

The marked intersection of 14th Street and New York Avenue of interest (as highlighted by the solid rectangular box in figure 18) is 83 ft long (curb to curb). The walk phase is illuminated for 31 s, and the don't walk phase is illuminated for 56 s. Figure 19 shows the southernmost crossing of 14th Street Northwest at New York Avenue Northwest.

Figure 19. Photo. An image of the southernmost crossing of 14th Street Northwest at New York Avenue Northwest. The photo is taken from the northwestern corner of the intersection.

Location 7

The seventh data collection area is located at 19th Street Northwest and Pennsylvania Avenue Northwest in Washington, DC. An aerial view of this data collection area can be seen in figure 20. Nineteenth Street Northwest runs north/south and is located toward the center of the image. Pennsylvania Avenue Northwest runs northwest/southeast and is located near the center/top of the image. The solid red rectangle highlights the intersection of 19th Street Northwest and Pennsylvania Avenue Northwest. The dotted red rectangle highlights the intersection of 19th Street Northwest and H Street Northwest. The DDOT camera was positioned on the northwest corner of the 19th and Pennsylvania intersection facing south (see figure 21). As a result, pedestrians making east/west crossings on 19th Street between Pennsylvania Avenue and H Street were captured. The distance between Pennsylvania Avenue and H Street is approximately 145 ft. Figure 21 shows marked crossings are present at both Pennsylvania Avenue Northwest (solid red line) and H Street Northwest (dotted red line) along 19th Street Northwest. Unlike the first six collection sites, the far marked crosswalk is not controlled by a signal (nor is it controlled by a stop sign). The AADT in this area is 11.9 (expressed in thousands and rounded to the nearest 100).[18]



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 20. Photo. Aerial view of Location 7.[(25)]

The neighborhood surrounding Location 7 consists of mostly businesses. The west side of 19th Street contains a single, large office building. In addition, several large flower planters and seating areas prevent easy access to the roadway from the sidewalk (although it is not impossible to access the roadway). The east side of 19th Street contains a small park area that is blocked from the sidewalk access along 19th Street by shrubbery.

Figure 21. Photo. Still image captured from the Location 7 camera.

Nineteenth Street Northwest is a one-way street with traffic flowing south. There are three travel lanes and a single parking lane on the east side of the roadway. A bus stop is present on the western portion of the roadway. The roadway north of Pennsylvania (behind the camera view) contains two travel lanes and parking on both sides of the roadway.

The marked intersection of 19th Street and Pennsylvania Avenue of interest (as highlighted by the solid rectangular box in figure 21) is 43 ft long (curb to curb). The walk phase is illuminated for 44 s, and the don't walk phase is illuminated for 52 s. Figure 22 illustrates what a pedestrian might see as he or she attempts to cross from the west side of 19th Street Northwest to the east side of the street along Pennsylvania Avenue Northwest.

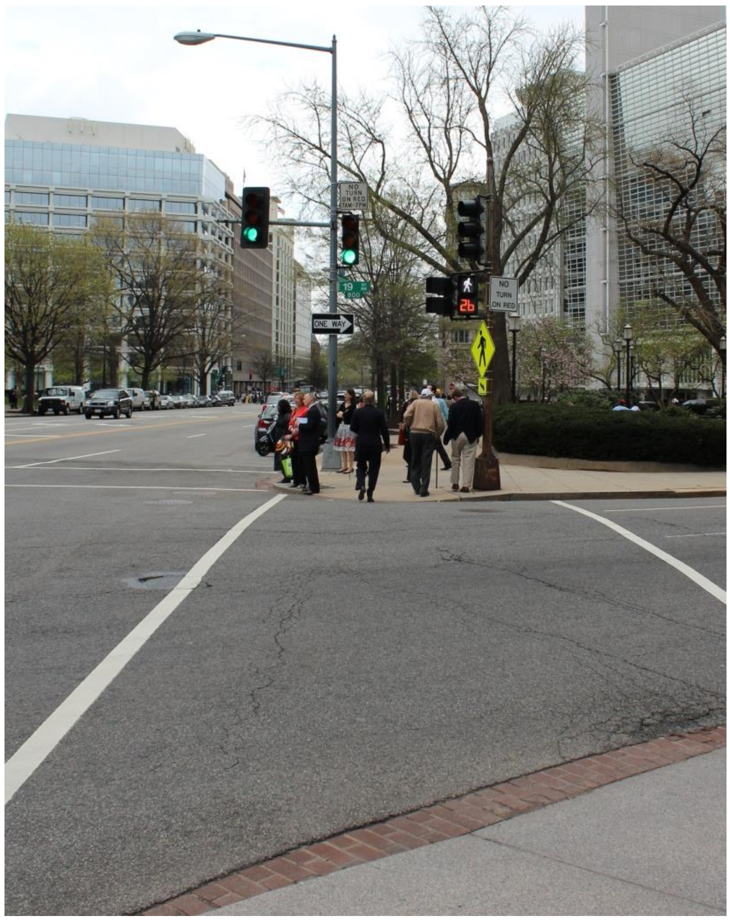
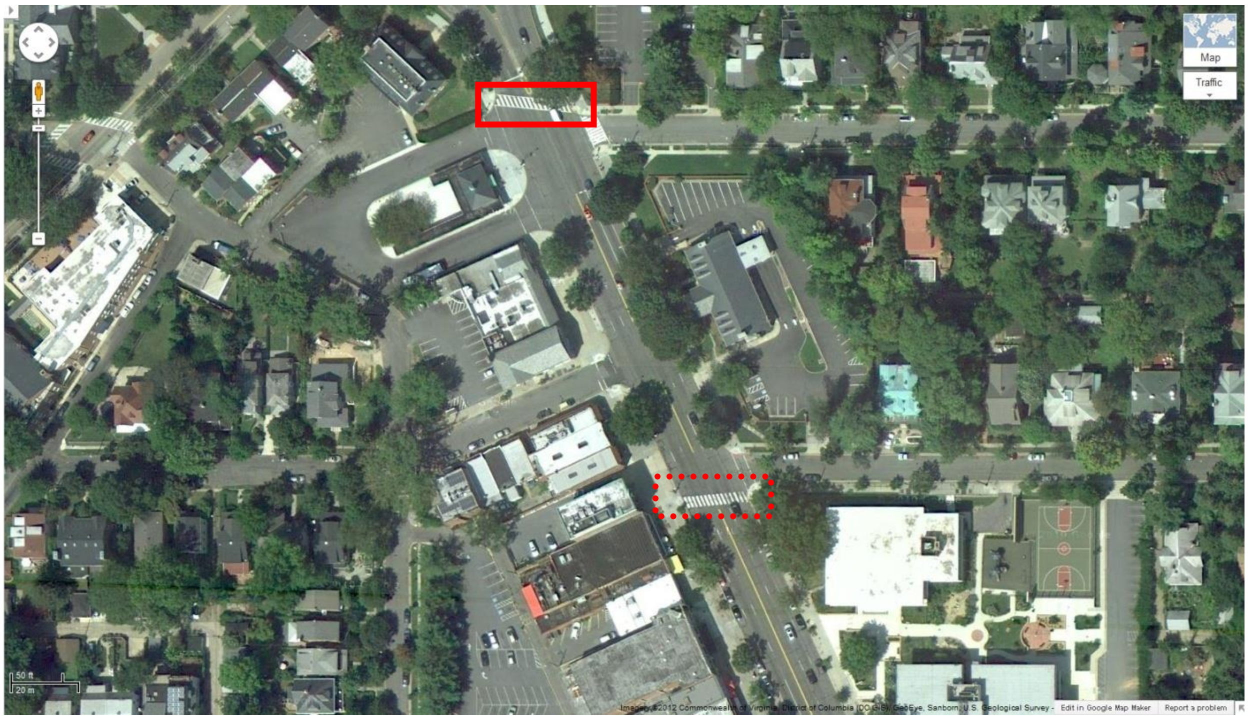


Figure 22. Photo. Illustration of what a pedestrian might see as he or she attempts to crossing from the west side of 19th Street Northwest to the east side of the street along Pennsylvania Avenue Northwest.

Location 8

The eighth data collection area is located at Connecticut Avenue Northwest and Oliver Street Northwest in Washington, DC. An aerial view of this data collection area can be seen in figure 23. Connecticut Avenue Northwest runs north/south and is located toward the center of the image. Oliver Street Northwest travels east/west and is located toward the top of the image. The solid red rectangle highlights the intersection of Oliver Street Northwest and Connecticut Avenue Northwest. The dotted red rectangle highlights the intersection of Northampton Street Northwest and Connecticut Northwest. The DDOT camera was positioned north of the

Connecticut and Oliver intersection facing south (see figure 24). As a result, pedestrians making east/west crossings on Connecticut Avenue between Oliver Street and Northampton Street Northwest were captured. The distance between Oliver Street and Northampton Street is approximately 433 ft. Figure 24 shows marked crossings are present at both Oliver Street Northwest (solid red line) and Northampton Street Northwest (dotted red line) along Connecticut Avenue Northwest. Unlike the first six data collection sites, the far marked crosswalk is not controlled by a signal (nor is it controlled by a stop sign). The far marked crossing uses a flag crossing system (see figure 25). The AADT in this area is 24.2 (expressed in thousands and rounded to the nearest 100).(18)



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 23. Photo. Aerial view of Location 8.(25)

The neighborhood surrounding Location 8 consists of a mix of businesses and homes. The west side of Connecticut Avenue contains banks, small restaurants, and other small businesses. The east side of 19th Street contains a bank. This area has a more suburban feel than the other seven urban environments in this phase.

Figure 24. Photo. Still image captured from the Location 8 camera.

Figure 25. Photo. An image of the (far) flag crossing at Connecticut Avenue Northwest and Northampton Street Northwest.

Connecticut Avenue Northwest is a two-way street flowing north/south. There are three northbound travel lanes and three southbound travel lanes. The marked intersection of Oliver Street and Connecticut Avenue of interest (as highlighted by the solid rectangular box in figure 24) is 70 ft long (curb to curb). The walk phase is illuminated for 19 s, and the don't walk phase is illuminated for 79 s. Figure 26 illustrates what a pedestrian might see as he or she attempts to cross from the west side of Connecticut Avenue Northwest to the east side of the street along Oliver Street Northwest.

Figure 26. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the west side of Connecticut Avenue Northwest to the east side of the street along Oliver Street Northwest.

DATA COLLECTION VALIDATION

Video recording pedestrian crossings is not a common method for assessing pedestrian behaviors. Further, to the authors' knowledge, no other studies have attempted to use existing traffic cameras/CCTV to assess pedestrian behavior. As such, it was deemed important to assess the validity of camera footage as a data collection methodology.

Researchers manually scored pedestrian crossing behaviors at Location 4 (13th Street and I Street Northwest) and Location 5 (14th Street and H Street Northwest) onsite. These two locations were selected for their physical proximity to one another. Researchers recorded the pedestrians' crossings and their interactions with vehicles (described in more detail in the next section) over three 15-min periods at both locations. The in-vivo recordings were made the morning of February 20, 2012 (President's Day). Unfortunately the camera recording Location 5 was facing the incorrect direction on this day. As a result, there is no video data to compare with the live, onsite scoring. However, the onsite pedestrian crossing scoring was compared with the DDOT video at Location 4.

At Location 4, there was a 100-percent agreement in the classification of the pedestrian crossings for both the first and last 15-min segments (18 and 21 crossings, respectively). However, in the second 15-min session, there was a single discrepancy; the onsite coding resulted in five total pedestrian crossings, and the video coding resulted in four crossings. The categorization of the four video crossings was the same as those in the in-vivo coding. This 98-percent agreement between the two coding methodologies provides evidence that video coding is a reliable methodology for coding and characterizing pedestrian crossing behaviors.

VIDEO DATA CODING

Many different types of pedestrian crossings and pedestrian interactions with vehicles in, and along, the roadway can be recorded and classified. Although it is difficult to code pedestrian crossings in an exhaustive manner, the current study sought to record enough information to interpret general crossing behaviors. For each pedestrian crossing, multiple factors were recorded. The following subsections describe each of these factors and how data were coded.

Crossing Factors

Data were coded between the marked intersection closest to the DDOT camera and a far marked intersection (as denoted in each of the location descriptions). Pedestrian crossings were not counted in the far marked intersections. Only completed crossings were recorded and included in data analysis. In other words, if a person walked partially into the roadway to hail a cab, it was not included as a pedestrian crossing.

Location/Crossing Area

The location where pedestrians crossed the road was classified in one of three categories:

- **Marked Intersection.** This included any crossing that occurred in any portion of the marked crosswalk at the intersection closest to the DDOT camera. Crossings within one car length of the marked crosswalk were also included in this category. This is simply because some of the marked intersections contained enough pedestrian traffic that all persons could not comfortably cross within the marked crosswalk.

- **Unmarked Intersection.** This was any crossing at an intersection without a marked crosswalk. This type of crossing only applied to Location 3.

- **Unmarked Non-Intersection.** This type of crossing refers to any pedestrian crossing that occurred at a non-intersection location without a marked crossing.

Traffic

The status of vehicular traffic was also noted.

- **With Traffic.** This is a crossing that does not conflict with traffic flow. An example is a crossing in the crosswalk with the walk sign activated.

- **Against Traffic.** This is a crossing that conflicts with traffic flow. An example is crossing in the crosswalk while oncoming traffic has a green light and the don't walk sign is activated. (The don't walk sign must be in the steady state to be counted as in the don't walk phase.)

- **Traffic Flow Change.** This is a crossing that starts either with or against traffic, but ends with the opposite traffic flow. An example of this type of crossing is one in which a pedestrian starts crossing the street with the don't walk sign activated and completes the crossing with the walk sign activated.

Yielding Behavior

Yielding behavior of both pedestrians and vehicles was recorded. A note on where the yielding occurred and the light status was recorded. Vehicle or pedestrian right of way can be established using this information. (Note that right-of-way laws vary by State. However, in the present context, the legality of the crossing is not considered.)

- **Pedestrian Yielding**. This was recorded when a pedestrian yielded to a vehicle. An example is a pedestrian pausing in the roadway to allow a turning vehicle to complete a turn, prior to the pedestrian completing a crossing.

- **Vehicle Yielding**. This was recorded when a vehicle yielded to a pedestrian. An example is a vehicle pausing mid-turn to allow a pedestrian to complete the crossing.

Evasive Pedestrian Actions

Actions made by pedestrians to avoid conflict or potential collisions were also recorded. A distinction between evasive actions in the first half and second half of the crossing was made.

- **Running/Accelerated Walking.** This was recorded when a pedestrian either ran or noticeably increased walking speed to avoid collision or potential conflict with a vehicle. Note that pedestrians who ran across the intersection, but were not taking evasive actions (e.g., joggers), were not coded as taking this type of evasive action.

- **Abrupt Stopping.** This was recorded when a pedestrian stopped abruptly in the roadway to avoid collision or potential conflict with a vehicle.

- **Directional Change.** This was recorded when a pedestrian changed travel direction, once in the roadway, to avoid collision or potential conflict with a vehicle. An example of this is a pedestrian stepping into the roadway and then subsequently returning to the curb (direction change) after noting an oncoming vehicle.

Evasive Vehicle Actions

Evasive actions taken by vehicles were also recorded. A distinction between evasive actions taken by the vehicle closest to the pedestrian and a following vehicle (if any) was made.

- **Abrupt Braking (First Vehicle).** This was recorded when a vehicle was forced to abruptly brake (not a gradual deceleration) to avoid collision with a pedestrian.

- **Abrupt Braking (Second Vehicle).** This was recorded when the action of the vehicle closest to the pedestrian required the next vehicle to brake abruptly to avoid collision.

- **Directional Change (First Vehicle).** This was recorded when a vehicle swerved (or otherwise modified direction) to avoid collision with a pedestrian.

- **Directional Change (Second Vehicle).** This was recorded when the action of the vehicle closest to the pedestrian required the next vehicle to modify direction to avoid collision.

Other Relevant Information

Other relevant information related to the pedestrian crossings was also recorded. For example, if an ambulance or presidential motorcade interrupted regular traffic flow, this was marked to accommodate potential irregular data coding.

Dates/Times Coded

Only sub-portions of the vast quantity of video recorded data were coded, owing to both time and project scope requirements of the current study. The scope of the present study included only daytime pedestrian crossings. As such, nighttime data were not examined.

Each of the eight cameras was coded for the entire day of February 9, 2012 (daytime hours only). The peak pedestrian traffic times were selected based on this information. As a result of pedestrian traffic and sunrise/sunset times, data were coded from 7:30 to 9:30 a.m., 11:30 to 1:30 p.m., and 4:00 to 5:00 p.m. Locations 1, 3, 4, 6, 7, and 8 were coded Monday through Friday, February 9 through February 21, 2012. Location 2 was not coded on February 10 or 13 because of a camera malfunction that resulted in a "frozen" image. In other words, no new feed from the camera was recorded. Location 5 was not coded after February 13 because the camera was facing a different direction that did not allow for data coding based on the previously mentioned location requirements.

Weather

Table 1 describes the weather and corresponding sunrise/sunset times for each of the days that data were coded.

Table 1. Relevant sunrise, sunset, and weather for each of the coded data collection days.

Date	Sunrise (a.m.)	Sunset (p.m.)	High Temperature (°F)	Low Temperature (°F)	General Weather	Precipitation Accumulation (inches)
2/09/2012	7:07	5:39	47	33	Partly Cloudy	—
2/10/2012	7:05	5:40	47	32	Rain	0.11
2/13/2012	7:02	5:43	49	24	Partly Cloudy	—
2/14/2012	7:01	5:44	56	38	Mostly Cloudy	—
2/15/2012	7:00	5:45	54	39	Windy	—
2/16/2012	6:58	5:46	47	42	Rain	.09
2/17/2012	6:57	5:48	54	39	Fog	—
2/20/2012	6:53	5:51	50	34	Partly Cloudy	—
2/21/2012	6:52	5:52	50	33	Windy	—

— Indicates no recorded precipitation.

Inter-Rater Reliability

Three different researchers coded the video data. Each of the researchers had been to the actual data collection/DDOT camera locations. To ensure that each rater was coding instances similarly, inter-rater reliability was assessed. Three randomly selected 5-min segments of video were coded by all three researchers. There was a 100-percent agreement among the raters. This is not to say that all three raters agreed on every crossing across all of the data. However, it does provide evidence that all three raters were using the same crossing factor definitions, and the video provided enough information to clearly identify the circumstances of the pedestrian crossings.

Each of the raters coded approximately one-third of the total video data in this phase.

RESULTS

The follow subsections describe the overall crossing behavior results from phase 1.

Descriptive Data

Table 2 summarizes the crossing behaviors recorded during the coded data collection times. All values are combined over all eight data collection locations. The following subsections explain the basic descriptive data for each of the eight locations in further detail.

Table 2. Summary of pedestrian crossings combined across all eight data collection locations.

		Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
	Total Crossings	Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	51,956	119	9,272	855	13	18	4	—	2	4
+traffic flow change	527	10	42	128	1	1	—	—	—	—
Don't Walk	5,480	4	15	334	68	41	1	—	—	—
+traffic flow change	1,041	17	7	27	13	1	—	—	—	—
Sum	***59,004***	***150***	***9,336***	***1,344***	***95***	***61***	***5***	**—**	***2***	***4***
Unmarked Non-Intersection										
With Traffic	2,924	16	16	109	5	5	1	—	—	—
+traffic flow change	120	4	2	18	—	—	—	—	—	—
Against Traffic	1,126	35	14	129	10	3	—	—	—	—
+traffic flow change	229	17	—	11	6	—	—	—	—	—
Sum	***4,399***	***72***	***32***	***267***	***21***	***8***	***1***	—	—	—
Unmarked Intersection										
With Traffic	954	3	1	9	—	—	—	—	—	—
+traffic flow change	84	3	3	5	—	1	—	—	—	—
Against Traffic	1,251	67	13	47	1	3	—	—	—	—
+traffic flow change	33	3	—	—	—	—	—	—	—	—
Sum	***2,322***	***76***	***17***	***61***	***1***	***4***	**—**	**—**	**—**	**—**
Grand Total	**65,725**	**298**	**9,385**	**1,672**	**117**	**73**	**6**	**—**	**2**	**4**

— Indicates no actions of this type were recorded.

Location 1

Total Crossings:

There were a total of 1,110 pedestrian crossings on H Street Northeast between 3rd and 4th Streets Northeast during the coded data collection times (a total of just over 48 h of video). (See table 3 for a summary of the crossings.) Of these crossings, 976 (or 87.93 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 834 pedestrians crossed the marked intersection. An additional 94 crossings occurred in the marked intersection during the don't walk phase. In addition, 48 crossings occurred in the marked intersection that included a traffic flow change. Of these crossings, eight began in the walk phase and ended in the don't walk phase. An additional 40 began in the don't walk phase and concluded in the walk phase. In other words, pedestrians who cross during a crosswalk light phase change were approximately equally likely to start the crossing during the don't walk phase as during the walk phase.

At Location 1, 134 (or 12.07 percent) of the total 1,110 crossings took place at the unmarked non-intersection areas. Of these crossings, 58 took place with traffic, and 64 took place against traffic. A portion of the pedestrian crossings that took place at an unmarked non-intersection area involved a traffic flow change. Five of these crossings began with traffic and ended against traffic, and seven began against traffic and ended with traffic.

Yielding:

In total, there were 45 yielding behaviors (combined across pedestrians and vehicles). In 34 instances, a vehicle yielded to a pedestrian crossing in the marked intersection during a walk phase. In other words, vehicles were appropriately yielding to the pedestrians crossing during the appropriate light phase. There was a single case where a pedestrian yielded to a vehicle while crossing in the marked intersection during a walk phase.

Ten pedestrian crossings with yielding occurred outside the marked intersection. In four cases, pedestrians yielded to vehicles in the unmarked non-intersection. In six instances, vehicles yielded to pedestrians who were crossing in the unmarked non-intersection.

Evasive Pedestrian Actions:

A total of 97 pedestrians took evasive actions at Location 1. (Note that some pedestrians took more than one evasive action, e.g., returning to the curb followed by running.) There were 29 instances of pedestrian running/accelerated walking while in the marked intersection during the walk phase. Although a pedestrian taking an evasive action while crossing the street during a walk phase in the marked intersection may seem counterintuitive, there were many instances of "courtesy" acceleration. In other words, it appeared that pedestrians would run, or accelerate, through a crossing to allow turning vehicles to complete their turn during the signal phase. There were 20 instances of pedestrian running/accelerated walking while in the marked intersection during the don't walk phase. In six instances, pedestrians ran/accelerated while in the marked intersection and a traffic flow change was involved. Of these, one began in the walk phase and was completed during the don't walk phase, and five began in the don't walk phase and were completed in the walk phase. In addition, there were 28 instances of running/accelerated walking while in an unmarked non-intersection area.

There were also eight instances where pedestrians abruptly stopped while crossing the roadway. In a single instance, a pedestrian abruptly stopped while walking in the marked intersection during the walk signal phase to yield to a vehicle. In two instances, pedestrians abruptly stopped while walking in the marked intersection during a traffic flow change (from the don’t walk phase to the walk phase). An additional four pedestrians abruptly stopped in the marked intersection during the don’t walk phase. Finally, four pedestrians stopped during crossings at unmarked non-intersection locations.

In five instances, pedestrians made a travel directional change (e.g., returned to the curb). One of these occurred at an unmarked non-intersection area, three occurred at the marked intersection during the don’t walk phase, and one occurred at the marked intersection during the walk phase.

Evasive Vehicle Actions:

In a total of two instances, a vehicle took an evasive action to avoid a potential collision with a pedestrian at Location 1. In one instance, a vehicle abruptly braked for a pedestrian crossing at an unmarked non-intersection area. In the second instance, a vehicle abruptly braked for a pedestrian crossing marked intersection during the don’t walk phase.

Table 3. Summary of pedestrian crossings at Location 1.

	Total Crossings	Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
		Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	834	1	34	29	1	1	—	—	—	—
+traffic flow change	8	—	—	1	—	—	—	—	—	—
Don't Walk	94	—	—	20	4	3	1	—	—	—
+traffic flow change	40	—	—	5	2	—	—	—	—	—
Sum	***976***	***1***	***34***	***55***	***7***	***4***	***1***	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	58	2	3	11	—	—	1	—	—	—
+traffic flow change	5	1	—	—	—	—	—	—	—	—
Against Traffic	64	—	3	16	3	1	—	—	—	—
+traffic flow change	7	1	—	1	1	—	—	—	—	—
Sum	***134***	***4***	***6***	***28***	***4***	***1***	***1***	**—**	**—**	**—**
Location 1 Total	**1,110**	**5**	**40**	**83**	**11**	**5**	**2**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 2

Total Crossings:

There were a total of 4,631 pedestrian crossings on New York Avenue Northwest between 7th Street Northwest and 6th Street Northwest during the coded data collection times. (See table 4 for a summary of the crossings.) Location 2 was not coded on February 10 or 13 because of a camera malfunction that resulted in a "frozen" image. In other words, no new feed from the camera was recorded during this time frame. Of the recorded and coded crossings, 4,228 (or 91.3 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 4,071 pedestrians crossed entirely within the near marked intersection. An additional 81 crossings occurred entirely in the marked intersection during the don't walk phase. In addition, 76 crossings occurred in the marked intersection and included a traffic flow change. Of these crossings, 52 began in the walk phase and ended in the don't walk phase. An additional 24 began in the don't walk phase and concluded in the walk phase. In other words, pedestrians who crossed during a crosswalk light phase change were more likely to start the crossing during the walk phase than the don't walk phase.

At Location 2, 403 (or 8.7 percent) of the total 4,631 crossings took place at unmarked non-intersection areas. Of these crossings, 289 took place entirely with traffic, and 74 took place entirely against traffic. A portion of the pedestrian crossings that took place at an unmarked non-intersection area involved a traffic flow change. Fourteen of these crossings began with traffic and ended against traffic, and 26 began against traffic and ended with traffic.

Yielding:

In total, there were 342 yielding behaviors (combined across pedestrians and vehicles) at Location 2. In 294 instances, a vehicle yielded to a pedestrian in the marked intersection during a walk phase. In five instances, a pedestrian yielded to a vehicle while crossing in the marked intersection during a walk phase. In addition, seven pedestrian crossings took place in the marked intersection area and involved a traffic flow change. Of these crossings, one began in the walk phase and ended in the don't walk phase. An additional six began in the don't walk phase and concluded in the walk phase.

There were 25 instances of a pedestrian yielding to a vehicle while crossing at an unmarked non-intersection location.

Evasive Pedestrian Actions:

A total of 268 pedestrians took evasive actions at Location 2. There were 198 instances of pedestrian running/accelerated walking while in the marked intersection during the walk phase. There were also 13 instances of pedestrian running/accelerated walking while in the marked intersection during the don't walk phase. In addition, 14 pedestrians crossed during a traffic flow change in the marked intersection. Two people began crossing during the don't walk phase and completed during the walk phase, and 12 began crossing during the walk phase and completed the crossing during the don't walk phase. In addition, 25 pedestrians ran/accelerated at an unmarked non-intersection area.

In addition, in 16 cases, pedestrians abruptly stopped while crossing the roadway. In two instances, pedestrians abruptly stopped while walking in the marked intersection during the walk signal phase to yield to a vehicle. Three pedestrians abruptly stopped in the marked intersection during the don't walk phase. There were also three cases of abruptly stopping during a traffic flow change, one during the walk phase and completed the crossing during the don't walk phase, and two that began crossing during the don't walk phase and completed during the walk phase. Eight pedestrians abruptly stopped while crossing in an unmarked non-intersection location.

In six instances, pedestrians made a travel directional change (i.e., returned to the curb). Two of these occurred in the marked intersection during the walk phase, and the remaining four occurred at an unmarked non-intersection area.

Evasive Vehicle Actions:

In a total of 10 instances, a vehicle took an evasive action to avoid a potential collision with a pedestrian at Location 2. All 10 of these instances occurred while the pedestrians were crossing at the marked intersection during the walk phase.

Table 4. Summary of pedestrian crossings at Location 2.

		Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
	Total Crossings	Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	4,071	5	294	198	2	2	4	—	2	4
+traffic flow change	52	1	—	12	1	—	—	—	—	—
Don't Walk	81	—	—	13	3	—	—	—	—	—
+traffic flow change	24	6	—	2	2	—	—	—	—	—
Sum	***4,228***	***12***	***294***	***225***	***8***	***2***	***4***	**—**	***2***	***4***
Unmarked Non-Intersection										
With Traffic	289	6	—	8	3	3	—	—	—	—
+traffic flow change	14	1	—	—	—	—	—	—	—	—
Against Traffic	74	9	—	13	2	1	—	—	—	—
+traffic flow change	26	9	—	4	3	—	—	—	—	—
Sum	***403***	***25***	**—**	***25***	***8***	***4***	**—**	**—**	**—**	**—**
Location 2 Total	**4,631**	**37**	**294**	**250**	**16**	**6**	**4**	**—**	**2**	**4**

— Indicates that no actions of this type were recorded.

Location 3

Total Crossings:

There were a total of 5,200 pedestrian crossings on Rhode Island Avenue Northwest between 7th Street Northwest and 6th Street Northwest during the coded data collection times. (See table 5 for a summary of the crossings.) Of these crossings, 2,646 (or 50.9 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into where they occurred during the light phases. During the walk phase, 2,317 pedestrians crossed within the near marked intersection. An additional 298 crossings occurred in the marked intersection during the don't walk phase. In addition, 31 crossings occurred in the marked intersection that included a traffic flow change. Of these crossings, 20 began in the walk phase and ended in the don't walk phase. An additional 11 began in the don't walk phase and concluded in the walk phase. In other words, pedestrians who crossed during a crosswalk light phase change were more likely to start the crossing during the walk phase than the don't walk phase.

At Location 3, 232 (or 4.5 percent) of the total 5,200 crossing took place at unmarked non-intersection areas. Of these crossings, 60 took place with traffic; 5 of these included the pedestrian waiting on the median (4 included a traffic flow change to against traffic). The remaining 172 crossings that took place at an unmarked non-intersection location occurred against traffic, 77 of which included the pedestrian waiting on the median. (Five included a traffic flow change to with traffic.)

Pedestrian crossings at the unmarked intersection of Marion Street Northwest and Rhode Island Avenue Northwest were also recorded. Marion Street is located to the south of Rhode Island Avenue. Northbound Marion Street traffic must turn (either right or left) when it meets Rhode Island Avenue. This intersection does not contain a marked pedestrian crossing. There were 2,322 crossings (or 44.7 percent of the 5,200 total crossings) at this unmarked intersection. Of these, 954 occurred with traffic; 42 included the pedestrian waiting on the median. An additional 84 crossings took place with traffic, but concluded against traffic; 48 of these crossings included the pedestrian waiting on the median. A further 1,251 crossings at the unmarked intersection occurred against traffic; 855 of these crossings included the pedestrian waiting on the median. The remaining 33 crossings involved a traffic flow change where pedestrians began crossing against traffic and concluded the crossing with traffic; 15 of these crossings included the pedestrian waiting on the median. In total, 960 (or 41 percent) of the 2,322 crossings that occurred at the unmarked intersection involved the pedestrian waiting on the median.

Yielding:

In total, there were 105 yielding behaviors (combined across pedestrians and vehicles) at Location 3. None of these occurred while a pedestrian was in the marked intersection.

There were 11 crossings where pedestrians yielded to vehicles at unmarked non-intersection locations. There was a single instance where a vehicle yielded to pedestrian at an unmarked non-intersection area.

In 76 instances, pedestrians yielded to vehicles at the unmarked intersection. In an additional 17 cases, a vehicle yielded to a pedestrian at the unmarked intersection.

Evasive Pedestrian Actions:

A total of 113 pedestrians took evasive actions. There were four instances of pedestrian running/accelerated walking while in the marked intersection during the walk phase. An additional four pedestrians began crossing during the walk phase but completed their crossing in the don't walk phase, who ran/accelerated while in the marked intersection. Nineteen pedestrians ran/accelerated while crossing at the marked intersection during the don't walk phase. In addition, 17 pedestrians ran/accelerated while crossing at unmarked non-intersection locations. At the unmarked intersection, 61 pedestrians ran/accelerated through the crossing.

In a total of three instances, the pedestrian abruptly stopped to avoid a potential collision with a vehicle. Of these, two occurred during the don't walk phase in the marked intersection, and one took place in the unmarked intersection.

On six occasions, pedestrians made a travel directional change (i.e., returned to the curb). One occurred in the marked intersection during the walk phase, one occurred at an unmarked non-intersection location, and the remained four took place at the unmarked intersection.

Evasive Vehicle Actions:

No vehicle evasive actions were recorded during the data collection period at Location 3.

Table 5. Summary of pedestrian crossings at Location 3.

	Total Crossings	Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
		Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	2,317	—	—	4	—	1	—	—	—	—
+traffic flow change	20	—	—	4	—	—	—	—	—	—
Don't Walk	298	—	—	19	2	—	—	—	—	—
+traffic flow change	11	—	—	—	—	—	—	—	—	—
Sum	***2,646***	**—**	**—**	***27***	***2***	***1***	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	52	—	—	2	—	—	—	—	—	—
+traffic flow change	8	—	—	—	—	—	—	—	—	—
Against Traffic	164	9	1	14	—	1	—	—	—	—
+traffic flow change	8	2	—	1	—	—	—	—	—	—
Sum	***232***	***11***	***1***	***17***	**—**	***1***	**—**	**—**	**—**	**—**
Unmarked Intersection										
With Traffic	954	3	1	9	—	—	—	—	—	—
+traffic flow change	84	3	3	5	—	1	—	—	—	—
Against Traffic	1,251	67	13	47	1	3	—	—	—	—
+traffic flow change	33	3	—	—	—	—	—	—	—	—
Sum	***2,322***	***76***	***17***	***61***	***1***	***4***	**—**	**—**	**—**	**—**
Location 3 Total	**5,200**	**87**	**18**	**105**	**3**	**6**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 4

Total Crossings:

There were a total of 13,199 pedestrian crossings on I (eye) Street Northwest between 13th and 14th Streets northwest during the coded data collection times. (See table 6 for a summary of crossings.) Of these crossings, 12,034 (or 91.2 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 8,973 pedestrians crossed within the near marked intersection. An additional 2,361 crossings occurred in the marked intersection during the don't walk phase. In addition, 700 crossings occurred in the marked intersection and included a traffic flow change. Of these crossings, 94 began in the walk phase and ended in the don't walk phase. An additional 606 began in the don't walk phase and concluded in the walk phase. In other words, pedestrians were more likely to begin their crossing during the don't walk phase than the walk phase.

At Location 4, 1,165 (or 8.8 percent) of the total 13,199 crossings took place at unmarked non-intersection areas. Of these crossings, 710 took place with traffic, and 365 took place against traffic. A portion of the pedestrian crossings that took place at an unmarked non-intersection area involved a traffic flow change. Twenty-two of these crossings began with traffic and ended against traffic, and 68 began against traffic and ended with traffic.

Yielding:

In total, there were 2,693 yielding behaviors (combined across pedestrians and vehicles) at Location 4. In 15 cases, the pedestrian yielded to the vehicle in the marked intersection during the walk phase. In 2,681 instances, a vehicle yielded to a pedestrian in the marked intersection during the walk phase.

In addition, there were 11 instances of yielding behavior while pedestrians crossed during a traffic flow change. In six of these cases, the pedestrians began crossing during the don't walk phase and completed the crossing during the walk phase and vehicles yielded to the pedestrian. In three cases, pedestrians yielded to vehicles after beginning to cross during the don't walk phase and completing the crossing the walk phase. In the remaining two instances, pedestrians that began their crossing during the walk phase and completed it during the don't walk phase yielded to vehicles in the marked intersection.

Evasive Pedestrian Actions:

A total of 288 pedestrians took evasive actions. There were 136 instances of pedestrian running/accelerated walking while in the marked intersection during the walk phase. An additional 12 pedestrians who began crossing during the walk phase but completed their crossing in the don't walk phase, ran/accelerated while in the marked intersection. During the don't walk phase, 104 pedestrians ran/accelerated while crossing at the marked intersection. An additional six pedestrians began crossing during the don't walk phase but completed during the walk phase while running/accelerated walking. While in the unmarked non-intersection, 16 pedestrians ran/accelerated while completing their crossing.

In a total of 10 instances, the pedestrian abruptly stopped to avoid a potential collision with a vehicle. Of these, four occurred during the walk phase in the marked intersection. Three crossings occurred entirely during the don’t walk phase. An additional three pedestrians abruptly stopped in the marked intersection after beginning crossing during the don’t walk phase and completed during the walk phase.

In five instances, pedestrians made a travel directional change. Of these, three occurred in the marked intersection during the walk phase, one occurred in the marked intersection during the don’t walk phase, and one occurred in an unmarked non-intersection location.

Evasive Vehicle Actions:

No vehicle evasive actions were recorded during the data collection period at Location 4.

Table 6. Summary of pedestrian crossings at Location 4.

		Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
	Total Crossings	Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	8,973	15	2,681	136	4	3	—	—	—	—
+traffic flow change	94	2	12	12	—	—	—	—	—	—
Don't Walk	2,361	—	—	104	3	1	—	—	—	—
+traffic flow change	606	3	6	6	3	—	—	—	—	—
Sum	***12,034***	***20***	***2,687***	***258***	***10***	***4***	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	710	1	5	9	—	1	—	—	—	—
+traffic flow change	22	—	—	—	—	—	—	—	—	—
Against Traffic	365	—	1	7	—	—	—	—	—	—
+traffic flow change	68	—	—	—	—	—	—	—	—	—
Sum	***1,165***	***1***	***6***	***16***	**—**	***1***	**—**	**—**	**—**	**—**
Location 4 Total	**13,199**	**21**	**2,693**	**274**	**10**	**5**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 5

Total Crossings:

There were a total of 10,635 pedestrian crossings on H Street Northwest between 14th and 15th Streets Northwest during the coded data collection times. (See table 7 for a summary of crossings.) Location 5 was not coded after February 13 because the camera was facing a different direction. Of the coded crossings, 10,032 (or 94.3 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 9,936 pedestrians crossed within the near marked intersection. An additional 52 crossings occurred in the marked intersection during the don't walk phase. In addition, 44 crossings occurred in the marked intersection that included a traffic flow change. Of these, 39 began in the walk phase and ended in the don't walk phase. Five crossings began in the don't walk phase and concluded in the walk phase.

At Location 5, 603 (or 5.7 percent) of the total 10,635 pedestrian crossing took place at unmarked non-intersection areas. Of these crossings, 552 took place with traffic, and 35 took place against traffic. A portion of the pedestrian crossings that took place at an unmarked non-intersection area involved a traffic flow change. Fifteen of these crossings began with traffic and ended against traffic, while one began against traffic and ended with traffic.

Yielding:

There were a total of 19 yielding behaviors (combined across pedestrians and vehicles) at Location 5. In three cases, pedestrians yielded to vehicles, and in a single case, a vehicle yielded to a pedestrian in the marked intersection during the walk phase. In addition, in 11 instances a vehicle yielded to a pedestrian in the marked intersection that involved a traffic flow change; in each, the pedestrian began his or her crossing during the walk phase and concluded during the don't walk phase.

In two instances, a pedestrian yielded to a vehicle, and in two instances, a vehicle yielded to a pedestrian in an unmarked non-intersection area.

Evasive Pedestrian Actions:

A total of 235 pedestrians took evasive actions. There were 163 instances of pedestrian running/accelerated walking while in the marked intersection during the walk phase. An additional 29 pedestrians, who began crossing during the walk phase but completed their crossing in the don't walk phase, ran/accelerated while in the marked intersection. During the don't walk phase, 13 pedestrians ran/accelerated while crossing at the marked intersection. An additional two pedestrians, who began crossing during the don't walk phase but completed their crossing in the walk phase, ran/accelerated while in the marked intersection. Nineteen pedestrians ran/accelerated while crossing in an unmarked non-intersection area.

In a total of five instances, the pedestrian abruptly stopped to avoid a potential collision with a vehicle. Of these, two occurred during the walk phase in the marked intersection. Two crossings occurred during the don't walk phase, and a single pedestrian abruptly stopped while crossing at an unmarked non-intersection location.

In eight instances, pedestrians made a travel directional change. Of these, four occurred in the marked intersection during the walk phase, and four occurred in the marked intersection during the don’t walk phase.

Evasive Vehicle Actions:

No vehicle evasive actions were recorded during the data collection period at Location 5.

Table 7. Summary of pedestrian crossings at Location 5.

	Total Crossings	Yielding: Pedestrian	Yielding: Vehicle	Evasive Pedestrian Actions: Running/ Accelerated Walking	Evasive Pedestrian Actions: Abrupt Stopping	Evasive Pedestrian Actions: Directional Change	Evasive Vehicle Actions: Abrupt Braking (1st Vehicle)	Evasive Vehicle Actions: Abrupt Braking (2nd Vehicle)	Evasive Vehicle Actions: Directional Change (1st Vehicle)	Evasive Vehicle Actions: Directional Change (2nd Vehicle)
Intersection										
Walk	9,936	3	1	163	2	4	—	—	—	—
+traffic flow change	39	—	11	29	—	—	—	—	—	—
Don't Walk	52	—	—	13	2	4	—	—	—	—
+traffic flow change	5	—	—	2	—	—	—	—	—	—
Sum	***10,032***	***3***	***12***	***207***	***4***	***8***	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	552	1	1	11	1	—	—	—	—	—
+traffic flow change	15	—	1	3	—	—	—	—	—	—
Against Traffic	35	1	—	5	—	—	—	—	—	—
+traffic flow change	1	—	—	—	—	—	—	—	—	—
Sum	***603***	***2***	***2***	***19***	***1***	**—**	**—**	**—**	**—**	**—**
Location 5 Total	**10,635**	**5**	**14**	**226**	**5**	**8**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 6

Total Crossings:

There were a total of 16,418 pedestrian crossings on 14th Street Northwest between New York Avenue Northwest and G Street Northwest during the coded data collection times. (See table 8 for a summary of crossings.) Of these crossings, 15,312 (or 93.3 percent) occurred within the marked intersection. These crossings can be broken down into when they occurred during the light phases. During the walk phase, 14,879 pedestrians crossed within the marked intersection. An additional 151 crossings occurred in the marked intersection during the don't walk phase. In addition, 282 crossings occurred in the marked intersection and included a traffic flow change. Of these, 135 began in the walk phase and ended in the don't walk phase. An additional 147 crossings began in the don't walk phase and concluded in the walk phase.

At Location 6, 1,106 (or 6.7 percent) of the total 16,418 crossings took place at unmarked non-intersection areas. Of these crossings, 767 took place with traffic, and 183 took place against traffic. A portion of the pedestrian crossings that took place at an unmarked non-intersection area involved a traffic flow change. Forty-five of these crossings began with traffic and ended against traffic, while 111 began against traffic and ended with traffic.

Yielding:

There were a total of 1,357 yielding behaviors (combined across pedestrians and vehicles) at Location 6. In 22 cases, pedestrians yielded to vehicles, and in 1,300 cases, vehicles yielded to pedestrians in the marked intersection during the walk phase. There were also eight instances of yielding that involved a traffic flow change in the marked intersection. In a single instance, a vehicle yielded to the pedestrian, who began the crossing during the walk phase and concluded during the don't walk phase in the marked intersection. In seven cases, the pedestrian yielded to a vehicle in a crossing that began during the don't walk phase of and concluded during the walk phase.

In 26 cases, pedestrians yielded to vehicles in an unmarked non-intersection area. In a single instance, a vehicle yielded to a pedestrian in an unmarked non-intersection.

Evasive Pedestrian Actions:

A total of 416 pedestrians took evasive actions. There were 263 instances of pedestrian running/walking while in the marked intersection during the walk phase. An additional 38 pedestrians, who began crossing during the walk phase but completed their crossing in the don't walk phase, ran/accelerated while in the marked intersection. During the don't walk phase, 31 pedestrians ran/accelerated while crossing at the marked intersection. An additional eight pedestrians, who began crossing during the don't walk phase but completed their crossing in the walk phase, ran/accelerated while in the marked intersection. Fifty-eight pedestrians ran/accelerated while crossing in an unmarked non-intersection area.

In a total of 13 instances, the pedestrian abruptly stopped to avoid a potential collision with a vehicle. Of these, four occurred during the walk phase, and four occurred during the don't walk phase in the marked intersection. Two additional cases involved a traffic flow change;

pedestrians began their crossing during the don’t walk phase and concluded during the walk phase. Three pedestrians abruptly stopped while crossing at an unmarked non-intersection location.

In 11 instances, pedestrians made a travel directional change. Of these, six occurred in the marked intersection during the walk phase, and four occurred in the marked intersection during the don’t walk phase. A single directional change instance involved a traffic flow change; the pedestrian began crossing during the don’t walk phase and concluded during the walk phase.

Evasive Vehicle Actions:

No vehicle evasive actions were recorded during the data collection period at Location 6.

Table 8. Summary of pedestrian crossings at Location 6.

		Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
	Total Crossings	Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	14,879	22	1,300	263	4	6	—	—	—	—
+traffic flow change	135	—	1	38	—	—	—	—	—	—
Don't Walk	151	—	—	31	4	4	—	—	—	—
+traffic flow change	147	7	—	8	2	1	—	—	—	—
Sum	***15,312***	***29***	***1,301***	***340***	***10***	***11***	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	767	5	1	22	1	—	—	—	—	—
+traffic flow change	45	1	—	11	—	—	—	—	—	—
Against Traffic	183	15	—	21	—	—	—	—	—	—
+traffic flow change	111	5	—	4	2	—	—	—	—	—
Sum	***1,106***	***26***	***1***	***58***	***3***	**—**	**—**	**—**	**—**	**—**
Location 6 Total	**16,418**	**55**	**1,302**	**398**	**13**	**11**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 7

Total Crossings:

There were a total of 12,958 crossings on 19th Street Northwest between Pennsylvania Avenue Northwest and H Street Northwest during the coded data collection times. (See table 9 for a summary of crossings.) Of these crossings, 12,567 (or 97.0 percent) occurred within the marked intersection. These crossings can be broken down into when they occurred during the light phases. During the walk phase, 9,778 pedestrians crossed within the marked intersection. An additional 2,422 crossings occurred in the marked intersection during the don't walk phase. In addition, 367 crossings occurred in the marked intersection and included a traffic flow change. Of these, 169 began in the walk phase and ended in the don't walk phase. A further 198 crossings began in the don't walk phase and concluded in the walk phase.

At Location 7, 391 (or 3.0 percent) of the total 12,958 crossings took place at unmarked non-intersection areas. Of these crossings, 235 took place with traffic, and 155 took place against traffic. Four crossings included a traffic flow change. A single pedestrian crossing began with traffic and ended against traffic, while three crossings began against traffic and ended with traffic.

Yielding:

There were a total of 5,100 yielding behaviors (combined across pedestrians and vehicles) at Location 7. In 72 instances, pedestrians yielded to vehicles, and in 4,958 cases, a vehicle yielded to a pedestrian in the marked intersection during the walk phase. There were also four cases where a pedestrian yielded to a vehicle and 15 cases where a vehicle yielded to a pedestrian in the marked intersection during the don't walk phase.

There were 37 instances of yielding that involved a traffic flow change in the marked intersection. In 28 instances, a vehicle yielded to the pedestrian, who began the crossing during the walk phase and concluded during the don't walk phase in the marked intersection. In seven cases, the pedestrian yielded to a vehicle in a crossing that began during the walk phase and concluded during the don't walk phase. There were two instances of yielding for pedestrians who began crossing during the don't walk phase and concluded during the walk phase; once the pedestrian yielded to the vehicle and once the vehicle yielded to the pedestrian.

In two cases, pedestrians yielded to vehicles in an unmarked non-intersection area. In 12 instances, a vehicle yielded to a pedestrian in an unmarked non-intersection.

Evasive Pedestrian Actions:

A total of 264 pedestrians took evasive actions. There were 22 instances of pedestrian running/accelerated walking while in the marked intersection during the walk phase. An additional 25 pedestrians, who began crossing during the walk phase but completed their crossing in the don't walk phase, ran/accelerated while in the marked intersection. During the don't walk phase, 126 pedestrians ran/accelerated while crossing at the marked intersection. Thirty-two pedestrians ran/accelerated while crossing in an unmarked non-intersection area.

In a total of 51 instances, the pedestrian abruptly stopped to avoid a potential collision with a vehicle. Of these, 49 occurred during the don't walk phase in the marked intersection. In a single case that involved a traffic flow change, the pedestrian began crossing during the don't walk phase and concluded during the walk phase. A single pedestrian abruptly stopped while crossing at an unmarked non-intersection location.

In 31 instances, pedestrians made a travel directional change. Of these, 29 occurred in the marked intersection during the don't walk phase. A single directional change instance involved a pedestrian who began crossing during the walk phase in the marked intersection. A single pedestrian had a directional change while crossing at an unmarked non-intersection location.

Evasive Vehicle Actions:

No vehicle evasive actions were recorded during the data collection period at Location 7.

Table 9. Summary of pedestrian crossings at Location 7.

		Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
	Total Crossings	Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	9,778	72	4,958	22	—	—	—	—	—	—
+traffic flow change	169	7	28	25	—	—	—	—	—	—
Don't Walk	2,422	4	15	126	49	—	—	—	—	—
+traffic flow change	198	1	1	—	1	—	—	—	—	—
Sum	***12,567***	***84***	***5,002***	***173***	***50***	**—**	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	235	1	5	10	—	—	—	—	—	—
+traffic flow change	1	—	—	—	—	—	—	—	—	—
Against Traffic	155	1	7	22	1	—	—	—	—	—
+traffic flow change	3	—	—	—	—	—	—	—	—	—
Sum	***391***	***2***	***12***	***32***	***1***	**—**	**—**	**—**	**—**	**—**
Location 7 Total	**12,958**	**86**	**5,014**	**205**	**51**	**—**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 8

Total Crossings:

There were a total of 1,574 crossings on Connecticut Avenue between Oliver Street and Northampton Street Northwest during the coded data collection times. (See table 10 for a summary of crossings.) Of these crossings, 1,209 (or 76.8 percent) occurred within the marked intersection. These crossings can be broken down into when they occurred during the light phases. During the walk phase, 1,168 pedestrians crossed within the marked intersection. An additional 21 crossings occurred in the marked intersection during the don’t walk phase. In addition, 20 crossings occurred in the marked intersection and included a traffic flow change. Of these, 10 began in the walk phase and ended in the don’t walk phase. An additional 10 crossings began in the don’t walk phase and concluded in the walk phase.

At Location 7, 365 (or 23.2 percent) of the total 1,574 crossings took place at unmarked non-intersection areas. Of these crossings, 261 took place with traffic, and 86 took place against traffic. A portion of the pedestrian crossings that took place at an unmarked non-intersection area involved a traffic flow change. Ten of these crossings began with traffic and ended against traffic, while eight began against traffic and ended with traffic.

In 12 instances, a pedestrian waited in the median to complete a crossing at Location 8. Three of these occurred when pedestrians crossed during the don’t walk phase in the marked intersection. There were also nine crossings involving waiting on the median that occurred in the marked intersection and included a traffic flow change. Two of these crossings began with traffic and ended against traffic, and six began against traffic and ended with traffic. In a single case, a pedestrian waited in the median area when crossing at an unmarked non-intersection location.

Yielding:

There were a total of 12 yielding behaviors (combined across pedestrians and vehicles) at Location 8. In a single instance, a pedestrian yielded to a vehicle, and in four cases, a vehicle yielded to a pedestrian in the marked intersection during the walk phase. Two instances of yielding involved a traffic flow change in the marked intersection. In both instances, a vehicle yielded to the pedestrian who began the crossing during the walk phase and concluded during the don’t walk phase in the marked intersection.

In a single case, a pedestrian yielded to a vehicle in an unmarked non-intersection area. In four instances, a vehicle yielded to a pedestrian in an unmarked non-intersection.

Evasive Pedestrian Actions:

A total of 136 pedestrians took evasive actions at Location 8. There were 40 instances of pedestrian running/accelerated walking while in the marked intersection during the walk phase. An additional seven pedestrians, who began crossing during the walk phase but completed their crossing in the don’t walk phase, ran/accelerated while in the marked intersection. During the don’t walk phase, eight pedestrians ran/accelerated while crossing at the marked intersection. An additional four pedestrians began crossing during the don’t walk phase, but completed their crossing in the walk phase, ran/accelerated while in the marked intersection. Seventy-two pedestrians ran/accelerated while crossing in an unmarked non-intersection area.

In a total of eight instances, the pedestrian abruptly stopped to avoid a potential collision with a vehicle. Of these, one occurred during the don’t walk phase in the marked intersection. In three cases that involved a traffic flow change, the pedestrian began crossing during the don’t walk phase and concluded during the walk phase. Four pedestrians abruptly stopped while crossing at an unmarked non-intersection location.

There was a single instance of a pedestrian directional change. In this case, there was a traffic flow change where the pedestrian began crossing during the walk phase and completed the crossing during the don’t walk phase.

Evasive Vehicle Actions:

No vehicle evasive actions were recorded during the data collection period at Location 8.

Table 10. Summary of pedestrian crossings at Location 8.

	Total Crossings	Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
		Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	1,168	1	4	40	—	—	—	—	—	—
+traffic flow change	10	—	2	7	—	1	—	—	—	—
Don't Walk	21	—	—	8	1	—	—	—	—	—
+traffic flow change	10	—	—	4	3	—	—	—	—	—
Sum	***1,209***	***1***	***6***	***59***	***4***	***1***	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	261	—	1	36	—	—	—	—	—	—
+traffic flow change	10	1	1	4	—	—	—	—	—	—
Against Traffic	86	—	2	31	4	—	—	—	—	—
+traffic flow change	8	—	—	1	—	—	—	—	—	—
Sum	***365***	***1***	***4***	***72***	***4***	**—**	**—**	**—**	**—**	**—**
Location Total	**1,574**	**2**	**10**	**131**	**8**	**1**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Predictive Model

It was hoped that the results of this study might be used to develop a model that would predict whether a pedestrian would cross at a marked intersection or an unmarked non-intersection based on the features of the environment. Several approaches were taken to model the data.

Location 3 contained a significant proportion of crossings at the unmarked intersection, which made it significantly different than the other seven data collection areas (which did not include this type of crossing). As a result, Location 3 was excluded from all modeling presented in this section.

Training and testing data sets were created from the raw data. The training data is used to build predictions about the testing data. (All data are drawn from the original raw data set of 65,725 crossings.) To generate the training data set, a stratified random sample without replacement was performed using PROC SURVEYSELECT in SAS®. Location (i.e., marked intersection or unmarked non-intersection) was the stratifying variable. Approximately 70 percent of the raw data was selected for the training data set, and the remaining 30 percent was assigned to the testing data set.

Of the 42,231 observations selected for the training data set, about 93 percent involved pedestrians crossing at marked intersections. Hence, unmarked non-intersection crossings were considered a rare event. One technique to handle the occurrence of rare events is to over sample the rare events in the training data set. This methodology was used here.

Ten subsets of the training data set were created. Each subset was designed so that 50 percent of the observations involved marked intersection crossings and the remaining 50 percent of the observations involved unmarked non-intersection crossings. All 2,893 unmarked non-intersection crossings from the original training set were included in each training subset. To generate the remaining observations for each subset, 2,893 observations were randomly selected using a simple random sample without replacement from the 39,338 marked intersection crossings in the original training set. This process did not involve stratifying by location. Each subset contained a different set of marked intersection crossings. Thus, each training subset contained 5,786 observations.

PROC GLMSELECT was used to model the pedestrian crossing location. Although the crossing location was a binary variable (i.e., only two possible outcomes), previous research has shown that appropriate linear model selection techniques can produce models whose prediction capabilities are competitive to those produced through logistic modeling.(27) Each training subset was used once to model the pedestrian crossing location so that 10 models were produced. The testing data set was used to test each model. Under each model, 33.33 percent of the training subset was reserved for model validation. Stepwise selection was performed. The adjusted r-square was used for selecting and stopping criteria. The average squared error of the validation data was used as the choosing criterion for the model to prevent over-fitting of the training data. Hierarchy was assumed for all model effects, meaning that an interaction term could not enter the model unless all main effects were already present in the model. Similarly, main effects could not exit the model before any respective interaction effects. Available predictors for each of the 10 models were A through O (see table 11; further details of each location are provided under each respective location description) and all second-order interactions, for a total of 121 effects. Predicted probabilities less than or equal to 0.5 corresponded to a predicted binary value of 0 (i.e., unmarked non-intersection). All other probabilities corresponded to a predicted binary value of 1 (i.e., marked intersection).

Table 11. Predictors and their respective descriptions used for the models.

Label	Description	Coding
A	Distance to the next marked crosswalk	Distance in ft
B	AADT	Expressed in thousands and rounded to the nearest 100
C	One-way or two-way street	1 or 2
D	Presence of physical barriers that might prevent a pedestrian from crossing the roadway	No barrier (0), partial barrier (1), or mostly blocked/large barrier (2)
E	Presence of a bus stop	None (0), bus exit near marked intersection (1), bus exit at non-intersection (2)
F	Range of the number of trip originators/ destinations	Range from very few (1) to a lot (5)
G	Presence of parking along the roadway	Yes (1) or no (0)
H	Presence of a center turning lane	Yes (1) or no (0)
I	Presence of a right turn only turning lane	Yes (1) or no (0)
J	Length of walk phase	Time in s
K	Length of don't walk phase	Time in s
L	Curb-to-curb distance	Distance in ft
M	Presence and type of median	No median (0), soft (1), hard (2), median only on one side of crosswalk (3)
N	Presence of cross streets between marked crosswalks	No cross street, light-controlled cross street, not light-controlled cross street
O	Far marked crosswalk light controlled	Yes (1) or no (0)

Note: Values in parentheses are the values assigned to categorical variables.

The following subsections present the 10 (statistically) chosen models. For categorical variables, the second value corresponds to the value of the variable. For instance, $x_{C,1}$ represents value 1 of predictor C (i.e., one-way traffic direction).

Model 1

- Chosen Effects: Intercept, XC, XD, XI, and XM.
- Adjusted r-square: 0.0551.
- Model:
  $Crossing_{Loc} = 0.1932 – 0.504x_{C,1} + 0.1385x_{D,0} + 0.4082x_{D,1} – 0.1265x_{I,2} + 0.2863x_{M,0} + 0.1102x_{M,2}$.
- Classification of Training Subset: 58.30 percent correct.
- Classification of Testing Data Set: 42.60 percent correct.
  - Of those correctly assigned, 87.91 percent were for marked intersection crossings.
  - Of those incorrectly assigned, 97.12 percent were for marked intersection crossings.

Model 2

- Chosen Effects: Intercept, XA, XD, XI, and XM.
- Adjusted r-square: 0.0603.
- Model:
  $Crossing_{Loc} = 0.1491 – 0.0000x_{A} + 0.1301x_{D,0} + 0.3542x_{D,1} – 0.0933x_{I,0} + 0.3138x_{M,0} + 0.1956x_{M,2}$.
- Classification of Training Subset: 58.62 percent correct.
- Classification of Testing Data Set: 42.60 percent correct.
  - Of those correctly assigned, 87.91 percent were for marked intersection crossings.
  - Of those incorrectly assigned, 97.12 percent were for marked intersection crossings.

Model 3

- Chosen Effects: Intercept, XD, XI, XJ, and XM.
- Adjusted r-square: 0.0614.
- Model:
  $Crossing_{Loc} = 0.8614 + 0.3906x_{D,0} + 0.9442x_{D,1} – 0.6139x_{I,0} – 0.0234x_{J} + 0.5613x_{M,0} + 0.2649x_{M,2}$.
- Classification of Training Subset: 58.95 percent correct.
- Classification of Testing Data Set: 42.60 percent correct.
  - Of those correctly assigned, 87.91 percent were for marked intersection crossings.
  - Of those incorrectly assigned, 97.12 percent were for marked intersection crossings.

Model 4

- Chosen Effects: Intercept, XD, XE, and XM.
- Adjusted r-square: 0.0524.
- Model:
  $Crossing_{Loc} = 0.0217 + 0.0806x_{D,0} + 0.3239x_{D,1} + 0.0642x_{E,0} + 0.3555x_{M,0} + 0.2333x_{M,2}$.
- Classification of Training Subset: 58.07 percent correct.
- Classification of Testing Data Set: 66.28 percent correct.
  - Of those correctly assigned, 94.89 percent were for marked intersection crossings.
  - Of those incorrectly assigned, 89.88 percent were for marked intersection crossings.

Model 5

- Chosen Effects: Intercept, XA, XD, XI, and XM.
- Adjusted r-square: 0.0560.
- Model:
  $Crossing_{Loc} = 0.1856 – 0.0001x_{A} + 0.1312x_{D,0} + 0.3366x_{D,1} – 0.0812x_{I,0} + 0.2868x_{M,0} + 0.1745x_{M,2}$.
- Classification of Training Subset: 58.14 percent correct.
- Classification of Test Data Set: 42.60 percent correct.
  - Of those correctly assigned, 87.91 percent were for marked intersection crossings.
  - Of those incorrectly assigned, 97.12 percent were for marked intersection crossings.

Model 6

- Chosen Effects: Intercept, XD, XI, XJ, and XM.
- Adjusted r-square: 0.0588.
- Model:
  $Crossing_{Loc} = 1.1831 + 0.5053x_{D,0} + 1.1918x_{D,1} – 0.8352x_{I,0} – 0.0354x_{J} + 0.7382x_{M,0} + 0.3473x_{M,2}$.
- Classification of Training Subset: 57.93 percent correct.
- Classification of Test Data Set: 42.60 percent.
  - Of those correctly assigned, 87.91 percent were for marked intersection crossings.
  - Of those incorrectly assigned, 97.12 percent were for marked intersection crossings.

Model 7

- Chosen Effects: Intercept, XC, XD, XI, and XM.
- Adjusted r-square: 0.0584.
- Model:
  $Crossing_{Loc} = 0.1559 – 0.0453x_{C,1} + 0.1663x_{D,0} + 0.4348x_{D,1} – 0.1771x_{I,0} + 0.2877x_{M,0} + 0.0888x_{M,2}$.
- Classification of Training Subset: 58.38 percent correct.
- Classification of Test Data Set: 42.60 percent correct.
  - Of those correctly assigned, 87.91 percent were for marked intersection crossings.
  - Of those incorrectly assigned, 97.12 percent were for marked intersection crossings.

Model 8

- Chosen Effects: Intercept, XD, XI, XJ, and XM.
- Adjusted r-square: 0.0476.
- Model:
  $Crossing_{Loc} = 1.4533 + 0.5920x_{D,0} + 1,3440x_{D,1} – 1.0218x_{I,0} – 0.0426x_{J} + 0.7929x_{M,0} + 0.3502x_{M,2}$.
- Classification of Training Subset: 57.86 percent correct.

- Classification of Testing Data Set: 42.60 percent correct.
    - Of those correctly assigned, 87.91 percent were for marked intersection crossings.
    - Of those incorrectly assigned, 97.12 percent were for marked intersection crossings.

Model 9

- Chosen Effects: Intercept, XD, XI, XJ, and XM.
- Adjusted r-square: 0.0519.
- Model:
  $Crossing_{Loc} = 1.6741 + 0.7527x_{D,0} + 1.6295x_{D,1} – 1.2252x_{I,0} – 0.0524x_{J} + 0.9266x_{M,0} + 0.4021x_{M,2}$.
- Classification of Training Subset: 58.37 percent correct.
- Classification of Testing Data Set: 66.28 percent correct.
    - Of those correctly assigned, 94.89 percent were for marked intersection crossings.
    - Of those incorrectly assigned, 89.88 percent were for marked intersection crossings.

Model 10

- Chosen Effects: Intercept, XC, XD, XI, and XM.
- Adjusted r-square: 0.0546.
- Model:
  $Crossing_{Loc} = 0.1803 – 0.0506x_{C,1} + 0.1533x_{D,0} + 0.4221x_{D,1} – 0.1205x_{I,0} + 0.2801x_{M,0} + 0.1033x_{M,2}$.
- Classification of Training Subset: 58.16 percent correct.
- Classification of Testing Data Set: 42.60 percent correct.
    - Of those correctly assigned, 87.91 percent were for marked intersection crossings.
    - Of those incorrectly assigned, 97.12 percent were for marked intersection crossings.

Model Summary

Of the 121 effects entered into each of the 10 models, only XA, XC, XD, XE, XI, XJ, and XM were ever chosen. No interactions were selected for the models using the aforementioned model restrictions. Table 12 summarizes each of the chosen effects and their respective parameter estimates.

Table 12. Summary of each of the model-selected effects (predictors) and their parameter estimates.

Effect	Mean	Minimum	Maximum	Occurrences in Model
Intercept	0.6058	0.0217	1.6741	10
XA	-0.0001	-0.0001	0.0000	2
XC,1	-0.0488	-0.0506	-0.0453	3
XD,0	0.3041	0.0806	0.7527	10
XD,1	0.7389	0.3239	1.6295	10
XE	0.0642	0.0642	0.0642	1
XI,0	-0.4705	-1.2252	-0.0812	9
XJ	-0.0385	-0.0524	-0.0234	4
XM,0	0.4829	0.2801	0.9266	10
XM,2	0.2290	0.0888	0.4021	10

XD (the presence of a physical barrier) and XM (the presence of a median) were selected for every model. Each of these variables had three values, two of which were assigned parameter estimates. For XD, value 0 (no barrier) always yielded a smaller parameter estimate than value 1 (partial barrier/blocked crosswalk). For XM, value 2 (median only on one side of the crosswalk) always yielded a smaller parameter estimate than value 0 (no median). XI,0 (no dedicated right turn only lane) was chosen in 9 of the 10 models. Parameter estimates for XC (traffic directionality), XI (dedicated right turn only lane), and XJ (length of walk phase) were always negative, indicating that these effects tended to decrease the probability of a marked intersection crossing (i.e., increase the probability of an unmarked non-intersection crossing). The mean intercept parameter estimate was 0.6058 (greater than 0.5), indicating that baseline predictions yielded a marked intersection crossing. Although XA (distance to the next marked crossing) was selected for the model twice, the influence of this variable was negligible in both cases.

Each of the 10 models accurately predicted the testing data set only about 50 percent of the time. Furthermore, the largest adjusted r-square value was only .0614. In other words, the model explained only about 6.14 percent of the variance in the data. These two factors combined suggest that any single model calculated thus far is not sufficient to predict whether pedestrians are more likely to cross at a marked intersection than at an unmarked non-intersection. As a result, more detailed and site- and factor-specific human factors analyses are described in the next section. It is hoped that this will provide greater insight regarding which environmental factors influence pedestrian crossing behavior.

Factor Specific Analyses

This results section evaluates each of the recorded crossing variables in detail. Although there are too few data collection sites in phase 1 to use inferential statistics to compare one site with another, general trends are examined.

Crossing Location

Table 13 summarizes the percentage of pedestrians, by location, who crossed at marked intersections, unmarked non-intersections, and unmarked intersections. The percentage of each type of crossing is presented at each location. For example, at Location 1, 75.13 percent of the total crossings took place in the marked intersection during the walk phase. When all locations are combined, the mean percentage of pedestrians who crossed at the marked intersection is 85.35. However, the Location 3 marked intersection percentage of 50.9 is 2.27 standard deviations below the mean, making it an outlier.

Further examination of Location 3 shows that the relatively low number of pedestrians crossing at the marked intersection is the result of pedestrians crossing at the unmarked intersection. In fact, pedestrians were about equally likely to cross in the marked intersection (50.88 percent) as the unmarked intersection (44.65 percent).

If Location 3 is removed, the mean percentage of pedestrians who crossed at the marked intersection in the remaining seven locations is 90.27. Here, the Location 8 marked intersection value of 76.8 percent is 2.05 standard deviations below the mean, making it an outlier. The Location 7 marked intersection crossing value of 97.0 percent is 1.02 standard deviations above the mean. While this is not an outlier, it is the most extreme high value. As a result, this is explored further in the subsequent discussion section.

Because of the third crossing area choice at Location 3 (i.e., the unmarked intersection), it is worthwhile to further explore the percentage of pedestrians who crossed at unmarked non-intersection areas. Not surprisingly, the Location 8 unmarked non-intersection value of 28.2 percent is 2.32 standard deviations above the mean and consequently is classified as an outlier. If the Location 8 value is removed, the mean percentage of pedestrians crossing at an unmarked non-intersection at the remaining seven locations is reduced to 7.06. No further outliers exist. However, Location 1 and Location 7 remain the two most extreme values at 1.63 standard deviations above the mean and 1.34 standard deviations below the mean, respectively.

Further exploration for the possible reasons for these differences is presented in more detail in the phase 1 discussion section.

Table 13. Percentage of pedestrians at each crossing area in each data collection location.

	Location							
	1	2	3	4	5	6	7	8
Marked Intersection								
Walk	75.13	87.91	44.56	67.98	93.43	90.63	75.46	74.21
+traffic flow change	.72	1.22	.38	.71	.37	.82	1.30	.64
Don't Walk	8.47	1.75	5.73	17.89	.49	.92	18.69	1.33
+traffic flow change	3.60	.52	.21	4.59	.05	.90	1.53	.64
Overall in Intersection	***87.93***	***91.30***	***50.88***	***91.17***	***94.33***	***93.26***	***96.98***	***76.81***
Unmarked Non-Intersection								
With Traffic	5.23	6.24	1.00	5.38	5.19	4.67	1.81	16.58
+traffic flow change	.45	.30	.15	.17	.14	.27	.01	.64
Against Traffic	5.77	1.60	3.15	2.77	.33	1.11	1.20	5.46
+traffic flow change	.63	.56	.15	.52	.01	.68	—	.51
Overall in Unmarked Non-Intersection	***12.07***	***8.70***	***4.46***	***8.83***	***5.67***	***6.74***	***3.02***	***23.19***
Unmarked Intersection								
With Traffic	—	—	18.34	—	—	—	—	—
+traffic flow change	—	—	1.62	—	—	—	—	—
Against Traffic	—	—	24.06	—	—	—	—	—
+traffic flow change	—	—	.63	—	—	—	—	—
Overall in Unmarked Intersection	**—**	**—**	***44.65***	**—**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Pedestrian Yielding

Table 14 summarizes the percentage of pedestrians who yielded to vehicles within each crossing type. As an example, at Location 1, of the 834 pedestrians who crossed during the walk phase in the marked intersection, 1 pedestrian yielded to a vehicle. This is equivalent to .12 percent. Also at Location 1, of the total 976 crossings in the marked intersection, only 1 pedestrian yielded to a vehicle. This is the equivalent of .10 percent of the total crossings in the marked intersection.

Overall, the mean percentage of pedestrians who yielded to vehicles was .53. If all of the locations are compared with one another, the Location 3 value of 1.67 percent was 2.15 standard deviations above the mean and is considered an outlier. If Location 3 is removed from these values, no other outliers remain. These overall yielding behaviors do not provide much information about where pedestrians are yielding to vehicles. As a result, yielding behaviors by crossing area are examined next.

The mean percentage of pedestrians who yielded to vehicles in the marked intersection was .19. If all of the locations are compared with one another, the Location 7 value of .67 percent was 2.42 standard deviations above the mean and is considered an outlier. If Location 7 is removed, no further outliers exist.

Next, the mean percentage of pedestrians who yielded to vehicles in unmarked non-intersections was examined. Overall, the mean percentage of yielding was 2.19. No outliers exist here. In other words, when looking at these eight locations alone, none are significantly different with regard to the proportion of pedestrians who yielded to vehicles in unmarked non-intersection areas.

A *t*-test was performed to determine whether the proportion of pedestrian yielding behaviors differed between the marked intersection and the unmarked non-intersection.

A significant difference between the two locations was found, $t(7) = -2.40$, $p = .048$. Crossings where the pedestrian crossed entirely during the walk phase in the marked intersection were compared with all other crossings made where the pedestrian yielded. There was no significant difference in the percentage of pedestrians who yielded to vehicles during the walk phase in the marked intersection (M = .18 percent) compared with those pedestrians who yielded to vehicles in all other situations (M = 1.68 percent), $t(7) = -2.11$, $p > .05$.

Table 14. Percentage of pedestrians yielding to vehicles in each crossing area at each data collection location.

	Location							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Marked Intersection								
Walk	.12	.12	—	.18	.03	.15	.74	.09
+traffic flow change	—	1.92	—	2.12	—	—	4.14	—
Don't Walk	—	—	—	0	—	—	.17	—
+traffic flow change	—	25.00	—	.50	—	4.76	.51	—
Overall Yielding in Intersection	***.10***	***.28***	**—**	***.17***	***.03***	***.19***	***.67***	***.08***
Unmarked Non-Intersection								
With Traffic	3.45	2.08	—	.14	.18	.65	.43	—
+traffic flow change	20	7.14	—	—	—	2.22	—	10
Against Traffic	—	12.16	5.49	—	2.86	8.20	.65	—
+traffic flow change	14.29	34.62	25.00	—	—	4.50	—	—
Overall Yielding in Unmarked Non-Intersection	***2.99***	***6.20***	***4.74***	***.09***	***.33***	***2.35***	***.51***	***.27***
Unmarked Intersection								
With Traffic	—	—	.31	—	—	—	—	—
+traffic flow change	—	—	3.57	—	—	—	—	—
Against Traffic	—	—	5.36	—	—	—	—	—
+traffic flow change	—	—	9.09	—	—	—	—	—
Overall Yielding in Unmarked Intersection	**—**	**—**	***3.27***	**—**	**—**	**—**	**—**	**—**
Grand Percentage	**.45**	**.80**	**1.67**	**.16**	**.05**	**.34**	**.66**	**.13**

— Indicates no actions of this type were recorded.

Vehicle Yielding

Table 15 summarizes the percentage of vehicles that yielded to pedestrians within each crossing area at each location. As an example, at Location 1, there were three instances of vehicles yielding to pedestrians with traffic at the unmarked non-intersection. This is 5.17 percent of the 58 total crossings in this area.

The overall percentage of crossings that involved a vehicle yielding to a pedestrian was compared across locations. The mean percentage of crossings that involved vehicle yielding was 9.77. The Location 7 value of 38.70 percent was 2.15 standard deviations above the mean and considered an outlier. If the Location 7 value is removed, Location 4 becomes an outlier at 2.05 standard deviations above the mean. If Location 4 is removed from these values, no other outliers remain. These overall yielding behaviors do not provide much information about where vehicles are yielding to pedestrians. As a result, yielding behaviors by crossing area are examined next.

The mean percentage of vehicles that yielded to pedestrians in the marked intersections was 10.21. If all of the locations are compared with one another, the Location 7 value of 39.80 percent was 2.11 standard deviations above the mean and is considered an outlier. If Location 7 is removed, Location 4 becomes an outlier at 2.05 standard deviations above the mean. If Location 4 is removed from these values, no other outliers remain.

Next, the mean percentage of vehicles that yielded to pedestrians in unmarked non-intersections was examined. Overall, the mean percentage of yielding was 1.25. No outliers exist here. In other words, when looking at these eight locations alone, none are significantly different with regard to the proportion of drivers who yielded to pedestrians in unmarked non-intersection areas.

A *t*-test was performed to determine whether the proportion of vehicle yielding behaviors differed between the marked intersections and the unmarked non-intersections. No significant difference between the two locations was found, $t(7) = 1.86$, $p > .05$. Next, crossings where the pedestrian crossed entirely during the walk phase in the marked intersection were compared with all other vehicle yielding. Once again, there was no significant difference in the percentage of vehicles that yielded to pedestrians during the walk phase in the marked intersection (M = 12.62 percent) compared with those vehicles who yielded to vehicles in all other situations (M = .97 percent), $t(7) = 1.81$, $p > .05$.

Table 15. Percentage of vehicles yielding to pedestrians within each crossing area at each data collection location.

	Location							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Marked Intersection								
Walk	4.08	7.22	—	29.88	.01	8.74	50.71	.34
+traffic flow change	—	—	—	—	28.21	.74	16.57	20
Don't Walk	—	—	—	—	—	—	.62	—
+traffic flow change	—	—	—	.99	—	—	.51	—
Overall Yielding in Intersection	***3.49***	***6.95***	**—**	***22.34***	***.12***	***8.50***	***39.80***	***.50***
Unmarked Non-Intersection								
With Traffic	5.17	—	—	.70	.18	.13	2.13	.38
+traffic flow change	—	—	—	—	6.67	—	—	10
Against Traffic	4.69	—	.61	.27	—	—	4.52	2.33
+traffic flow change	—	—	—	—	—	—	—	—
Overall Yielding in Unmarked Non-Intersection	***4.48***	**—**	***.43***	***.52***	***.33***	***.09***	***3.07***	***1.10***
Unmarked Intersection								
With Traffic	—	—	.11	—	—	—	—	—
+traffic flow change	—	—	3.57	—	—	—	—	—
Against Traffic	—	—	1.04	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—
Overall Yielding in Unmarked Intersection	**—**	**—**	***.73***	**—**	**—**	**—**	**—**	**—**
Grand Percentage	**3.60**	**6.35**	**.35**	**20.4**	**.16**	**7.93**	**38.70**	**.64**

— Indicates no actions of this type were recorded.

Yielding Comparison

It is important to understand overall yielding behavior. Here pedestrian and vehicle yielding are compared. First, yielding behaviors that occurred within the marked intersection were explored. No significant difference in the percentage of pedestrians yielding to vehicles (M = 0.19 percent) and the percentage of vehicles yielding to pedestrians (M = 10.21 percent), was found, $t(7) = -2.05$, $p > .05$. Similarly, no significant difference in pedestrian yielding (M = 2.19 percent) and vehicle yielding (M = 1.25 percent) in pedestrian crossings occurring in unmarked non-intersections was found, $t(7) = .87$, $p > .05$.

Next, yielding behaviors within the marked intersection that took place entirely during the walk light phase were examined. A significant difference in the percentage of pedestrians who yielded to vehicles (M = .18 percent) and the percentage of vehicles who yielded to pedestrians was not found (M = 12.62 percent), $t(7) = -1.95$, $p > .05$. Next, yielding behaviors that took place while the pedestrian crossed outside the marked intersection or in the marked intersection that was not entirely during the walk light phase were examined. A paired comparison revealed that there was no significant difference in the percentage of pedestrians who yielded to vehicles

(M = 1.68 percent) and the percentage of vehicles who yielded to pedestrians (M = 0.97 percent), $t(7) = .769$, $p > .05$.

Evasive Pedestrian Actions

Table 16 summarizes the percentage of pedestrian evasive actions in each crossing area at each of the data collection locations. Each of the three types of evasive actions (running/ accelerated walking, abrupt stopping, and directional change) was combined to obtain a better overall perspective on pedestrian evasive actions. As an example, at Location 1, there were 29 instances of running/accelerated walking, 2 abrupt stops, and 1 directional change in the marked intersection during the walk phase. This is 3.72 percent of 834 total crossings in this area.

The overall percentage of crossings that involved a pedestrian evasive action was compared across locations. The mean percentage of crossings that involved a pedestrian evasive action was 4.39. None of the locations had a mean percentage that was more than 2 standard deviations from this mean. In other words, no outliers existed. These overall values do not provide much information about where pedestrians are taking evasive actions. As a result, evasive actions by crossing area are examined next.

The mean percentage of pedestrians who took evasive actions in the marked intersection was 3.44. If all of the locations are compared with one another, none are considered outliers.

Next, the mean percentage of pedestrians who took evasive actions in unmarked non-intersections was examined. Overall, the mean percentage was 10.17. No outliers exist here. In other words, when looking at these eight locations, none are significantly different in regard to the proportion of pedestrians who took evasive actions in unmarked non-intersection areas.

A *t*-test was performed to determine whether a difference existed in the percentage of pedestrian evasive actions between the marked intersection and the unmarked non-intersection. Indeed a significant difference between the two locations was found, $t(7) = -2.85$, $p = .025$. Next, crossings where the pedestrian made the entire crossing during the walk phase in the marked intersection were compared with all other pedestrian evasive actions. Here, once again, there was a significant difference in the percentage of pedestrians who took evasive actions during the walk phase in the marked intersection (M = 2.21 percent) compared with those pedestrians who took evasive actions in all other situations (M = 11.77 percent), $t(7) = -3.51$, $p = .010$.

Table 16. Percentage of pedestrian evasive actions in each crossing area at each data collection location.

	Location							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
marked intersection								
Walk	3.72	4.96	.22	1.60	1.70	1.83	.24	3.42
+traffic flow change	12.50	25.00	20.0	12.77	74.36	28.15	14.79	80.0
Don't Walk	28.72	19.75	7.05	4.57	36.54	25.83	8.42	42.86
+traffic flow change	17.50	16.67	—	1.49	40.0	7.48	.51	70.0
Overall Evasive Actions in Intersection	***6.76***	***5.56***	***1.13***	***2.26***	***2.18***	***2.36***	***2.01***	***5.29***
Unmarked Non-Intersection								
With Traffic	18.97	4.84	3.85	1.41	2.17	2.30	4.68	13.79
+traffic flow change	—	—	—	—	20.00	24.44	—	40.0
Against Traffic	31.25	21.62	9.15	1.92	14.29	11.48	14.84	40.70
+traffic flow change	28.57	26.92	12.50	—	—	5.41	—	12.50
Overall Evasive Actions in Unmarked Non-Intersection	***24.63***	***9.18***	***7.76***	***1.46***	***3.32***	***5.52***	***8.70***	***20.82***
Unmarked Intersection								
With Traffic	—	—	.94	—	—	—	—	—
+traffic flow change	—	—	7.14	—	—	—	—	—
Against Traffic	—	—	4.08	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—
Overall Evasive Actions in Unmarked Intersection	**—**	**—**	***2.84***	**—**	**—**	**—**	**—**	**—**
Grand Percentage	**8.92**	**5.87**	**2.19**	**2.19**	**2.25**	**2.57**	**2.21**	**8.89**

— Indicates no actions of this type were recorded.

Evasive Vehicle Actions

Table 17 summarizes the percentage of vehicle evasive actions within each crossing area at each of the data collection locations. Each of the four types of evasive actions (abrupt braking—first vehicle, abrupt braking—second vehicle, directional change—first vehicle, and directional change—second vehicle) were combined to obtain a better overall perspective on vehicle evasive actions. As an example, at Location 2, there were four instances of abrupt braking by the first vehicle, two directional changes by the first vehicle, and four directional changes by the second vehicle in the marked intersection during the walk phase. This is .25 percent of the 4,071 total crossings at this area.

The overall percentage of crossings that involved a vehicle evasive action was compared across locations. The mean percentage of crossings that involved a vehicle evasive action was .05. None of the locations had a mean percentage that was more than 2 standard deviations away from the mean. In other words, no outliers existed. These overall values do not provide much information about where vehicles are taking evasive actions. As a result, evasive actions by crossing area are examined next.

The mean percentage of vehicles that took evasive actions in the marked intersection was .04. If all of the locations are compared with one another, the Location 2 value of .24 percent is 2.27 standard deviations above the mean, making it an outlier. If Location 2 is removed, not surprisingly, Location 1 (the only other non-zero value) becomes an outlier at 2.27 standard deviations above the mean.

Next, the mean percentage of vehicles that took evasive actions in unmarked non-intersections was examined. Overall, the mean percentage was .09. Not surprisingly, Location 1 (the only non-zero value) was an outlier at 2.47 standard deviations above the mean.

A *t*-test was performed to determine whether a difference existed in the percentage of vehicle evasive actions between the marked intersection and the unmarked non-intersection. No significant difference between the two locations was found, $t(7) = -.568$, $p > .05$. Next, crossings where the pedestrian completed the entire crossing during the walk phase in the marked intersection were compared with all other vehicle evasive actions. Here, there was no significant difference in the percentage of vehicles who took evasive actions during the walk phase in the marked intersection (M = .03 percent) compared with those vehicles who took evasive actions in all other situations (M = .09 percent), $t(7) = -.600$, $p > .05$.

Table 17. Percentage of vehicle evasive actions within each crossing area at each data collection location.

	Location							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Marked Intersection								
Walk	—	.25	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—
Don't Walk	1.06	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—
Overall Evasive Actions in Intersection	***.10***	***.24***	**—**	**—**	**—**	**—**	**—**	**—**
Unmarked Non-Intersection								
With Traffic	1.72	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—
Against Traffic	—	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—
Overall Evasive Actions in Unmarked Non-Intersection	***.75***	**—**	**—**	**—**	**—**	**—**	**—**	**—**
Unmarked Intersection								
With Traffic	—	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—
Against Traffic	—	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—
Overall Evasive Actions in Unmarked Intersection	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**
Grand Percentage	**.18**	**.22**	**—**	**—**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Evasive Action Comparison

It is important to understand overall evasive action behavior. Here pedestrian and vehicle evasive actions are compared. First evasive actions that occurred within the marked intersection were explored. A significant difference in the percentage of pedestrians taking evasive actions (M = 3.44 percent) and the percentage of vehicles taking evasive actions (M = .04 percent) was found, $t(7) = 4.74$, $p = .002$. Similarly a significant difference in pedestrian evasive actions (M = 10.17 percent) and vehicle evasive actions (M = 0.09 percent) in pedestrian crossings occurring in unmarked non-intersections was found, $t(7) = 3.54$, $p = .010$.

Next, evasive behaviors within the marked intersection that took place entirely during the walk light phase were examined. A significant difference in the percentage of pedestrians who took evasive actions (M = 2.21 percent) and the percentage of vehicles that took evasive actions (M = .03 percent) was found, $t(7) = 3.78$, $p = .007$. Next, evasive actions that took place while the pedestrian crossed either in the unmarked non-intersection or in the marked intersection at least partially during the don't walk phase were examined. Again, there was a significant difference in the percentage of pedestrians who took evasive actions (M = 11.77 percent) and the percentage of vehicles that took evasive actions (M = .09 percent), $t(7) = 3.83$, $p = .006$.

DISCUSSION

An overarching goal of the present study is to determine which environmental factors influence where pedestrians cross the roadway. In phase 1 of this study, pedestrian crossing behaviors were recorded and coded over a 2-week period at eight different locations. It was hoped that these data would help to identify factors that influence pedestrians to cross at unmarked non-intersection locations. Furthermore, it was hoped that these data would produce a model that might predict pedestrian crossings. However, of the total 65,725 crossings, only 4,399 (or 6.7 percent) took place in an unmarked non-intersection location. In other words, these crossings are generally rare events. As a result, the number of location areas limits the statistically appropriate modeling techniques available. These methodologies were unable to successfully model the pedestrian crossing data from these eight locations.

To attempt to more accurately model and predict pedestrian crossing behavior, data from an additional 12 locations were collected. These data are described further in phases 2 and 3. Here, the data and trends for the eight locations from phase 1 are discussed.

Crossing Location

As noted previously, few crossings took place in an unmarked non-intersection location. Overall, only 6.7 percent of the crossings occurred outside an intersection (marked or unmarked). Another way to examine these crossings is to explore the distributions of crossings at each location. Location 8 is considered an outlying value, with 28.2 percent of the crossings occurring at unmarked non-intersection areas. This warrants further discussion about the characteristics of Location 8 that might cause this result.

The distance to the next marked crossing for Location 8 was approximately 433 ft. This location is not considered an outlier (nor are any of the other locations) in the current eight locations, which have a mean distance of 418.9 ft. The AADT value of 21 is not considered an outlier (nor is the AADT for any of the other locations) in the current eight locations, which have a mean of 20.7. The eight locations also did not significantly vary in the length of the walk phase, the length of the don't walk phase, or the width of the crossing. As such, it is not likely that any of these factors alone caused the above average number of crossings at an unmarked non-intersection.

Location 8, however, does require pedestrians to travel at a speed of 3.7 ft/s to cross in the marked intersection entirely during the walk light phase. This rate is greater than the *Manual on Uniform Traffic Control Devices* (MUTCD) recommended rate of 3.5 ft/s. Furthermore, the MUTCD states, "Where pedestrians who walk slower than 3.5 ft/s, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 3.5 ft/s should be considered in determining the pedestrian clearance time."[(28)] Given that there is an elementary school approximately two blocks away from this intersection and that there are small suburban type establishments (including a church, neighborhood market, and library) in the general area, it is likely that there is substantial pedestrian traffic near this intersection that regularly travels at a rate of less than 3.5 ft/s.

Although pedestrians were not specifically queried about their crossings, it is possible that pedestrians may feel rushed while crossing at the marked intersection. This rapid pace required to cross at the marked intersection during the walk phase may lead pedestrians to feel hurried and uncomfortable crossing at this location. This intersection is also just outside a traffic circle. This location prevents pedestrians from being able to see traffic from a distance adequate to determine whether a vehicle will continue traveling within the traffic circle or exit toward the intersection. Furthermore, this location reduces pedestrians' abilities to confidently determine whether the vehicle will cross their potential path during a crossing that takes place (at least partially) during the don't walk phase (a scenario that is likely if the pedestrian is not already waiting at the intersection and can cross at a rapid pace). This time pressure, combined with a long wait time for the next walk phase (79 s), may encourage pedestrians to cross outside this marked intersection.

As noted previously, perceived control of a situation influences pedestrians' intentions to cross the roadway. Given the short crossing time and pedestrians' inability to confidently predict behavior of traffic exiting from the traffic circle, it is possible that pedestrians may feel that crossing at unmarked non-intersection areas increases their control of the situation (i.e., perceived control). Moving south of the marked intersection to cross the roadway provides pedestrians the opportunity to see bi-directional vehicle travel from a greater distance and to potentially find longer gaps in traffic to permit crossing at a more leisurely pace. In addition, the next marked crossing is not light controlled. As a result, pedestrians must still find an appropriate gap to cross traffic, and consequently using that marked crossing is not likely to present a greater level of perceived control. As such, crossing at an unmarked non-intersection may optimize pedestrians' perceived control and perceived time efficiency in crossing the roadway.

There were no outliers in terms of the lowest percentage of crossings at unmarked non-intersection areas. However, Location 7 did have the lowest percentage, only 3.0. This low value is likely the result of a several factors. First, the distance between the marked intersection of interest and the next marked crossing is only 145 ft. While this is not an outlier, it is the most extreme value at 1.7 standard deviations below the mean value of 418.9 ft. Furthermore, there are few trip originators or destinations. Along the east side of the block is a park. However, shrubbery blocks entrance along this side, and pedestrians need to go to an adjacent side of the park to obtain entry. In other words, crossing the road between the two marked crossings does not provide an advantage in gaining entrance to the park. Along the west side of the block, there is a single large office building. Although it was not specifically recorded, anecdotal evidence suggests that most pedestrians who crossed at an unmarked non-intersection area were traveling to or from this office building. Furthermore, along this west side of the block, there are several large flower planters and concrete benches (that face away from the roadway). These objects do not prevent pedestrians from crossing in this area, but they do impede a simple and direct travel path from the sidewalk to the roadway. It is likely that the concrete structures deter pedestrians from crossing outside the nearby marked crosswalks.

At both Location 7 and Location 4, more than 90 percent of the crossings took place within the marked intersection. These two locations also had the two highest percentages of crossings that took place in the marked intersection during the don’t walk light phase (17.9 and 18.7, respectively, compared with an overall mean of 6.9). As a result, it is important to explore the factors that might influence these crossings. At both locations, there is a left turn arrow that guides traffic through the marked intersection that might be difficult to see from the pedestrian’s perspective.

At Location 7, Pennsylvania Avenue Northwest travels east/west, just north and perpendicular to the marked intersection of interest. Prior to the walk phase, vehicles traveling west on Pennsylvania Avenue are given a green arrow to turn south—turning through the marked intersection. However, pedestrians traveling east at this intersection cannot see that the left turning vehicles have a green light. Instead these pedestrians can see that cross traffic has a red light and that the opposite walk signal has just turned from walk to don’t walk. As such, pedestrians here may incorrectly assume that it is safe to begin crossing, perhaps presuming that the light is simply in the “delay” time period, and they anticipate that it will turn to the walk phase shortly after entering the crosswalk. Again, it should be noted that pedestrians were not asked about their crossings. However, given the unique characteristics of this crossing location, this is a reasonable and logical explanation of the pedestrian crossing behavior.

At Location 4, 13th Street Northwest travels north/south, just east and perpendicular to the marked intersection of interest. Just after the conclusion of the walk phase, vehicles traveling north on 13th Street are given a green arrow to turn west—turning through the marked intersection. However, pedestrians traveling south at this intersection cannot see that the left turning vehicles have a green light and may incorrectly assume that the vehicles have a red light and will stop. Similarly to Location 7, pedestrians here may think that it is safe to cross the roadway, when indeed this may not be the case.

Location 3 had a large proportion of pedestrian crossings at an unmarked intersection. In fact, pedestrians were approximately equally likely to cross at the unmarked intersection as the marked intersection. This finding suggests that pedestrians perceive the unmarked intersection to be a safe, and acceptable, place to cross the roadway. Although the traffic light phasing was not set to incorporate pedestrian crossings, pedestrians took advantage of the median separating east and west traveling traffic. Given that 41 percent of the crossings at the unmarked intersection involved waiting on the median, it appears that pedestrians were not trapped on the median as previous research has reported. Rather, at this location pedestrians plan their crossing in phases; crossing a segment and waiting on the median and then completing the crossing. This is a tactic that presumably increases perceived control.

Beyond the ability to divide the crossing into two portions, environmental factors both encourage crossing at the unmarked intersection and discourage traveling to the marked intersection. Pedestrians traveling to/from the north side of Rhode Island Avenue and Marion Street are required to travel out of the way to cross at the marked intersection. This is a result of the juxtaposition of the streets. Rhode Island Avenue is a "diagonal" street. This means that pedestrians need to travel south along Rhode Island in addition to west to reach the marked intersection, when traveling north. (When traveling south, pedestrians must travel farther south than desired and then return north while traveling east to reach Marion Street.) Furthermore, the marked intersection involves three segments (crossings at only the center and main segment were specifically counted in this study), which, combined, are wider than the single unmarked intersection. Each segment is divided by a concrete median/island that includes a separate crosswalk signal. This means that it is possible to begin crossing the street in one light phase, but the pedestrian may need to wait on a median/island until the next light phase to complete the crossing. To pedestrians, these two factors combined may outweigh the potential benefits of crossing during a protected light phase—especially given the relatively rare occurrence of a vehicle–pedestrian collision. In addition, the unmarked intersection has several factors that afford a crossing. It is obvious that this is at an intersection—a location where most marked crossings are found. Further, this location lies at a junction where it is natural to want to travel. There is Metro station only one block west of the marked intersection, on the north side. As a result, crossing at the unmarked intersection when traveling to/from the Metro station, along Marion Street, is likely the most direct and efficient route. Finally, the median in the unmarked intersection looks like a sidewalk. Pedestrians can clearly see a concrete area on the end of the median that is approximately the width of a standard sidewalk (e.g., a firm, raised surface that serves as a barrier from roadway vehicles). As such, this area affords the same things to pedestrians as a standard sidewalk. It is likely that pedestrians interpret use of this area as they would any other sidewalk area.

Pedestrian Yielding

In total, 298 of the 65,725 crossings (.45 percent) involved pedestrian yielding. Overall, the mean percentage of pedestrians who yielded to vehicles was .53 (i.e., the mean of the percentage of pedestrians who yielded to vehicles at each location).

Overall, Location 3 had a significantly greater percentage of pedestrians who yielded to vehicles. However, this value is inflated owing to the crossings that occurred in the unmarked intersection location. As a result, of this unique crossing situation, Location 3 is not discussed further here.

The mean percentage of pedestrians who yielded to vehicles in the marked intersection was .19. Location 7 was an outlier in the percentage of pedestrians that yielded to vehicles, with 2.42 standard deviations above the mean. This area had a substantial number of vehicles turning right and passing through the intersection. While the exact circumstances of each yielding behavior were not recorded, it was noted on several occasions that pedestrians would allow vehicles to pass to relieve vehicle congestion. In other words, a pedestrian(s) would allow vehicles to complete a right turn so that other traffic traveling straight through might pass. There were also several instances where a left-turning vehicle yielded to a pedestrian while the vehicle had a protected turn (i.e., a green left turn arrow), but was left in the intersection when oncoming vehicular traffic started flowing. In these circumstances, pedestrians often yielded to vehicles during the walk phase to allow the vehicle to complete the turn and avoid traffic delays.

Overall, significantly more pedestrians yielded to vehicles in the unmarked non-intersections than in the marked intersections. This suggests that pedestrians who cross outside the marked intersection are more likely to encounter a situation that requires yielding to avoid collision.

Vehicle Yielding

In total, 9,385 of the 65,725 crossings (14 percent) involved a vehicle yielding to a pedestrian. Overall, vehicle yielding did not vary by pedestrian crossing location. The mean percentage of drivers who yielded to pedestrians was 9.77 (i.e., the mean of the percentage of vehicles who yielded to pedestrians at each location). Overall, Location 7 (38.7 percent) had a significantly greater percentage of vehicles that yielded to pedestrians. As noted in the previous section, a large number of vehicles turned through the marked intersection area at Location 7. As a result of the turning traffic having a green light and the pedestrian signal in the walk phase, vehicles often waited to complete their turn (i.e., yielded) while pedestrians crossed the roadway. A similar situation to Location 7 presents itself at Location 4. At Location 4, right turning vehicles have a green light at the same time that the pedestrian signal is in the walk phase. As a result, vehicles often waited to complete their turn (i.e., yielded) while pedestrians crossed the roadway.

Yielding Comparison

A surprising result is that there is no significant difference in the percentage of pedestrians who yielded to vehicles and the percentage of vehicles that yielded to pedestrians during the walk phase in the marked intersection. One would expect that few pedestrians would yield to vehicles. This lack of a difference could be the result of several factors.

It is possible (and likely) that pedestrians are aware of the extreme traffic congestion in Washington, DC. This may lead them to intermittently allow vehicles to complete turns, which allows following traffic to continue straight and subsequently alleviates minor intersection congestion. It is also possible that pedestrians simply feel safer in allowing the vehicle to turn prior to completing their crossing. In other words, if a pedestrian–vehicle collision were to occur, it is more likely that the pedestrian would be injured than the driver of the vehicle, even at low speeds. As a result, pedestrians may simply be exhibiting caution.

Evasive Pedestrian Actions

In total, 1,862 of the 65,725 crossings (2.83 percent) involved an evasive pedestrian action. Overall, the mean percentage of pedestrians who took evasive actions was 4.39 (i.e., the mean of the percentage of evasive pedestrian actions at each location). The percentage of evasive actions was fairly consistent across locations and across crossing types. At the present time, the data do not suggest any clear environmental reason for these evasive pedestrian actions.

The percentage of evasive pedestrian actions did, however, vary by pedestrian crossing location. Pedestrians were more likely to take evasive actions in the unmarked non-intersection areas than the marked intersection. Likewise, pedestrians were less likely to take evasive actions while crossing entirely during the walk light phase in the marked crossing than in all other crossings.

Evasive Vehicle Actions

In total, 12 of the 65,725 crossings (.02 percent) involved an evasive vehicle action. Overall, the mean percentage of vehicles that took evasive actions was .05 (i.e., the mean of the percentage of evasive vehicle actions at each location). The only evasive vehicle actions took place in Location 1 and Location 2. This, combined with the small total number of vehicle evasive actions, does not provide the opportunity to make inferences at this time.

Further, the percentage of vehicle evasive actions did not vary by pedestrian crossing location. That is, vehicles were equally likely to take an evasive action in the unmarked non-intersection as in the marked intersection.

Evasive Action Comparison

In all crossing locations, pedestrians were more likely to take an evasive action than vehicles. This suggests that pedestrians may take a proactive approach to increase their safety by evading potential collisions with vehicles.

General Discussion

In the present set of data, non-intersection crossings are relatively rare. This makes it difficult to make predictions about where pedestrians will cross the roadway. Furthermore, of the 65,725 coded crossings, there was only a single close call/near miss. This near miss occurred at Location 7 during the walk phase in the marked intersection. In this instance, two pedestrians were about to enter the roadway while at the same time, a vehicle began to make a right turn (passing through the marked intersection). One person pulled the other person back to the curb. Although it is not clear from the video, it appears that the vehicle may have nearly collided with the pedestrian had he or she not been pulled back to the curb. Despite the pedestrian having the right of way in this case, it is easy to understand why the driver continued with the right turn. Prior to the pedestrians attempting to cross the roadway, they stood on the curb facing the opposite crossing direction (i.e., facing north, rather than east). Furthermore, the walk phase had been initiated for more than 10 s prior to the pedestrians attempting to enter the marked intersection. These clues could easily lead a driver to interpret the pedestrians as not a potential hazard.

The subsequent sections discuss data collection and findings from phases 2 and 3.

PEDESTRIAN CROSSING BEHAVIORS: PHASE 2

To more thoroughly assess pedestrian crossing behaviors, seven additional pedestrian crossing locations in Washington, DC, were selected. Similarly to phase 1, pedestrian crossings were video recorded and later coded at each of the locations.

DATA COLLECTION LOCATIONS

The same criteria were used to select the second set of cameras as those used in phase 1. Video feed was recorded from each of the seven cameras from 7:00 a.m. to 5:00 p.m. and from 8:00 p.m. to 11:00 p.m. Eastern Standard Time from February 22, 1012, to March 9, 2012. The following section describes each of the seven data collection locations, which are labeled in no particular order.

Location 9

The ninth data collection area is located at the intersection of Connecticut Avenue Northwest and Florida Avenue Northwest in Washington, DC. Figure 27 is an aerial view of this data collection area. Connecticut Avenue runs northwest/southeast and is located near the center of the image. Florida Avenue runs northeast/southwest and is located on the right side of the image. The solid red rectangle highlights the intersection of Connecticut Avenue Northwest and Florida Avenue Northwest. The dotted red rectangle highlights the intersection of Connecticut Avenue Northwest and Leroy Place (west of Connecticut)/T Street (east of Connecticut) Northwest. The DDOT camera was positioned on the southwest corner of the Connecticut and Florida facing north (see figure 28). As a result, pedestrians making east/west crossings on Connecticut Avenue between Florida and Leroy Place/T Street were captured. (Leroy Place meets Connecticut on the west and T Street meets Connecticut on the east.) The distance from Florida Avenue to Leroy Place is roughly 551 ft. Approximately 135 ft north of the intersection of Connecticut and Florida, Bancroft Street meets with the west side of Connecticut. Both right and left turns can be made from Bancroft onto Connecticut. Figure 28 shows marked crossings are present at both Florida Avenue Northwest (solid red line) and Leroy Place Northwest (dotted red line). The AADT in this area is 34 (expressed in thousands and rounded to the nearest 100).(18)

Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 27. Photo. Aerial view of Location 9.[29]

The neighborhood around this location is a combination of residential homes and commercial buildings. The area along the east side of Connecticut Avenue contains a fitness center, a major drug chain store, a local restaurant, and office space. Along the west side of the same block, there are non-profit organizations, a church, and a national university satellite location. The area directly west of this block consists nearly entirely of residential homes.

Figure 28. Photo. Still image captured from the Location 9 camera.

There are three northbound and three southbound lanes. (These lanes continue both north and south of the relevant data collection block.) In addition, on the northbound side, an additional lane serves as a bus lane near the southern portion. Further north, this lane is available for metered parking outside rush hours. On the southbound side, an additional lane serves as a right turn only lane near the intersection with Florida Avenue. Further north, this lane is available for metered parking outside rush hours.

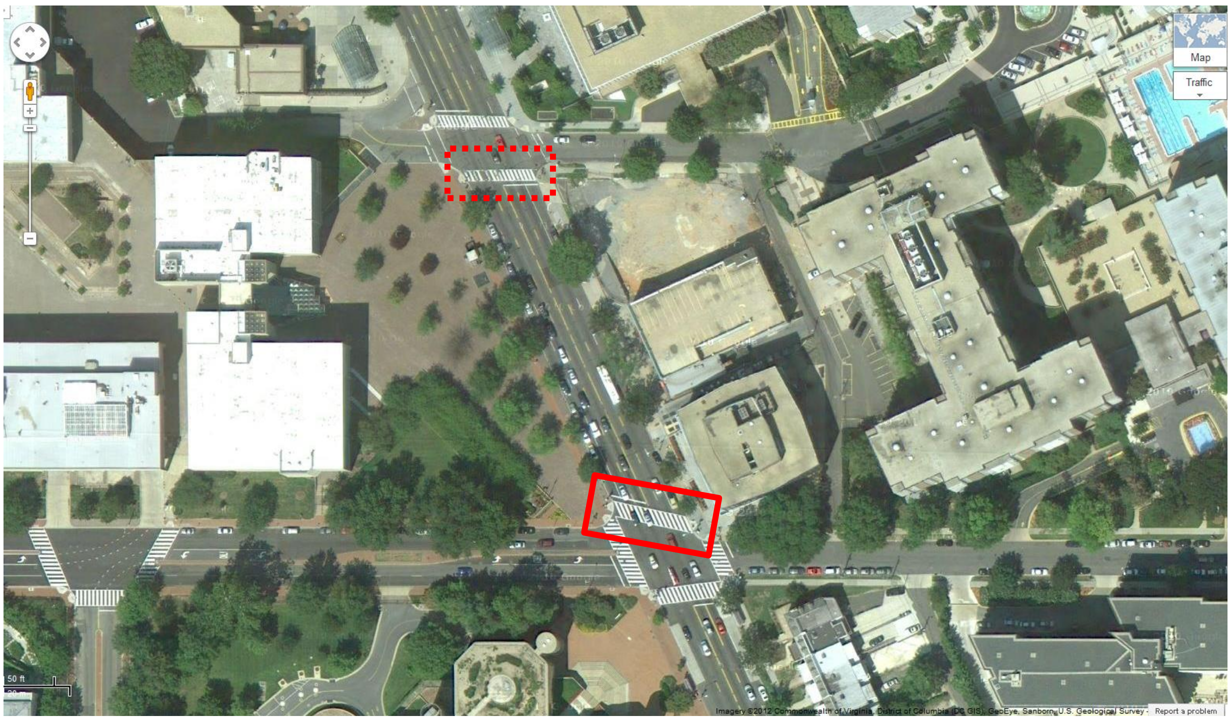
The marked intersection of Connecticut and Florida Avenues of interest (as highlighted by the solid rectangular box in figure 28) is 109 ft long (curb to curb). Each of the raised concrete medians is 5 ft in width. The walk phase is illuminated for 30 s, and the don’t walk phase is illuminated for 68 s. Figure 29 illustrates what a pedestrian might see as he or she attempts to cross from the west side of Connecticut Avenue to the east side along Florida Avenue Northwest.

Figure 29. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the west side of Connecticut Avenue Northwest to the east side of the street along Florida Avenue Northwest.

Location 10

The 10th data collection area is located at the intersection of Connecticut Avenue Northwest and Van Ness Street Northwest in Washington, DC. Figure 30 is an aerial view of this data collection area. Connecticut Avenue runs northwest/southeast and is located in the center of the image. Van Ness Street runs east/west and is located toward the bottom of the image. The solid red rectangle highlights the intersection of Connecticut Avenue Northwest and Van Ness Street Northwest.

The dotted red rectangle highlights the intersection of Connecticut Northwest and Veazey Terrace. The DDOT camera was positioned on the southwest corner of the Connecticut and Van Ness facing north (see figure 31). As a result, pedestrians making east/west crossings on Connecticut Avenue between Van Ness Street and Veazey Terrace were captured. The distance from Van Ness Street and Veazey Terrace is approximately 361 ft. Figure 30 shows marked crossings are present at both Van Ness Street Northwest (solid red line) and Veazey Terrace Northwest (dotted red line). The AADT of this specific block on Connecticut Avenue was not known. As a result, an average value based on the blocks north and south of the relevant block was computed for an estimated AADT of 41.8 (expressed in thousands and rounded to the nearest 100).[18]



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 30. Photo. Aerial view of Location 10. [30]

The neighborhood around this location is a combination of residential homes and commercial buildings. The entire west side of Connecticut Avenue is part of the University of the District of Columbia campus, which consists of mostly green space near the roadway. Along the east side of Connecticut Avenue in the same block, there is an ATM station, several small local restaurants, a liquor store, dry cleaning services, chain convenience store, office space, and a service station. Just north of Veazey Terrace is the Van Ness Metro station, which has entrances on both the east and west sides of the roadway.

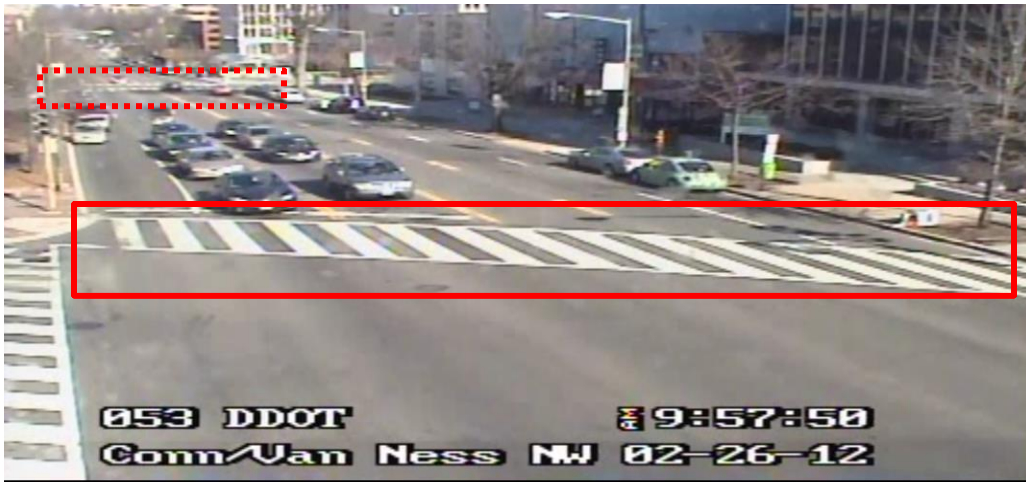


Figure 31. Photo. Still image captured from the Location 10 camera.

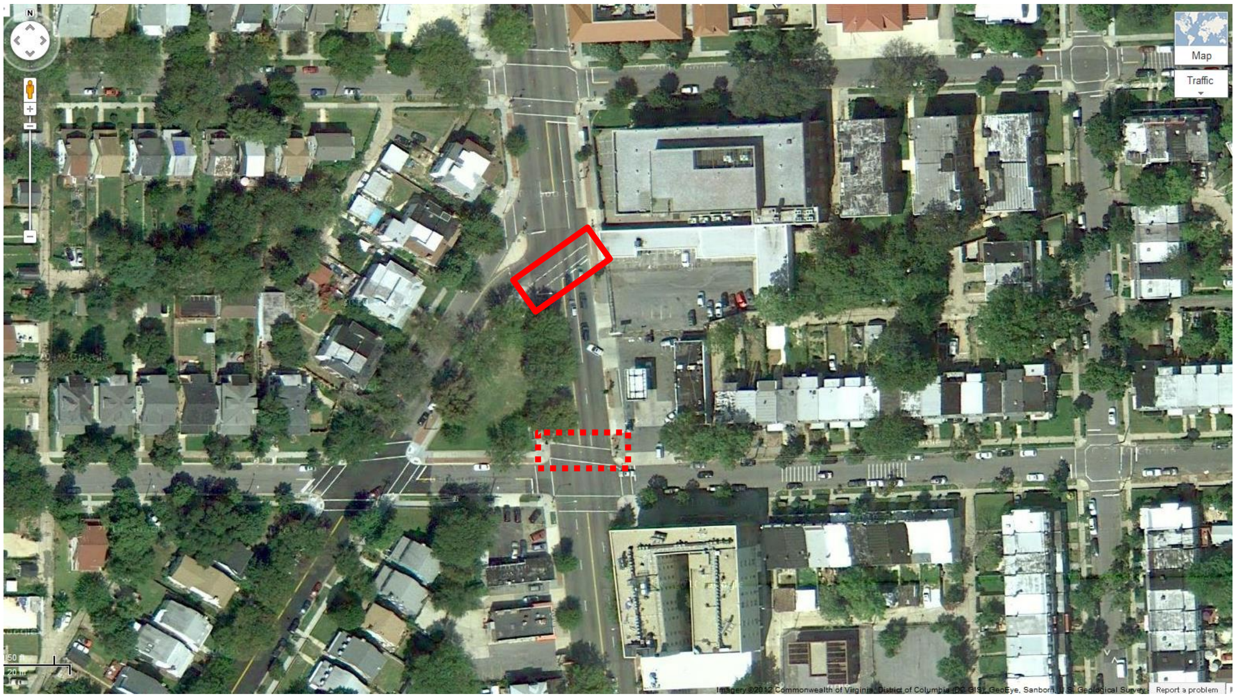
During the morning rush hour, there are four southbound lanes and two northbound lanes of traffic. During the evening rush hour, there are two southbound lanes and four northbound lanes of traffic. During the remaining times, there are two northbound and two southbound lanes of traffic, flanked by metered parking on both sides of the roadway. (These lanes continue both north and south of the relevant data collection block.)

The marked intersection of Connecticut Avenue and Van Ness Street of interest (as highlighted by the solid rectangular box in figure 31) is 72.5 ft long (curb to curb). The walk phase is illuminated for 24 s, and the don't walk phase is illuminated for 75 s. Figure 32 illustrates what a pedestrian might see as he or she attempts to cross from the west side of Connecticut Avenue to the east side along Van Ness Street Northwest.

Figure 32. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the west side of Connecticut Avenue Northwest to the east side of the street along Van Ness Street Northwest.

Location 11

The 11th data collection area is located at the intersection of Georgia Avenue Northwest and Arkansas Avenue Northwest in Washington, DC. Figure 33 is an aerial view of this data collection area. Georgia Avenue runs north/south and is located in the center area of the image. Arkansas Avenue runs northeast/southwest and is located toward the left in the image. The solid red rectangle highlights the intersection of Georgia Avenue Northwest and Arkansas Avenue Northwest. The dotted red rectangle highlights the intersection of Georgia Avenue and Farragut Street. The DDOT camera was positioned on the northeast corner of the Georgia and Arkansas intersection facing south (see figure 34). As a result, pedestrians making east/west crossings on Georgia Avenue between Arkansas Avenue and Farragut Street were captured. The distance from Arkansas Avenue and Farragut Street is approximately 193 ft. Figure 33 shows marked crossings are present at both Arkansas Avenue Northwest (solid red line) and Farragut Street Northwest (dotted red line). The intersection of Farragut Street and Georgia Avenue is not light controlled. The AADT in this area is 22.9 (expressed in thousands and rounded to the nearest 100).[18]



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 33. Photo. Aerial view of Location 11.(31)

The neighborhood around this location consists of mainly residential homes. The area along the east side of Georgia Avenue contains an automotive collision center, a service station, and a convenience store. Along the west side of the same block, there is a park that fills the entire relevant block.

Figure 34. Photo. Still image captured from the Location 11 camera.

There are two northbound and two southbound lanes of traffic. (These lanes continue both north and south of the relevant data collection block.) There is a driveway entrance to Georgia Avenue on the northbound lane. In addition, there is a southbound bus stop near the intersection of Georgia Avenue and Farragut Street.

The marked intersection of Georgia Avenue and Arkansas Avenue of interest (as highlighted by the solid rectangular box in figure 34) is 68.3 ft long (curb to curb). The walk phase is illuminated for 19 s, and the don't walk phase is illuminated for 80 s. Figure 35 illustrates what a pedestrian might see as he or she attempts to cross from the west side of Georgia Avenue to the east side along Arkansas Avenue Northwest.

Figure 35. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the west side of Georgia Avenue Northwest to the east side of the street along Arkansas Avenue Northwest.

Location 12

The 12th data collection area is located at the intersection of Georgia Avenue Northwest and Irving Street Northwest in Washington, DC. Figure 36 is an aerial view of this data collection area. Georgia Avenue runs north/south and is located in the center of the image. Irving Street runs east/west and is located in the lower portion of the image. The solid red rectangle highlights the intersection of Georgia Avenue Northwest and Irving Street Northwest. The dotted red rectangle highlights the intersection of Georgia Avenue and Kenyon Street. The DDOT camera was positioned on the southwest corner of the Georgia and Irving facing north (see figure 37). As a result, pedestrians making east/west crossings on Georgia Avenue between Irving Street and

Kenyon Street were captured. The distance from Irving Street and Kenyon Street is approximately 277 ft. Figure 36 shows marked crossings are present at both Irving Street Northwest (solid red line) and Kenyon Street Northwest (dotted red line). The AADT of this specific block on Georgia Avenue was not known. As a result, an average value based on the blocks north and south of the relevant block was computed for an estimated AADT of 19.75 (expressed in thousands and rounded to the nearest 100).[18]

Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 36. Photo. Aerial view of Location 12.[32]

The neighborhood around this location is a combination of residential homes and commercial buildings. The eastern and western sides of Georgia Avenue contain largely the same types of establishments: barber shops, hair salons, a thrift store, local restaurant, and small neighborhood markets. Just north of Irving Street, there is a southbound bus stop on Georgia Avenue.

Figure 37. Photo. Still image captured from the Location 12 camera.

There are two northbound and two southbound lanes of traffic, flanked by metered parking on both sides of the roadway. (These lanes continue both north and south of the relevant data collection block.)

The marked intersection of Georgia Avenue and Irving Street of interest (as highlighted by the solid rectangular box in figure 37) is 64.5 ft long (curb to curb). The walk phase is illuminated for 20 s, and the don't walk phase is illuminated for 78 s. Figure 38 illustrates what a pedestrian might see as he or she attempts to cross from the east side of Georgia Avenue to the west side along Irving Street Northwest.

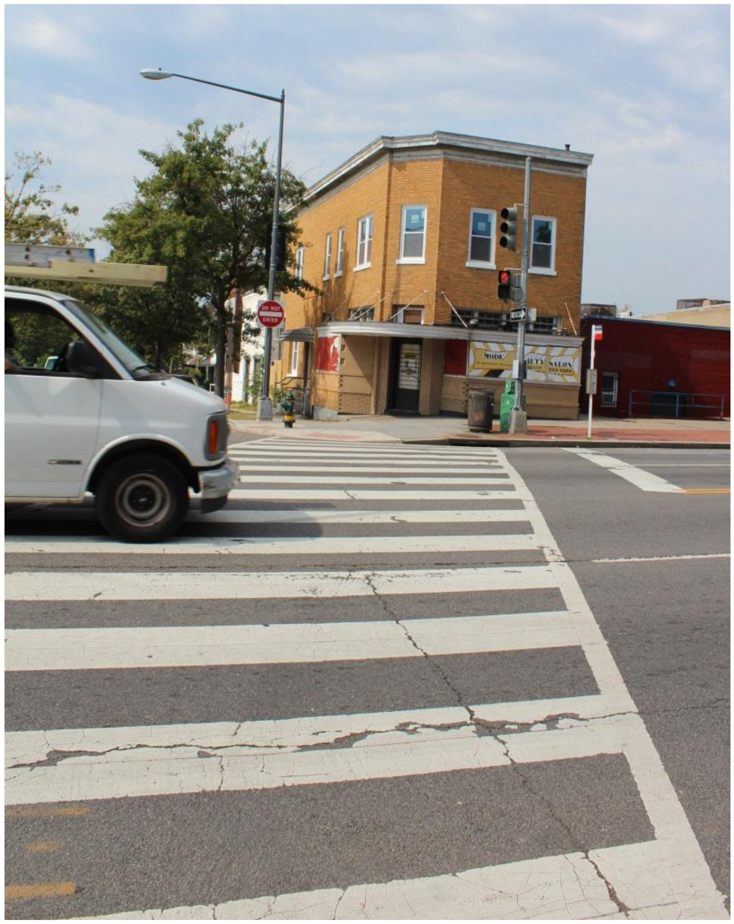
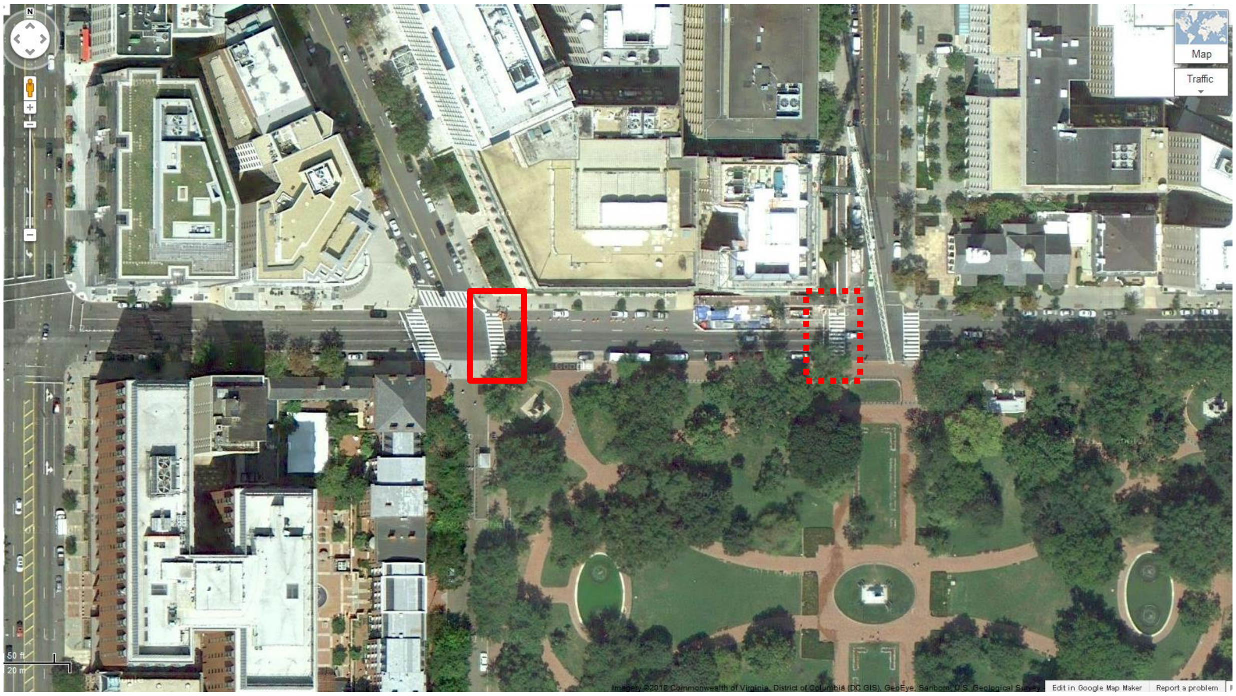


Figure 38. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the east side of Georgia Avenue Northwest to the west side of the street along Irving Street Northwest.

Location 13

The 13th data collection area is located at the intersection of H Street Northwest and Connecticut Avenue Northwest. Figure 39 is an aerial view of this data collection area. H Street runs east/west and is located in the center of the image. Connecticut Avenue runs southeast/northwest and is located to the left of the image; it creates a t-intersection. The solid red rectangle highlights the intersection of H Street Northwest and Connecticut Avenue Northwest. The dotted red rectangle highlights the intersection of H Street and 16th Street. The DDOT camera was positioned on the northwest corner of the H and Connecticut facing east (see figure 40). As a result, pedestrians making north/south crossings on H Street between Connecticut Avenue and 16th Street were captured. The distance from Connecticut Avenue and 16th Street is approximately 316 ft. Figure 39 shows marked crossings are present at both Connecticut Avenue Northwest (solid red line) and 16th Street Northwest (dotted red line). The AADT in this area is 15.1 (expressed in thousands and rounded to the nearest 100).[18]



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 39. Photo. Aerial view of Location 13.(33)

The neighborhood around this location consists of mostly commercial buildings and tourist attractions. The north side of H Street contains the U.S. Chamber of Commerce and a hotel. The south side is entirely bordered by Lafayette Square (a park located between the White House and H Street). Along the south side of H Street there are also several bus and trolley stops.

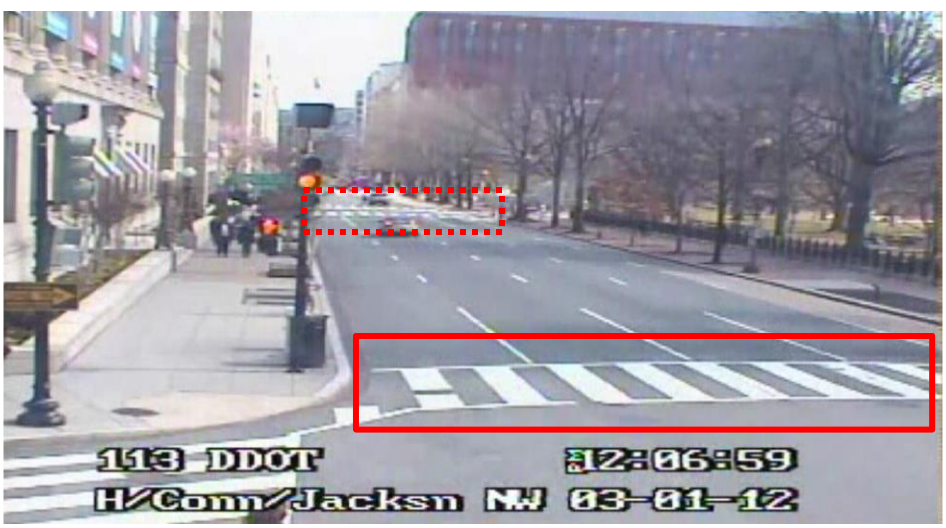


Figure 40. Photo. Still image captured from the Location 13 camera.

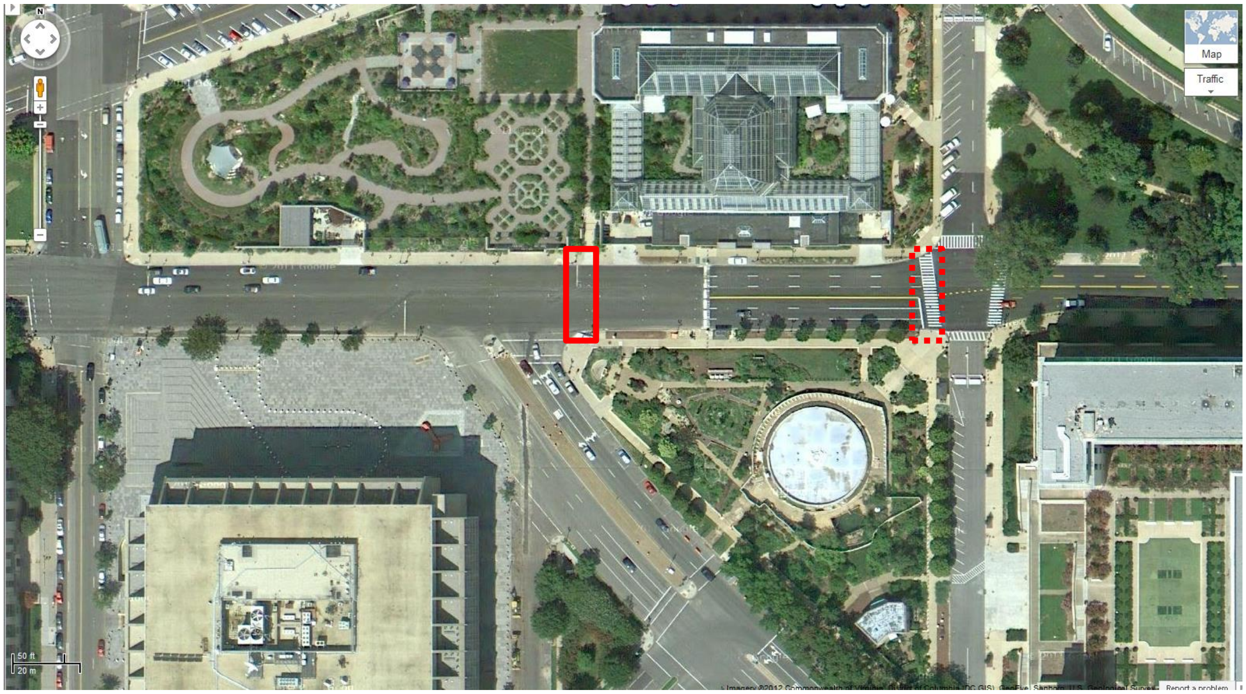
There are four eastbound lanes of traffic (H Street is a one-way street) and a bus lane on the southern portion of the street during rush hour. During the remaining hours of the day, the northernmost lane is available for metered parking. (These lanes continue east of the relevant data collection block.)

The marked intersection of H Street and Connecticut Avenue of interest (as highlighted by the solid rectangular box in figure 40) is 50 ft long (curb to curb). The walk phase is illuminated for 10 s, and the don't walk phase is illuminated for 89 s. Figure 41 illustrates what a pedestrian might see as he or she attempts to cross from the north side of H Street to the south side along Connecticut Avenue Northwest.

Figure 41. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the north side of H Street Northwest to the south side of the street along Connecticut Avenue Northwest.

Location 14

The 14th data collection area is located at the intersection of Independence Avenue Southwest and Washington Avenue Southwest in Washington, DC. Figure 42 is an aerial view of this data collection area. Independence Avenue runs east/west and is located in the center of the image. Washington Avenue runs southeast/northwest and is located in the lower portion of the image; it creates a T-intersection with Independence Avenue. The solid red rectangle highlights the intersection of Independence Avenue Southwest and Washington Avenue Southwest. The dotted red rectangle highlights the intersection of Independence and 1st. The DDOT camera was positioned on the northwest corner of Independence and Washington facing east (figure 43). As a result, pedestrians making north/south crossings on Independence Avenue between Washington Avenue and 1st Street were captured. The distance from Washington Avenue to 1st Street is approximately 338 ft. Figure 43 shows marked crossings are present at both Washington Avenue Southwest (solid red line) and 1st Street Southwest (dotted red line). The AADT in this area is 34.7 (expressed in thousands and rounded to the nearest 100).(18)



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 42. Photo. Aerial view of Location 14.(34)

The neighborhood around this location consists of mostly government buildings and tourist attractions. Both the northern and southern portions of Independence Avenue contain the United States Botanic Garden.

Figure 43. Photo. Still image captured from the Location 14 camera.

There are three eastbound and three westbound lanes of traffic. (These lanes continue east of the relevant data collection block.)

The marked intersection of Independence Avenue and Washington Avenue of interest (as highlighted by the solid rectangular box in figure 43) is 68.25 ft long (curb to curb). The walk phase is illuminated for 30 s, and the don't walk phase is illuminated for 67 s. Figure 44 illustrates what a pedestrian might see as he or she attempts to cross from the north side of Independence Avenue to the south side along Washington Avenue Southwest.

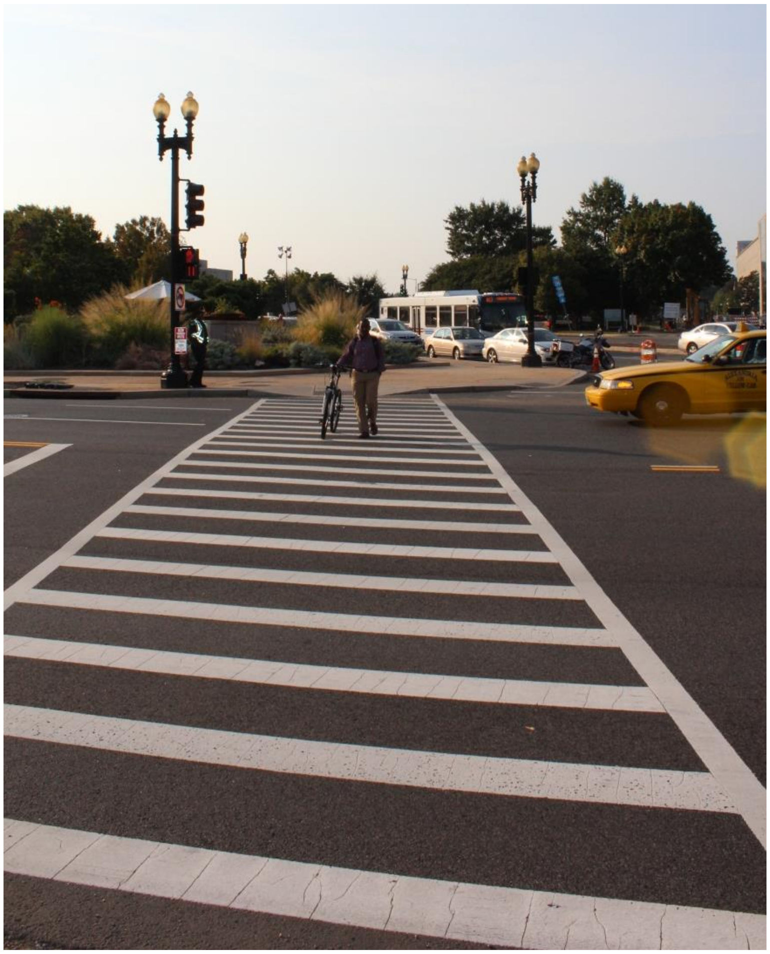
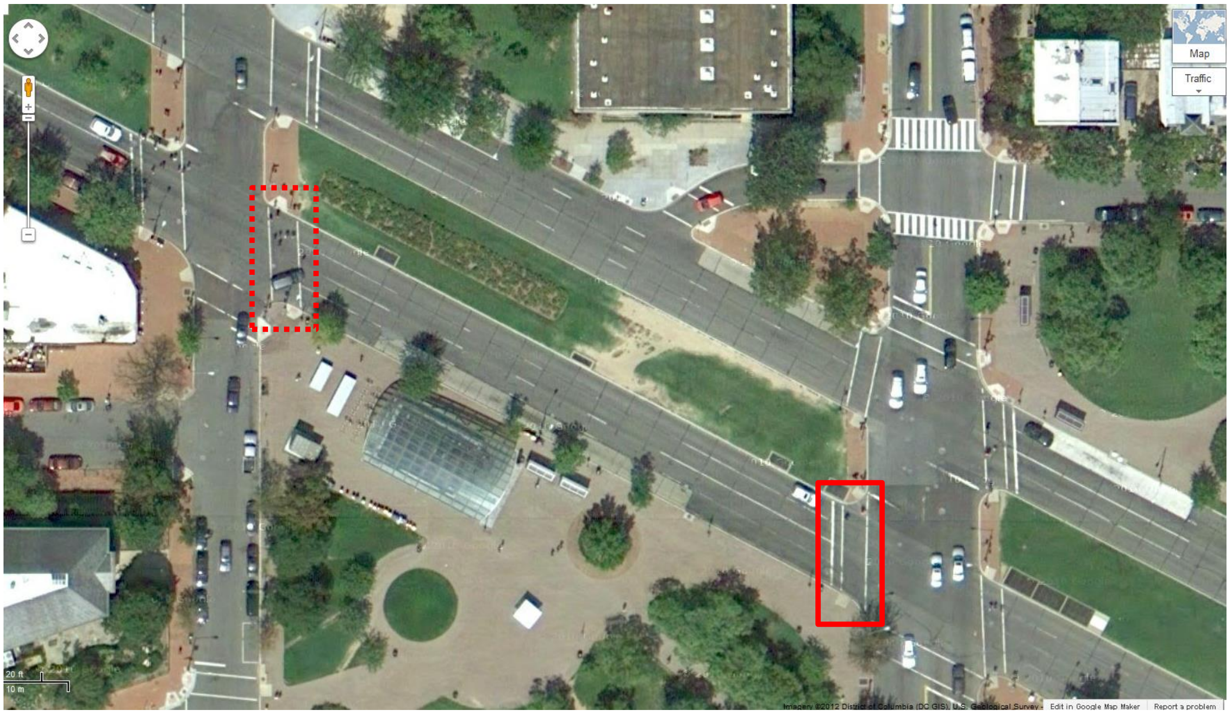


Figure 44. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the north side of Independence Avenue Southwest to the south side of the street along Washington Avenue Southwest.

Location 15

The 15th data collection area is located at the intersection of Pennsylvania Avenue Southeast and 8th Street Southeast in Washington, DC. Figure 45 is an aerial view of this data collection area. Pennsylvania Avenue runs southeast/northwest and is located in the center of the image. Eighth Street runs south/north and is located in right portion of the image. The solid red rectangle highlights the intersection of Pennsylvania Avenue Southeast and 8th Street Southeast. The dotted red rectangle highlights the intersection of Pennsylvania and 7th Street. The DDOT camera was positioned on the northeast corner of Pennsylvania and 8th facing west (see figure 46). As a result, pedestrians making north/south crossings on Pennsylvania Avenue between 8th Street and 7th Street were captured. The distance from 8th Street to 7th Street is approximately 297.5 ft. Figure 45 shows marked crossings are present at both 8th Street Southeast (solid red line) and 7th Street Southeast (dotted red line). The AADT of this specific block on Pennsylvania Avenue was not known. As a result, an average value based on the adjacent blocks of the relevant block was computed for an estimated AADT of 18.3 (expressed in thousands and rounded to the nearest 100).(18)



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 45. Photo. Aerial view of Location 15.(35)

The neighborhood around this location consists primarily of residential homes with some commercial buildings. The south side of this block of Pennsylvania Avenue is a park area with an entrance to the Eastern Market Metro station and a Capital Bikeshare™ station. A wide grass median divides the southeast bound lanes of traffic and the northwest bound lanes of traffic. A junior high school spans the north side of Pennsylvania Avenue.

Figure 46. Photo. Still image captured from the Location 15 camera.

There are three southeast bound lanes of traffic on Pennsylvania Avenue. (These lanes continue east of the relevant data collection block.) In addition, there is a fourth bus lane for stops outside the Metro station. Crossings on the north side of the grass median were not assessed.

The marked intersection of Pennsylvania Avenue and 8th Street of interest (as highlighted by the solid rectangular box in figure 46) is 45.5 ft long (curb to curb). The walk phase is illuminated for 39 s, and the don’t walk phase is illuminated for 60 s. Figure 47 illustrates what a pedestrian might see as he or she attempts to cross from the south side of Pennsylvania Avenue to the north side along 8th Street Southeast.

Figure 47. Photo. Illustration of what a pedestrian might see as he or she attempts to make a crossing from the south side of Pennsylvania Avenue Southeast to the north side of the street along 8th Street Southeast.

DATA COLLECTION VALIDATION

Just as in phase 1, the validity of the camera footage was assessed for the second set of cameras. Researchers manually scored pedestrian crossing behaviors at Location 10 (Connecticut and Van Ness Northwest), Location 13 (H and Connecticut Northwest), and Location 15 (Pennsylvania and 8th Southeast). Researchers recorded the pedestrian crossings and their interactions with vehicles over three 15-min periods at both locations. The in-vivo recordings were made the morning of March 1, 2012.

At Location 10, there was a 100-percent agreement in the classification of the pedestrian crossings for both the second and third 15-min segments. However, in the first 15-min session, there was a single discrepancy; the onsite coding resulted in 25 total pedestrian crossings and the video coding resulted in 24 crossings. At Location 13, there was a 100-percent agreement in the classification of the pedestrian crossings for both the second and last 15-min segments. However, in the first 15-min session, there was a discrepancy; the onsite coding resulted in 81 total pedestrian crossings and the video coding resulted in 75 crossings. It is likely that this difference is the result of the large number of people crossing during this short time frame. The video allowed the researchers to slow the rate of crossing for a theoretically more accurate count in crossings. At Location 15, there was a 100-percent agreement in the classification of the pedestrian crossings for both the second and last 15-min segments. However, in the first 15-min session, there was a discrepancy; the onsite coding resulted in 24 total pedestrian crossings and the video coding resulted in 22 crossings. Across all three sites, there was a 98.5-percent agreement in crossing classifications.

VIDEO DATA CODING

Many different types of pedestrian crossings and pedestrian interactions with vehicles in, and along, the roadway can be recorded. Although it is difficult to code pedestrian crossings in an exhaustive manner, the current study sought to record enough information to interpret general crossing behaviors. For each pedestrian crossing, multiple factors were recorded.

Crossing Factors

The same crossing factors as phase 1 were used to classify crossing behaviors in the second set of cameras.

Dates/Times Coded

Only sub-portions of the vast amount of video recorded data were coded owing to both time and project scope requirements of the current study. The scope of the present study included only daytime pedestrian crossings. As such, nighttime data were not examined.

Because there were no significant differences in pedestrian crossing behavior patterns based on the day of the week or the time of day in phase 1, fewer days and segments of video were coded in phase 2. Four days were randomly selected to code: February 24, February 27, March 1, and March 2. On each of these days, samples of crossings were selected throughout the day from 7:00 a.m. to 5:00 p.m., for a total of approximately 1.5 h of coded video per location, per day. The video feed from Location 11 on March 2 and from Location 13 on February 27 was blurred and could not be coded.

Weather

Table 18 describes the weather and corresponding sunrise/sunset times for each of the days that data were coded.

Table 18. Relevant sunrise, sunset, and weather for each of the coded data collection days.

Date	Sunrise (a.m.)	Sunset (p.m.)	High Temperature (°F)	Low Temperature (°F)	General Weather	Precipitation Accumulation (inches)
2/24/2012	6:48	5:55	57	46	Rain	.28
2/27/2012	6:44	5:59	64	36	Windy	—
3/01/2012	6:40	6:02	70	45	Mostly Cloudy	—
3/02/2012	6:38	6:03	55	41	Rain	.40

— Indicates no recorded precipitation.

RESULTS

The follow subsections describe the overall crossing behavior results from phase 2.

Descriptive Data

Table 19 summarizes the crossing behaviors recorded during the coded data collection times. All values are combined over the seven data collection locations. The following subsections explain the basic descriptive data for each of the seven locations in further detail.

Table 19. Summary of pedestrian crossings—combined across all seven data collection locations.

	Total Crossings	Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
		Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	2,002	—	205	5	—	—	—	—	—	—
+traffic flow change	93	—	4	2	—	—	—	—	—	—
Don't Walk	393	—	—	22	-	1	—	—	—	—
+traffic flow change	85	1	—	2	1	—	—	—	—	—
Sum	***2,573***	***1***	***209***	***31***	***1***	***1***	—	—	—	—
Unmarked Non-Intersection										
With Traffic	388	1	1	5	—	—	—	—	—	—
+traffic flow change	16	—	—	1	—	—	—	—	—	—
Against Traffic	207	18	16	28	1	3	2	—	—	—
+traffic flow change	5	—	—	0	—	—	—	—	—	—
Sum	***616***	***19***	***17***	***34***	***1***	***3***	—	—	—	—
Grand Total	**3,189**	**20**	**226**	**65**	**2**	**4**	**2**	—	—	—

— Indicates no actions of this type were recorded.

Location 9

Total Crossings:

There were a total of 805 pedestrian crossings on Connecticut Avenue Northwest between Florida Avenue and Leroy Place Northwest. (See table 20 for a summary of these crossings.) Of these crossings, 717 (or 89.07 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 625 pedestrians crossed in the marked intersection. An additional 33 crossings occurred in the marked intersection during the don't walk phase. In addition, 59 crossings occurred in the marked intersection that included a traffic flow change. Of these crossings, 20 began in the walk phase and ended in the don't walk phase. An additional 39 began in the don't walk phase and concluded in the walk phase.

At Location 9, 88 (or 10.93 percent) of the total 805 crossings took place at the unmarked non-intersection areas. Of these, 29 took place with traffic, and 53 took place against traffic. A portion of the pedestrian crossings that took place at an unmarked non-intersection area involved a traffic flow change. Four of these crossings began with traffic and ended against traffic, and two began against traffic and ended with traffic.

Yielding:

In total, there were three yielding behaviors (combined across pedestrians and vehicles). In two instances, pedestrians yielded to vehicles and a single vehicle yielded to a pedestrian at an unmarked non-intersection location against traffic. No other yielding behaviors were observed.

Evasive Pedestrian Actions:

A total of seven pedestrians took evasive actions at Location 9; all involved running/accelerated walking. There were three instances of pedestrian running/accelerated walking while in the marked intersection entirely during the don't walk phase. In an additional case, a pedestrian began crossing during the don't walk phase and completed the crossing during the walk phase. There were also three instances of pedestrian running/accelerated walking while crossing at and unmarked non-intersection location.

Evasive Vehicle Actions:

No recorded evasive vehicle actions were recorded at Location 9.

Table 20. Summary of pedestrian crossings at Location 9.

	Total Crossings	Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
		Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	625	—	—	—	—	—	—	—	—	—
+traffic flow change	20	—	—	—	—	—	—	—	—	—
Don't Walk	33	—	—	3	—	—	—	—	—	—
+traffic flow change	39	—	—	1	—	—	—	—	—	—
Sum	***717***	—	—	***4***	—	—	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	29	—	—	—	—	—	—	—	—	—
+traffic flow change	4	—	—	—	—	—	—	—	—	—
Against Traffic	53	2	1	3	—	—	—	—	—	—
+traffic flow change	2	—	—	—	—	—	—	—	—	—
Sum	***88***	***2***	***1***	***3***	**—**	**—**	**—**	**—**	**—**	**—**
Grand Total	**805**	**2**	**1**	**7**	**—**	**—**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 10

Total Crossings:

There were a total of 528 pedestrian crossings on Connecticut Avenue Northwest between Van Ness Street and Veazey Terrace. (See table 21 for a summary of these crossings.) Of these crossings, 446 (or 84.47 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 445 pedestrians crossed in the marked intersection. In a single additional instance, a pedestrian crossed starting in the don't walk phase but completed the crossing during the walk light phase.

At Location 10, 82 (15.53 percent) of the total 528 crossings took place in an unmarked non-intersection area. Of these, 46 took place with traffic, and 34 took place against traffic.

A portion of the pedestrian crossings that took place at an unmarked non-intersection area involved a traffic flow change. A single crossing began with traffic and ended against traffic, and a single crossing began against traffic and ended with traffic.

Yielding:

In total, there were 161 yielding behaviors (combined across pedestrians and vehicles). In a single case, a pedestrian who began crossing during the don't walk phase, but completed the crossing during the walk phase, yielded to a vehicle. There were also 10 cases where pedestrians yielded to vehicles while crossing in an unmarked non-intersection location. One of these instances occurred with traffic and nine occurred against traffic.

There were 150 cases of vehicles yielding to pedestrians. In 146 of these instances, vehicles yielded to pedestrians crossing during the walk phase in the marked intersection. The remaining four instances occurred when pedestrians were crossing at unmarked non-intersection locations against traffic.

Evasive Pedestrian Actions:

A total of 11 pedestrians took evasive actions at Location 10, and all involved running/accelerated walking. There were two instances of pedestrian running/accelerated walking while in the marked intersection during the walk phase. There were also nine instances of pedestrian running/accelerated walking while crossing at and unmarked non-intersection location.

Evasive Vehicle Actions:

No recorded evasive vehicle actions were recorded at Location 10.

Table 21. Summary of pedestrian crossings at Location 10.

	Total Crossings	Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
		Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	445	—	146	2	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Don't Walk	—	—	—	—	—	—	—	—	—	—
+traffic flow change	1	1	—	—	—	—	—	—	—	—
Sum	***446***	***1***	***146***	***2***	**—**	**—**	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	46	1	—	1	—	—	—	—	—	—
+traffic flow change	1	—	—	—	—	—	—	—	—	—
Against Traffic	34	9	4	8	—	—	—	—	—	—
+traffic flow change	1	—	—	—	—	—	—	—	—	—
Sum	***82***	***10***	***4***	***9***	**—**	**—**	**—**	**—**	**—**	**—**
Grand Total	**528**	**11**	**150**	**11**	**—**	**—**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 11

Total Crossings:

A total of 17 pedestrian crossings were recorded on Georgia Avenue Northwest between Arkansas Avenue and Farragut Street Northwest. (See table 22 for a summary of these crossings.) Of these crossings, 12 (or 70.59 percent) occurred within the marked intersection. These crossings can be broken down into when they occurred during the light phases. During the walk phase, there were 10 pedestrian crossings. During the don't walk phase, there were two crossings.

There were five total crossings in an unmarked non-intersection area. Of these, three occurred with traffic and two occurred against traffic.

Yielding:

No yielding behaviors were recorded at Location 11.

Evasive Pedestrian Actions:

No evasive pedestrian actions were recorded at Location 11.

Evasive Vehicle Actions:

No evasive vehicle actions were recorded at Location 11.

Table 22. Summary of pedestrian crossings at Location 11.

	Total Crossings	Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
		Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	10	—	—	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Don't Walk	2	—	—	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Sum	***12***	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	3	—	—	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Against Traffic	2	—	—	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Sum	***5***	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**
Grand Total	**17**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 12

Total Crossings:

There were a total of 185 crossings on Georgia Avenue Northwest between Irving Avenue and Kenyon Street Northwest. (See table 23 for a summary of these crossings.) Of these crossings, 127 (or 68.65 percent) occurred within the marked intersection. These crossings can be broken down into when they occurred during the light phases. During the walk phase, 120 pedestrians crossed in the marked intersection. An additional six crossings occurred in the marked intersection during the don't walk phase. There was also a single crossing that began during the walk phase and was completed during the don't walk phase.

At Location 12, 58 (31.35 percent) of the total 185 crossings took place at the unmarked non-intersection areas. Of these, 29 took place with traffic, and 27 took place against traffic. Two of these crossings began with traffic and ended against traffic.

Yielding:

In total, there were 23 yielding behaviors (combined across pedestrians and vehicles) at Location 12. There were five instances of pedestrians yielding to vehicles while crossing in the unmarked non-intersection area.

Of the 18 instances of vehicles yielding to pedestrians, 12 occurred while the pedestrian was crossing during the walk phase in the marked intersection. The remaining seven cases where vehicles yielded to pedestrians occurred during unmarked non-intersection crossings.

Evasive Pedestrian Actions:

No evasive pedestrian actions were recorded at Location 12.

Evasive Vehicle Actions:

There were two recorded instances of vehicles abruptly braking for pedestrians at Location 12. Both occurred while pedestrians were crossing at an unmarked non-intersection area.

Table 23. Summary of pedestrian crossings at Location 12.

		Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
	Total Crossings	Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	120	—	12	2	—	—	—	—	—	—
+traffic flow change	1	—	—	—	—	—	—	—	—	—
Don't Walk	6	—	—	2	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Sum	***127***	**—**	***12***	***4***	**—**	**—**	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	29	—	—	—	—	—	—	—	—	—
+traffic flow change	2	—	—	1	—	—	—	—	—	—
Against Traffic	27	5	6	6	—	—	2	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Sum	***58***	***5***	***6***	***7***	**—**	**—**	***2***	**—**	**—**	**—**
Grand Total	**185**	**5**	**18**	**11**	**—**	**—**	**2**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 13

Total Crossings:

There were a total of 609 crossings on H Street Northwest between Connecticut Avenue and 16th Street Northwest. (See table 24 for a summary of these crossings.) Of these crossings, 554 (or 90.97 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 173 pedestrians crossed in the marked intersection. An additional 285 crossings occurred in the marked intersection during the don't walk phase. In addition, 96 crossings occurred in the marked intersection that included a traffic flow change. Of these crossings, 66 began in the walk phase and ended in the don't walk phase. An additional 30 began in the don't walk phase and concluded in the walk phase.

At Location 13, 55 (or 9.03 percent) of the total 609 crossings took place in an unmarked non-intersection area. Of these, 31 took place with traffic, and 22 took place against traffic. An additional two of these crossings began with traffic and ended against traffic.

Yielding:

In total, there were 25 yielding behaviors. All of these instances involved vehicles yielding to pedestrians. Of these, 24 took place while a pedestrian was crossing in the marked intersection during the walk phase. In a single case, a vehicle yielded to a pedestrian crossing against traffic in an unmarked non-intersection area.

Evasive Pedestrian Actions:

A total of 20 pedestrians took evasive actions at Location 13. Of these, 18 involved running/accelerated walking. There was a single instance of pedestrian running/accelerated walking while in the marked intersection entirely during the walk phase. There were two cases where pedestrians began crossing during the walk phase but completed their crossing in the don't walk phase. In addition, 12 pedestrians ran/accelerated while crossing in the marked intersection entirely during the don't walk phase. Three pedestrians ran/accelerated while crossing in an unmarked non-intersection area.

In a single case, a pedestrian stopped while making a crossing that began during the don't walk phase and concluded during the walk phase. There was also a single pedestrian who changed directions while crossing in the marked intersection during the don't walk phase.

Evasive Vehicle Actions:

No evasive vehicle actions were recorded at Location 13.

Table 24. Summary of pedestrian crossings at Location 13.

	Total Crossings	Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
		Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	173	—	24	1	—	—	—	—	—	—
+traffic flow change	66	—	—	2	—	—	—	—	—	—
Don't Walk	285	—	—	12	—	1	—	—	—	—
+traffic flow change	30	—	—	—	1	—	—	—	—	—
Sum	***554***	**—**	***24***	***15***	***1***	***1***	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	31	—	—	—	—	—	—	—	—	—
+traffic flow change	2	—	—	—	—	—	—	—	—	—
Against Traffic	22	—	1	3	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Sum	***55***	**—**	***1***	***3***	**—**	**—**	**—**	**—**	**—**	**—**
Grand Total	**609**	**—**	**25**	**18**	**1**	**1**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 14

Total Crossings:

There were a total of 205 pedestrian crossings on Independence Avenue Southwest between Washington Avenue and 1st Street Southwest. (See table 25 for a summary of these crossings.) Of these crossings, 184 (or 89.76 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 165 pedestrians crossed in the marked intersection. An additional 10 crossings occurred in the marked intersection during the don't walk phase. In addition, nine crossings occurred in the marked intersection that included a traffic flow change. Of these crossings, three began in the walk phase and ended in the don't walk phase. An additional six began in the don't walk phase and concluded in the "walk phase."

At Location 14, 21 (or 10.24 percent) of the total 205 crossings took place at the unmarked non-intersection areas. Of these, 13 took place with traffic and 7 took place against traffic. One of these crossings began against traffic and ended with traffic.

Yielding:

In total, there were 27 yielding behaviors (combined across pedestrians and vehicles). In two instances, pedestrians yielded to vehicles at an unmarked non-intersection location against traffic.

There were 23 instances of vehicles yielding to pedestrians crossing in the marked intersection during the walk phase and a single case where a pedestrian began crossing during the walk phase but completed the crossing during the don't walk phase. There was also a single case where a vehicle yielded to a pedestrian crossing in the unmarked non-intersection area.

Evasive Pedestrian Actions:

A total of four pedestrians took evasive actions at Location 14; all involved running/accelerated walking. There were two instances of pedestrian running/accelerated walking while in the marked intersection entirely during the don't walk phase. There were also two instances of pedestrian running/accelerated walking while crossing at an unmarked non-intersection location.

Evasive Vehicle Actions:

No evasive vehicle actions were recorded at Location 14.

Table 25. Summary of pedestrian crossings at Location 14.

		Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
	Total Crossings	Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	165	—	23	—	—	—	—	—	—	—
+traffic flow change	3	—	1	—	—	—	—	—	—	—
Don't Walk	10	—	—	2	—	—	—	—	—	—
+traffic flow change	6	—	—	—	—	—	—	—	—	—
Sum	***184***	**—**	***24***	***2***	**—**	**—**	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	13	—	1	2	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Against Traffic	7	2	—	—	—	—	—	—	—	—
+traffic flow change	1	—	—	—	—	—	—	—	—	—
Sum	***21***	***2***	***1***	***2***	**—**	**—**	**—**	**—**	**—**	**—**
Grand Total	**205**	**2**	**25**	**4**	**—**	**—**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 15

Total Crossings:

There were a total of 840 pedestrian crossings on Pennsylvania Avenue Southeast between 8th Street and 7th Street Southeast. (See table 26 for a summary of these crossings.) Of these crossings, 533 (or 63.45 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 464 pedestrians crossed in the marked intersection. An additional 57 crossings occurred in the marked intersection during the don't walk phase. There were also 11 crossings that occurred in the marked intersection that included a traffic flow change. Of these crossings, three began in the walk phase and ended in the don't walk phase. An additional nine began in the don't walk phase and concluded in the walk phase.

At Location 15, 307 (or 36.55 percent) of the total 840 crossings took place at the unmarked non-intersection areas. Of these, 237 took place with traffic, and 62 took place against traffic. A portion of the pedestrian crossings that took place at an unmarked non-intersection area involved a traffic flow change. Seven of these crossings began with traffic and ended against traffic, and one began against traffic and ended with traffic.

Yielding:

In total, there were seven yielding behaviors. There were three instances of vehicles yielding to a pedestrian crossing in the marked intersection that began in the walk phase but concluded in the don't walk phase. There were also four cases of vehicles yielding to pedestrians crossing in an unmarked non-intersection area. No other yielding behaviors were observed.

Evasive Pedestrian Actions:

A total of 18 pedestrians took evasive actions at Location 15. There were three instances of pedestrian running/accelerated walking while in the marked intersection entirely during the don't walk phase. In an additional case, a pedestrian began crossing during the don't walk phase and completed the crossing during the walk phase. There were also 10 instances of pedestrian running/accelerated walking while crossing at and unmarked non-intersection location.

In a single case, a pedestrian stopped for a vehicle while crossing at an unmarked non-intersection area. In three instances, pedestrians changed directions while at an unmarked non-intersection area.

Evasive Vehicle Actions:

No evasive vehicle actions were recorded at Location 15.

Table 26. Summary of pedestrian crossings at Location 15.

		Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
	Total Crossings	Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	464	—	—	—	—	—	—	—	—	—
+traffic flow change	3	—	3	—	—	—	—	—	—	—
Don't Walk	57	—	—	3	—	—	—	—	—	—
+traffic flow change	9	—	—	1	—	—	—	—	—	—
Sum	***533***	**—**	***3***	***4***	**—**	**—**	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	237	—	—	2	—	—	—	—	—	—
+traffic flow change	7	—	—	—	—	—	—	—	—	—
Against Traffic	62	—	4	8	1	3	—	—	—	—
+traffic flow change	1	—	—	—	—	—	—	—	—	—
Sum	***307***	**—**	***4***	***10***	***1***	***3***	**—**	**—**	**—**	**—**
Grand Total	**840**	**—**	**7**	**14**	**1**	**3**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Predictive Model

Based on the results from the first eight cameras (and similarly low percentages of non-intersection crossings), another predictive modeling attempt was not made for cameras 9 through 15. Instead, modeling was completed after additional data were collected in phase 3.

Factor-Specific Analyses

This results section evaluates each of the recorded crossing variables in detail.

Crossing Location

Table 27 summarizes the percentage of pedestrians, by location, who crossed at marked intersections and unmarked non-intersections. The percentage of each type of crossing is presented at each location. For example, at Location 9, 77.64 percent of the total crossings took place in the marked intersection during the walk phase. When all locations are combined, the percentage of pedestrians who crossed at the marked intersection is 80.68. The mean percentage of pedestrians crossing at each of the seven locations is 79.57. None of the locations are outliers.

Table 27. Percentage of pedestrians at each crossing area in each data collection location.

	Location						
	9	**10**	**11**	**12**	**13**	**14**	**15**
Marked Intersection							
Walk	77.64	84.28	58.82	64.87	28.41	80.49	55.24
+traffic flow change	2.48	—	—	.54	10.84	1.46	.36
Don't Walk	4.10	—	11.75	3.24	46.80	4.88	6.79
+traffic flow change	4.84	.19	—	—	4.93	2.93	1.07
Overall in Intersection	***89.07***	***84.47***	***70.59***	***68.65***	***90.97***	***89.76***	***63.45***
Unmarked Non-Intersection							
With Traffic	3.60	8.71	17.65	15.68	5.09	6.34	28.21
+traffic flow change	.50	.19	—	1.08	.33	—	.83
Against Traffic	6.58	6.44	11.76	14.60	3.61	3.41	7.38
+traffic flow change	.25	.19	—	—	—	.49	.12
Overall in Unmarked Non-Intersection	***10.93***	***15.53***	***29.41***	***31.35***	***9.03***	***10.24***	***36.55***

— Indicates no actions of this type were recorded.

Pedestrian Yielding

Table 28 summarizes the percentage of pedestrians who yielded to vehicles within each crossing type. As an example, at Location 9, of the 53 total crossings made against traffic in the unmarked non-intersection area, 2 pedestrians yielded to a vehicle. This is the equivalent of 3.77 percent of the total crossings in this specific crossing type. The mean percentage of pedestrians yielding to vehicles across each of the seven locations is .86. If all of the locations are compared with one another, none are outliers.

The mean percentage of pedestrians who yielded to vehicles in the marked intersection was .03. If all of the locations are compared with one another, Location 10, the only non-zero value, is not surprisingly considered an outlier and is 2.27 standard deviations above the mean.

Next, the mean percentage of pedestrians who yielded to vehicles in unmarked non-intersections was examined. Overall, the mean percentage of yielding was 4.66. No outliers exist here. In other words, when looking at these seven locations alone, none are significantly different with regard to the proportion of pedestrians who yielded to vehicles in unmarked non-intersection areas.

A *t*-test was performed to determine whether the proportion of pedestrian yielding behaviors differed between the marked intersection and the unmarked non-intersection. No significant difference between the two locations was found, $t(6) = -2.34$, $p > .05$.

Crossings where the pedestrian completed the entire crossing during the walk phase in the marked intersection were compared with all other pedestrian yielding. Here, there were no instances of pedestrians yielding while crossing in the marked intersection entirely during the walk light phase. There was no significant difference in the percentage of pedestrians who yielded to vehicles during the walk phase in the marked intersection (M = 0 percent) compared with those pedestrians who yielded to vehicles in all other situations (M = 3.87 percent), $t(6) = -2.00$, $p > .05$.

Table 28. Percentage of pedestrians yielding to vehicles in each crossing area at each data collection location.

	Location						
	9	**10**	**11**	**12**	**13**	**14**	**15**
Marked Intersection							
Walk	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—
Don't Walk	—	—	—	—	—	—	—
+traffic flow change	—	100	—	—	—	—	—
Overall in Intersection	**—**	***.22***	**—**	**—**	**—**	**—**	**—**
Unmarked Non-Intersection							
With Traffic	—	2.17	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—
Against Traffic	3.77	26.47	—	18.52	—	28.57	—
+traffic flow change	—	—	—	—	—	—	—
Overall in Unmarked Non-Intersection	***2.27***	***12.2***	**—**	***8.62***	**—**	***9.52***	**—**
Grand Percentage	**.25**	**2.08**	**—**	**2.70**	**—**	**.98**	**—**

— Indicates no actions of this type were recorded.

Vehicle Yielding

Table 29 summarizes the percentage of vehicles that yielded to pedestrians within each crossing area at each location. As an example, at Location 14, there were 23 instances of vehicles yielding to pedestrians crossing in the walk phase in the marked intersection. This is 13.94 percent of the 165 total walk phase crossings at this location.

The overall percentage of crossings that involved a vehicle yielding to a pedestrian was compared across locations. The mean percentage of crossings that involved vehicle yielding was 9.71. The Location 10 value of 28.41 percent was 2.00 standard deviations above the mean and considered an outlier. If the Location 10 value is removed, no other outliers remain. These overall yielding behaviors do not provide much information about where vehicles are yielding to pedestrians. As a result, yielding behaviors by crossing area are examined next.

The mean percentage of vehicles that yielded to pedestrians in the marked intersection was 8.59. If all of the locations are compared with one another, the Location 10 value of 32.74 percent was 2.05 standard deviations above the mean and is considered an outlier. If Location 10 is removed, no other outliers remain.

Next, the mean percentage of drivers that yielded to pedestrians in unmarked non-intersections was examined. Overall, the mean percentage of yielding was 3.46. No outliers exist here. In other words, when looking at these seven locations alone, none are significantly different in the proportion of vehicles that yielded to pedestrians in unmarked non-intersection areas.

A *t*-test was performed to determine whether a difference existed in the percentage of vehicle yielding behaviors between the marked intersections and the unmarked non-intersections. No significant difference between the two locations was found, $t(6) = 1.28$, $p > .05$. Next, crossings where the pedestrian crossed entirely during the walk phase in the marked intersection were compared with all other vehicle yielding. Here, there was no significant difference in the percentage of vehicles that yielded to vehicles during the walk phase in the marked intersection (M = 10.09 percent) compared with those vehicles that yielded to vehicles in all other situations (M = 3.10 percent), $t(6) = 1.70$, $p > .05$.

Table 29. Percentage of vehicles yielding to pedestrians within each crossing area at each data collection location.

	Location						
	9	**10**	**11**	**12**	**13**	**14**	**15**
Marked Intersection							
Walk	—	32.81	—	10	13.87	13.94	—
+traffic flow change	—	—	—	—	—	33.33	100
Don't Walk	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—
Overall in Intersection	—	***32.74***	—	***9.45***	***4.33***	***13.04***	***.56***
Unmarked Non-Intersection							
With Traffic	—	—	—	—	—	7.69	—
+traffic flow change	—	—	—	—	—	—	—
Against Traffic	1.89	11.76	—	22.22	4.55	—	6.45
+traffic flow change	—	—	—	—	—	—	—
Overall in Unmarked Non-Intersection	***1.14***	***4.88***	—	***10.34***	***1.82***	***4.76***	***1.30***
Grand Percentage	**.12**	**28.41**	—	**9.73**	**4.11**	**12.20**	**.83**

— Indicates no actions of this type were recorded.

Yielding Comparison

It is important to understand overall yielding behavior. Here pedestrian and vehicle yielding are compared. First, yielding behaviors in the marked intersection were examined. No significant difference between pedestrian (M = .03 percent) and vehicle (M = 8.59 percent) yielding was found, $t(6) = -1.93$, $p > .05$. Similarly, when examining yielding behavior in the unmarked non-intersection, no significant difference between pedestrian (M = 4.66) and vehicle (M = .89 percent) yielding was found, $t(6) = -1.93$, $p > .05$.

Next, yielding behaviors within the marked intersection that took place entirely during the walk light phase were examined. A *t*-test revealed that there was no significant difference in the percentage of pedestrians who yielded to vehicles (M = 0 percent) and the percentage of vehicles who yielded to pedestrians (M = 10.09 percent), $t(6) = -2.24$, $p > .05$. Next, yielding behaviors that took place while the pedestrian crossed either in the unmarked non-intersection or at least partially during the don't walk phase in the marked intersection were examined. There was no significant difference in the percentage of pedestrians who yielded to vehicles (M = 3.86 percent) and the percentage of vehicles who yielded to pedestrians (M = 3.10 percent), $t(6) = 0.579$, $p > .05$.

Evasive Pedestrian Actions

Table 30 summarizes the percentage of pedestrian evasive actions within each crossing area at each of the data collection locations. Each of the three types of evasive actions (running/accelerated walking, abrupt stopping, and directional change) was combined to obtain a better overall perspective on pedestrian evasive actions.

The overall percentages of crossings that involved pedestrian evasive actions were compared across locations. The mean percentage of crossings that involved a pedestrian evasive action was 2.32. None of the locations had a mean percentage that was more than 2 standard deviations away from this mean. In other words, no outliers existed. These overall values do not provide much information about where pedestrians are making evasive actions. As a result, evasive actions by crossing area are examined next.

The mean percentage of pedestrians who took evasive actions in the marked intersection was 1.30. If all of the locations are compared with one another, none are considered outliers.

Next, the mean percentage of pedestrians who took evasive actions in unmarked non-intersections was examined. Overall, the mean percentage was 6.57. No outliers exist here. In other words, when looking at these eight locations, none are significantly different with regard to the proportion of pedestrians who took evasive actions in unmarked non-intersection areas.

A *t*-test was performed to determine whether a difference existed in the percentage of pedestrian evasive actions between the marked intersection and the unmarked non-intersection. A significant difference between the two locations was found, $t(6) = -3.51$, $p = .013$. Next, crossings where the pedestrian crossed entirely during the walk phase in the marked intersection were compared with all other pedestrian evasive actions. Here, there was again a significant difference in the percentage of pedestrians who took evasive actions during the walk phase in the marked intersection (M = .39 percent) compared with those pedestrians who took evasive actions in all other situations (M = 6.82 percent), $t(6) = -3.82$, $p = .009$.

Table 30. Percentage of pedestrian evasive actions within each crossing area at each data collection location.

	Location						
	9	**10**	**11**	**12**	**13**	**14**	**15**
Marked Intersection							
Walk	—	.45	—	1.67	.58	—	—
+traffic flow change	—	—	—	—	3.03	—	—
Don't Walk	9.09	—	—	33.33	4.56	20	5.26
+traffic flow change	2.56	—	—	—	33.33	—	11.11
Overall in Intersection	***.56***	***.45***	**—**	***3.15***	***3.07***	***1.09***	***.75***
Unmarked Non-Intersection							
With Traffic	—	2.17	—	—	—	15.38	.84
+traffic flow change	—	—	—	50.00	—	—	—
Against Traffic	5.66	23.53	—	22.22	13.64	—	19.35
+traffic flow change	—	—	—	—	—	—	—
Overall in Unmarked Non-Intersection	***3.41***	***10.98***	**—**	***12.07***	***5.45***	***9.52***	***4.56***
Grand Percentage	**.87**	**2.08**	**—**	**5.95**	**3.28**	**1.95**	**2.14**

— Indicates no actions of this type were recorded.

Evasive Vehicle Actions

Table 31 summarizes the percentage of vehicle evasive actions within each crossing area at each of the data collection locations. Each of the four types of evasive actions (abrupt braking—first vehicle, abrupt braking—second vehicle, directional change—first vehicle, and directional change—second vehicle) were combined to obtain a better overall perspective on vehicle evasive actions.

Location 12 was the only location where evasive actions were observed. As a result, no further analyses were completed.

Table 31. Percentage of vehicle evasive actions within each crossing area at each data collection location.

	Location						
	9	**10**	**11**	**12**	**13**	**14**	**15**
Marked Intersection							
Walk	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—
Don't Walk	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—
Overall in Intersection	—	—	—	—	—	—	—
Unmarked Non-Intersection							
With Traffic	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—
Against Traffic	—	—	—	7.41	—	—	—
+traffic flow change	—	—	—	—	—	—	—
Overall in Unmarked Non-Intersection	—	—	—	***3.45***	—	—	—
Grand Percentage	—	—	—	**1.08**	—	—	—

— Indicates no actions of this type were recorded.

Evasive Action Comparison

Because no vehicles took evasive actions, a comparison between vehicle and pedestrian evasive actions was not made.

DISCUSSION

An overarching goal of the present study is to determine which environmental factors influence where pedestrians cross the roadway. Pedestrian crossing behaviors were recorded and coded over a 2-week period at seven different locations. It was hoped that these data would help to identify factors that influence pedestrians to cross at unmarked non-intersection locations. As was discovered in phase 1 of this study, the number of non-intersection crossings is quite low. As a result, modeling and predicting pedestrian behavior is difficult using statistical methodologies. To more accurately describe pedestrian crossing behaviors, additional data are collected in phase 3 and described in more detail later. At present, the data and trends for the seven locations from phase 2 are discussed.

Crossing Location

As in phase 1, the majority of pedestrian crossed at marked intersection locations. Although none of the locations in phase 2 were considered outlying values in terms of crossing locations, three locations (11, 12, and 15) did have greater unmarked non-intersection crossing percentages than those in phase 1. These locations are discussed in more detail here.

Overall, Location 11 had very few crossings. However, this does not imply that there was no pedestrian traffic in this area. Rather, pedestrians did not have reason to cross the roadway at the specific location. While not specifically coded, it did appear that the majority of people crossing in the vicinity of Location 11 crossed at the far non-signalized marked crossing. This may have been the result of the increased perceived control of crossing when desired. This crossing is also quite close to a bus stop waiting area. Because of the small sample size (17 crossings), a small number of incidents can artificially influence the percentage of different types of crossings. As a result, Location 11 is excluded from further discussions.

Overall, Location 12 is quite representative of many city blocks in many cities. However, several factors, when combined, may contribute to a high number of unmarked non-intersection crossings. The first of these factors is that there are a large number of businesses on both sides of the street with parking located on both sides of the street. The result is that people frequently park on one side of the street and walk to a business on the opposite side. Further, the businesses along this block are mixed. This can result in people walking from their workplace to the other side of the street to obtain food. Although in many cases pedestrians may opt to walk to the marked crossing to cross the roadway, this portion of Georgia Avenue Northwest is relatively narrow, with a relatively low AADT. The low AADT provides gaps to cross the roadway that many pedestrians find acceptable. It is possible that pedestrians perceive that they will have more time to safely cross the roadway in these gaps than the forced 20-s crossing time (a crossing rate of 3.23 ft/s) at the marked intersection.

At Location 15, 36.55 percent of the pedestrians crossed at an unmarked non-intersection location. These crossings took place primarily in one specific area between the two marked crossings on Pennsylvania Avenue Southeast. On the south side of the relevant block, there are two primary pedestrian traffic originators/destinations: a Metro (subway) station and a bus stop that services multiple bus lines. On the north side of the relevant block, there is a large residential neighborhood. As such, many people travel between their homes and the public transportation stations/stops. Figure 45 shows there is a short section of roadway on the north side of Pennsylvania Avenue Southeast that connects westbound traffic to an intersecting street. This creates another vehicle intersection just west of 8th Street. While this is likely designed to alleviate vehicular traffic, it creates a "shortcut" for pedestrians. Pedestrians can see a clear pathway between the Metro station/bus stop areas to the residential area. In using this path to cross, pedestrians are able to make half of their crossing and wait on the grassy area that divides the north and south portions of Pennsylvania Avenue before completing the crossing, as needed. This is a tactic that would likely increase pedestrians' perceived control of their crossing. As figure 45 shows, pedestrians do indeed use this pathway regularly, so much so that the grass in the median area has been worn away.

At Location 13, most of the crossings did occur at the marked intersection (89.76 percent). However, more than half (62.57 percent) of these took place at least partially during the don’t walk phase. This extreme difference warrants discussion. There are several factors in this area that would draw people to cross at the marked intersection rather than an unmarked non-intersection. As figure 39 shows, there is a large park just to the south of the relevant block of H Street. This park provides the opportunity to walk “diagonally” through several blocks without encountering vehicle traffic. There are, however, small barriers around the park that inhibit entrance to the park outside pre-specified areas. As a result of pedestrians’ perceived advantages of walking through the park, they may also perceive an advantage to cross at the marked intersection to gain easier access to the park. This however, does not explain why pedestrians may have been persuaded to cross outside the walk phase.

As was mentioned in phase 1, it appears that the rate at which pedestrians must cross during walk phase may influence when and where pedestrians decide to cross the roadway. At Location 13, pedestrians must cross at a rate of 5 ft/s, which greatly exceeds the MUTCD recommendation of 3.5 to 3.7 ft/s.[28] At a rate of 5 ft/s (10 s to cross the roadway) it is possible that many pedestrians are simply not able to complete the crossing during the allotted time and are forced to complete the crossing during the don’t walk phase. In addition, other environmental factors in this area may influence pedestrians to cross during the don’t walk phase. There are two general expectation violations involved in this crossing. Because of southbound traffic on Connecticut Avenue turning left, pedestrians crossing west of the marked crossing of interest are allotted more time to cross the roadway. In other words, pedestrians waiting to cross in the marked intersection where crossings were recorded, were likely able to see pedestrians making a similar crossing in the adjacent crosswalk. Furthermore, the pedestrians may have been able to see the adjacent walk sign and perhaps presumed that there was an error or other problem with their respective walk sign and entered the roadway. In this case, pedestrians’ expectations to be able to cross at the same time as the pedestrians in the adjacent crossing were violated. Pedestrians crossing at this marked intersection can also view the time countdown on the perpendicular crossing light (i.e., the amount of time left for pedestrians travelling perpendicularly to cross). They might expect their own crossing light to change to walk shortly thereafter and preemptively begin crossing the roadway. This behavior may be particularly risky for pedestrians crossing from north to south because they cannot see the vehicles making left turns (and may not make appropriate evasive maneuvers). As mentioned in phase 1, it is also possible that pedestrians may not be able to see that vehicles have a turning arrow and inappropriately begin their crossings. This certainly could have been the case for pedestrians crossing from south to north in this area.

Pedestrian Yielding

In total, 20 of the 3,189 crossings (.62 percent) involved pedestrian yielding. Overall the mean percentage of pedestrians who yielded to vehicles was .86 (i.e., the mean of the percentage of pedestrians who yielded to vehicles at each location). There were no significant differences between locations when looking at total percentage of pedestrian yielding behaviors.

Only at Location 10 were there instances of pedestrians crossing in the marked intersection. However, the value of .22 percent of the total crossings within the marked intersection is within the range of observed values in phase 1. As a result, these crossings are not discussed further here. There were also no significant differences in the percentage of pedestrians who yielded to vehicles in unmarked non-intersections. All values were similar to those found in phase 1.

Vehicle Yielding

In total, 226 of the 3,189 crossings (7.09 percent) involved a vehicle yielding to a pedestrian. Overall, the mean percentage of vehicles that yielded to pedestrians was 9.71 (i.e., the mean of the percentage of vehicles that yielded to pedestrians at each location). This value is quite similar to phase 1.

Overall, Location 10 (28.41 percent) had a significantly greater percentage of vehicles that yielded to pedestrians. This high percentage is likely the result of turning vehicle traffic. Further exploration of this location reveals that the majority of these occurred in the marked intersection during the walk light phase. Vehicles originating from Van Ness Street have a green light to turn north on to Connecticut Avenue while pedestrians have a walk light phase. This then, would commonly result in vehicles yielding to pedestrians in the marked crosswalk.

There were also no significant differences in the percentage of drivers who yielded to pedestrians based on the area where pedestrians crossed the roadway.

Yielding Comparison

In phase 2, there were no significant differences in the percentage of pedestrians who yielded to vehicles and the percentage of vehicles that yielded to pedestrians.

Evasive Pedestrian Actions

In total, 71 of the 3,189 crossings (2.23 percent) involved an evasive pedestrian action. This value was similar to that for phase 1 (2.83 percent). The mean percentage of pedestrians who took evasive actions was 2.32 (i.e., the mean of the percentage of evasive pedestrian actions at each location). The percentage of evasive actions was fairly consistent across locations and across crossing types. At the present time, the data do not suggest any clear environmental reason for these evasive pedestrian actions.

Evasive Vehicle Actions

In total, 2 of the 3,189 crossings (.06 percent) involved an evasive vehicle action. This value is similar to that for phase 1 (.02 percent). The only evasive vehicle actions took place in Location 12. This, combined with the small total number of vehicle evasive actions, does not provide the opportunity to make inferences at this time.

General Discussion

In the present set of data, non-intersection crossings are relatively rare. This makes it difficult to make predictions about where pedestrians will cross the roadway. In this second phase, there were no recorded close calls or near misses. In phase 3, researchers recorded crossings at five sites in vivo. The results of these observations are discussed in the next section.

PEDESTRIAN CROSSING BEHAVIORS: PHASE 3

To more thoroughly assess pedestrian crossing behaviors, five additional pedestrian crossing locations in the Washington, DC, metropolitan area (including locations in Maryland and Virginia) were selected. Unlike in phases 1 and 2, data were coded in vivo by two researchers.

DATA COLLECTION LOCATIONS

Nearly the same criteria were used to select the locations used in the third set of data collection as those used in phase 1 and phase 2. The only difference was that researchers were placed in locations that could record pedestrian crossings and video cameras were not used. Data were collected in the late morning/early afternoons on several different days. Data for Locations 16 and 17 were collected on November 21, 2012. Data for Locations 18 and 19 were collected on December 3, 2012, and data for Location 20 were collected on December 4, 2012.

The following section describes each of the five data collection locations.

Location 16

The 16th data collection area is located at the intersection of King and Washington Streets in Alexandria, VA. Figure 48 is an aerial view of this data collection area. North Washington Street runs north/south and is located near the center of the image. King Street runs east/west and is also located toward the center of the image. The solid red rectangle highlights the intersection of King Street and North Washington Street. The dotted red rectangle highlights the intersection of North Washington Street and Cameron Street. Researchers recorded pedestrians crossing east/west on North Washington Street between King Street and Cameron Street. Researchers were positioned on the northwest corner of King and North Washington Streets. One researcher faced north and recorded pedestrians making east/west crossings on North Washington Street between King Street and Cameron Streets. Another researcher faced east and recorded pedestrians crossing east/west in the northernmost marked intersection of North Washington and King Streets. The distance from King Street to Cameron Street is approximately 361 ft. Figure 48 shows marked crossings are present at both King Street (solid red line) and Cameron Street (dotted red line). The AADT in this area is 28 (expressed in thousands and rounded to the nearest 100).[36]

Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 48. Photo. Aerial view of Location 16.[(37)]

The neighborhood around this location is a combination of residential homes and commercial buildings. Along both the eastern and western sides of North Washington Street, there are clothing stores, restaurants, and other small shops.

There are two northbound and two southbound lanes of North Washington Street. (These lanes continue both north and south of the relevant data collection block.) In addition, on the southbound side, an additional lane serves as a bus lane near the southern portion. Farther north, metered parking is available outside rush hours. On the northbound side, an additional lane serves metered parking outside rush hours.

The marked intersection of King and North Washington Streets of interest (as highlighted by the solid rectangular box in figure 48) is 75 ft long (curb to curb). A median separates the northbound and southbound traffic. This median is 7.5 ft wide and contains some flower boxes and trees (see figure 49). The walk phase is illuminated for 58 s, and the don’t walk phase is illuminated for 73 s.

Figure 49. Photo. Illustration of some of the foliage present in the median of North Washington Street.

Figure 50 illustrates what a pedestrian might see as he or she attempts to cross from the east side of North Washington Street to the west side along King Street.

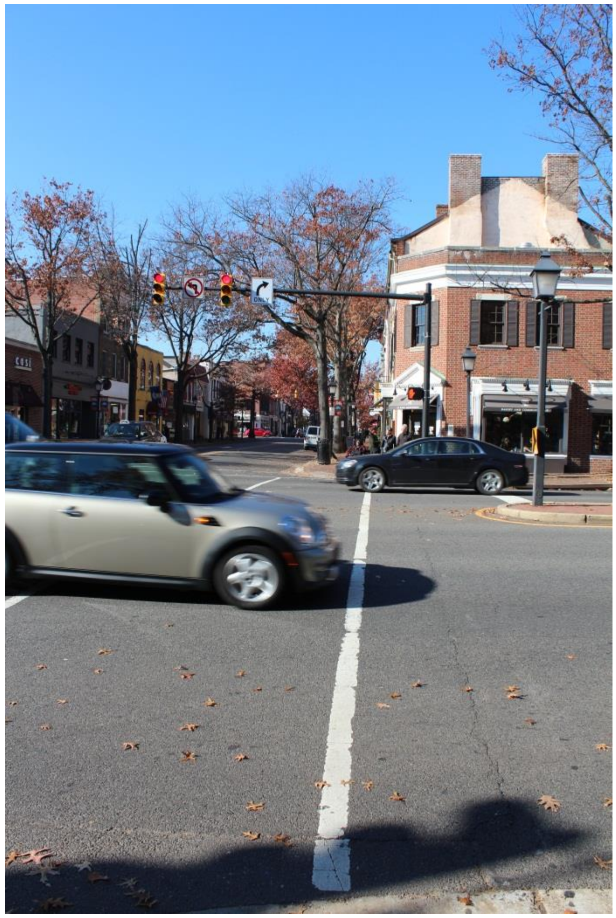
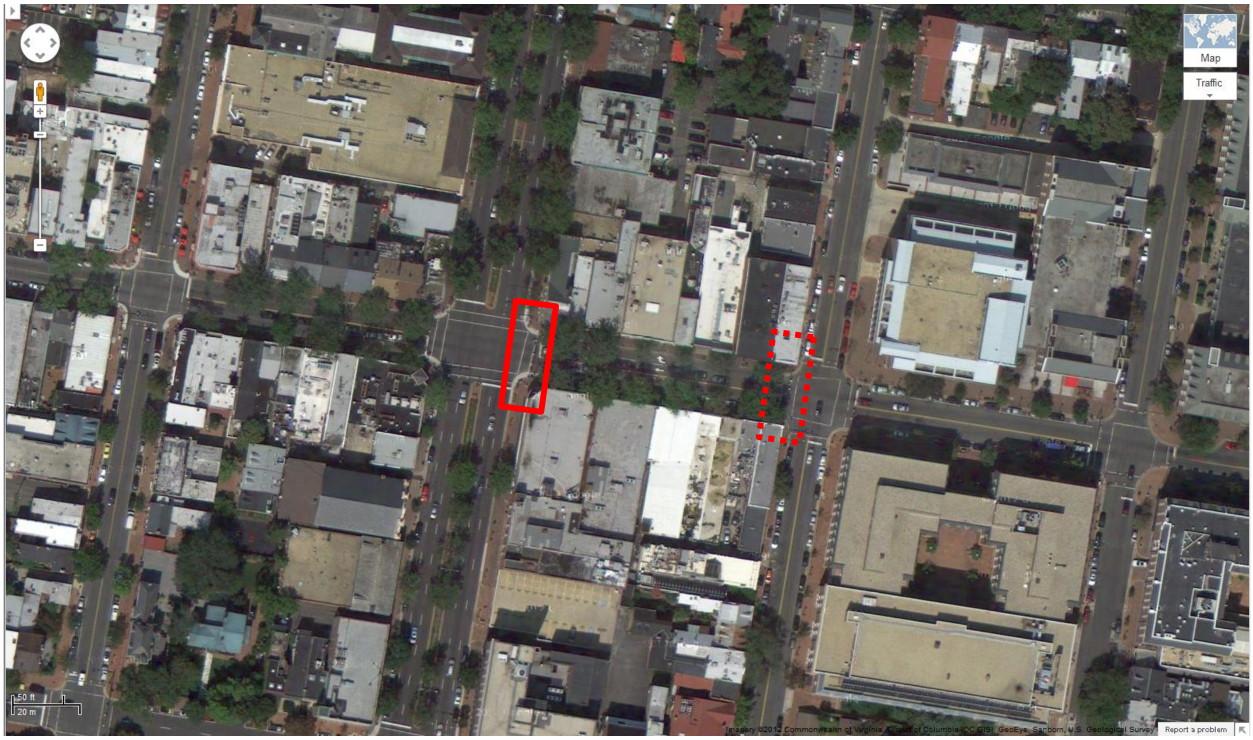


Figure 50. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the east side to the west side of North Washington Street along King Street.

Location 17

The 17th data collection area is located at the intersection of King and Washington Streets in Alexandria, VA. Figure 51 is an aerial view of this data collection area. North Washington Street runs north/south and is located just to the left of the center of the image. King Street runs east/west and is located toward the center of the image. The solid red rectangle highlights the intersection of King Street and North Washington Street. The dotted red rectangle highlights the intersection of King Street and North Saint Asaph Street. Researchers recorded pedestrians crossing north/south on King Street between North Washington Street and North Saint Asaph Street. Researchers were positioned on the southeast corner of King and North Washington Streets. One researcher faced north and recorded pedestrians making north/south crossings in the easternmost marked intersection of North Washington and King Streets. Another researcher faced east and recorded north/south crossings on King Street between North Washington Street and North Saint Asaph Street. The distance from North Washington Street to North Saint Asaph Street is approximately 266.5 ft. Figure 51 shows marked crossings are present at both North Washington Street (solid red line) and North Saint Asaph Street (dotted red line) along King Street. The AADT in this area is 8.1 (expressed in thousands and rounded to the nearest 100).[36]



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 51. Photo. Aerial view of Location 17.(37)

The neighborhood around this location is a combination of residential homes and commercial buildings. Along both the northern and southern sides of King Street are clothing stores, restaurants, and other small shops. This is primarily a shopping and commercial area.

There is one eastbound and one westbound lane of traffic on the relevant block of King Street. Parking is available on both sides of the street. Near the intersection of King Street and North Washington Street, the westbound traffic is provided with a right turn only lane to turn north. Just before the beginning of this lane, there is a bus stop.

The marked intersection of King and North Washington Streets of interest (as highlighted by the solid rectangular box in figure 51) is 43.25 ft long (curb to curb). The walk phase is illuminated for 64 s, and the don't walk phase is illuminated for 63 s.

Figure 52 illustrates what a pedestrian might see as he or she attempts to cross from the south side of King Street to the north side along North Washington Street.

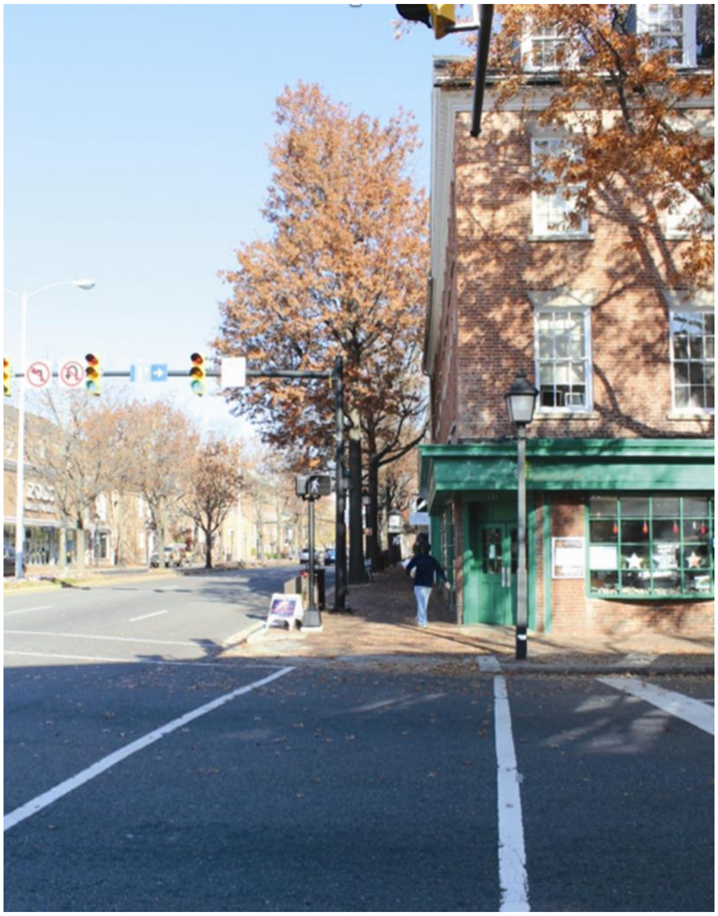
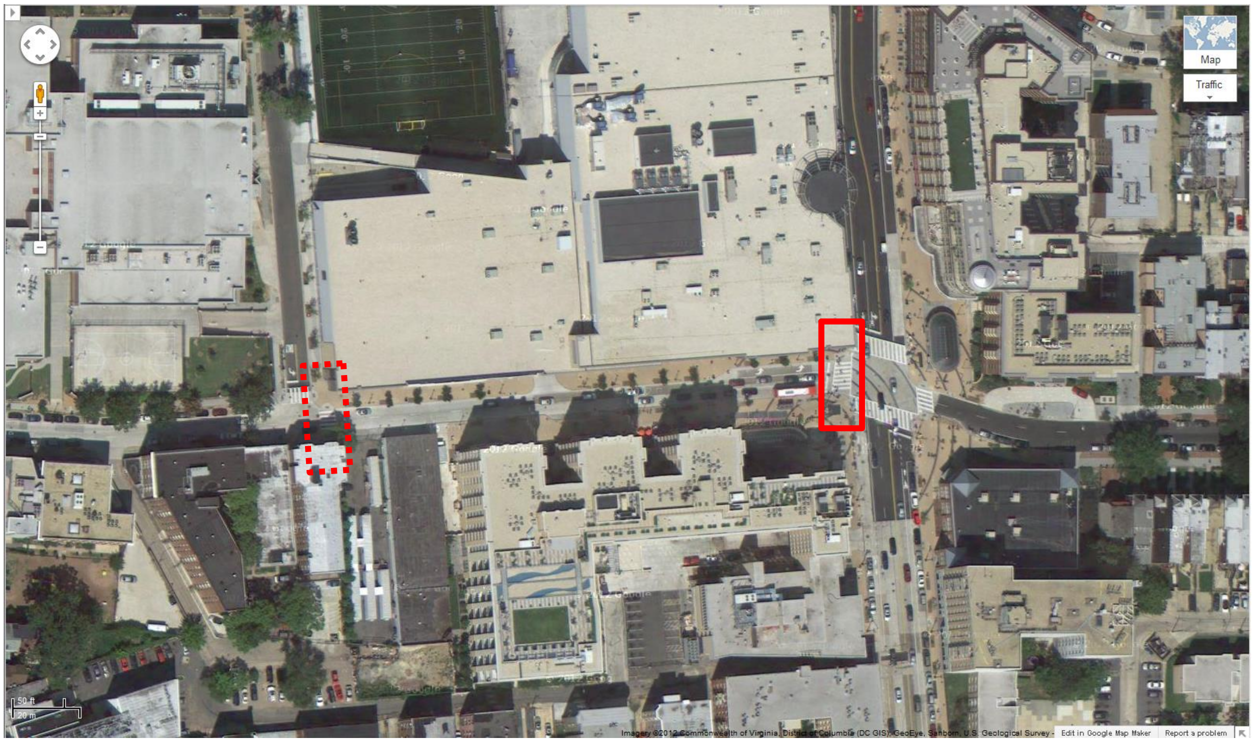


Figure 52. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the south side to the north side of King Street along North Washington Street.

Location 18

The 18th data collection area is located at the intersection of 14th Street Northwest and Irving Street Northwest in Washington, DC. Figure 53 is an aerial view of this data collection area. Irving Street Northwest runs east/west and is located in the center of the image. Fourteenth Street runs north/south and is located in the right half of the image. The solid red rectangle highlights the intersection of 14th and Irving Streets Northwest. The dotted red rectangle highlights the intersection of Irving Street and Hiatt Place Northwest in Washington, DC. Researchers recorded pedestrians crossing north/south on Irving Street between 14th Street and Hiatt Place. Researchers were positioned on the northwest corner of Irving and 14th Streets. One researcher faced south and recorded pedestrians making north/south crossings in the westernmost marked intersection of Irving and 14th Streets. Another researcher faced west and recorded north/south crossings on Irving Street between 14th Street and Hiatt Place.

The distance from 14th Street Northwest to Hiatt Place is approximately 511.25 ft. Figure 53 shows marked crossings at both 14th Street (solid red line) and Hiatt Place (dotted red line) along Irving Street. The AADT value for this specific block as not recorded. The value here was estimated based on a block to the east and to the west of the relevant roadway section. The estimated AADT in this area is 7.85 (expressed in thousands and rounded to the nearest 100).[18]



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 53. Photo. Aerial view of location 18.(38)

The neighborhood around this location is a combination of residential homes and commercial buildings. Along both the northern and southern sides of Irving Street Northwest are various restaurants and commercial businesses. Both the southwest and northeast corners of the relevant intersection contain entrances to the Metro (subway). The block northwest of this area also houses a school.

The relevant block of Irving Street Northwest is a one-way street that contains two lanes of eastbound traffic. Near the intersection of 14th Street, an additional lane is provided for left turns only. There is no parking along either side of the street. There is a bus stop near the intersection of Irving and 14th Streets on the south side of Irving.

The marked crosswalk at the relevant intersection of 14th Street and Irving Street Northwest (as highlighted by the solid rectangular box in figure 53) is 30 ft (curb to curb). The narrower portion of the street (that does not include the additional turn lane) is 20 ft (curb to curb). The walk phase is illuminated for 60 s, and the don’t walk phase is illuminated for 40 s.

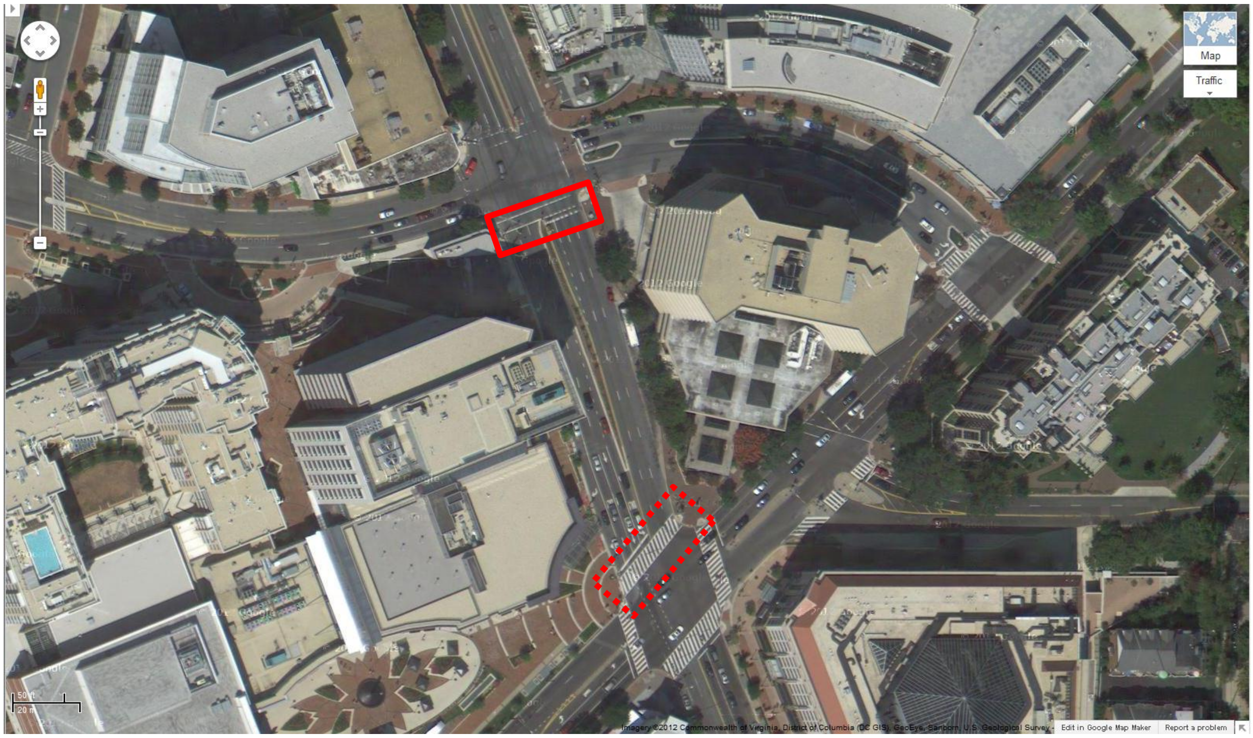
Figure 54 illustrates what a pedestrian might see as he or she attempts to cross from the north side of Irving Street Northwest to the south side along 14th Street Northwest.

Figure 54. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the north side to the south side of Irving Street Northwest along 14th Street Northwest in Washington DC.

Location 19

The 19th data collection area is located at the intersection of Wisconsin Avenue and Willard Avenue in Chevy Chase, Maryland. Figure 55 is an aerial view of this data collection area. Wisconsin Avenue runs southeast/northwest and is located in the center of the image. Willard Avenue runs east/west and is located in the upper portion of the image. The solid red rectangle highlights the intersection of Willard Avenue and Wisconsin Avenue. The dotted red rectangle highlights the intersection of Wisconsin Avenue and Western Avenue. Researchers recorded pedestrians crossing northeast/southwest on Wisconsin Avenue between Willard Avenue and Western Avenue. Researchers were positioned on the southwest corner of Wisconsin and Willard Avenues. One researcher faced east and recorded pedestrians making east/west crossings in the southernmost marked intersection of Willard and Wisconsin Avenues. Another researcher faced southeast and recorded northeast/southwest crossings on Wisconsin Avenue between Willard Avenue and Western Avenue.

The distance from Willard Avenue to Western Avenue is approximately 342 ft. Figure 55 shows marked crossings are present at both Willard Avenue (solid red line) and Western Avenue (dotted red line) along Wisconsin Avenue. The AADT value was not available for this specific block. As a result the value was estimated based on the block of Wisconsin Avenue directly south of the relevant roadway segment. The estimated AADT in this area is 23.2 (expressed in thousands and rounded to the nearest 100).(18)



Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 55. Photo. Aerial view of location 19.(39)

The neighborhood around this location is a combination of residential homes and commercial buildings. Along the southwest side of Wisconsin Avenue, there are many smaller retail shops. There are also several planters and elevated brick obstacles located between the roadway and sidewalk that can be seen in figure 56.

Figure 56. Photo. View of the planters located between the southbound lanes of traffic and the adjacent sidewalk along Wisconsin Avenue.

Along the northeast side of Wisconsin Avenue, there is a small convenience store, and entrance to a commercial building. This area, however, primarily serves as an entrance and awning to a large bus stop location. There are Metro (subway) entrances on both sides of Wisconsin Avenue near Western Avenue.

The relevant block of Wisconsin Avenue contains two lanes of southbound traffic. Near the intersection of Willard Avenue, two additional lanes act as dedicated left and right turn only lanes. There are also three lanes of northbound traffic. Near the intersection with Willard Avenue, an additional lane serves as a dedicated left turn only lane. There is a single bus stop along this side of the roadway near the intersection of Willard Avenue.

The marked crosswalk at the relevant intersection of Wisconsin Avenue and Willard Avenue (as highlighted by the solid rectangular box in figure 55) is 80 ft (curb to curb). A median divides north and southbound traffic. It is approximately 5 ft wide, and as figure 57 shows, it is more difficult to traverse in some areas because of increased elevation and foliage. The walk phase is illuminated for 30 s, and the don’t walk phase is illuminated for 70 s.

Figure 57. Photo. Illustration of some of the foliage and elevation present in the median of Wisconsin Avenue.

Figure 58 illustrates what a pedestrian might see as he or she attempts to cross from the north side of Irving Street Northwest to the South side along 14th Street Northwest.

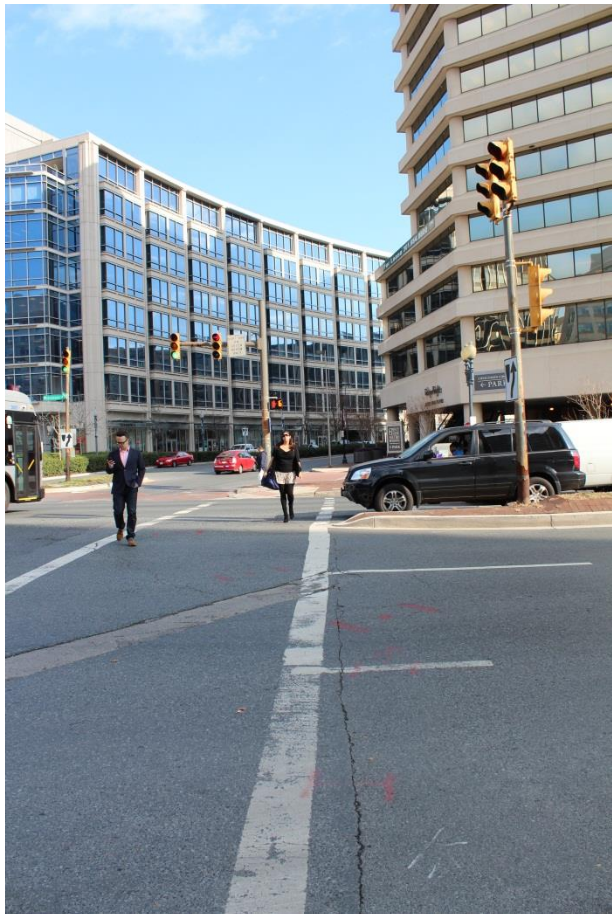


Figure 58. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the west side to the east side of Wisconsin Avenue along Willard Avenue.

Location 20

The 20th data collection area is located at the intersection of Clarendon Boulevard and North Edgewood Street in Arlington, VA. Figure 59 is an aerial view of this data collection area. Clarendon Boulevard runs northeast/southwest and is located toward the center of the image. North Edgewood runs north/south and is located in the center of the image. The solid red rectangle highlights the intersection of Clarendon Boulevard and North Edgewood Street. The dotted red rectangle highlights the intersection of Clarendon Boulevard and North Fillmore Street in Arlington, VA. Researchers recorded pedestrians crossing north/south Along Clarendon Boulevard between North Fillmore Street and North Edgewood Street. Researchers were positioned on the southwest corner of Clarendon Boulevard and North Edgewood Street. One researcher faced north and recorded pedestrians making north/south crossings in the westernmost marked intersection of Clarendon Boulevard and North Edgewood Street. Another researcher faced west and recorded north/south non-intersection crossings on Clarendon Boulevard between Edgewood Street and North Fillmore Street.

The distance from North Edgewood Street to North Fillmore Street is approximately 339.5 ft. Figure 59 shows marked crossings are present at both North Edgewood Street (solid red line) and

North Fillmore Street (dotted red line) along Clarendon Boulevard. The AADT in this area is 13 (expressed in thousands and rounded to the nearest 100).[36]

Original image: ©2012 Google®; map annotations provided by SAIC.

Figure 59. Photo. Aerial view of Location 20.[40]

The neighborhood around this location is a combination of residential homes and commercial buildings. Along both the northern and southern sides of Clarendon Boulevard are various restaurants and commercial businesses. The relevant block of Clarendon Boulevard is a one-way street that contains two lanes of eastbound traffic. Metered parking is available on both sides of the roadway.

The marked crosswalk at the relevant intersection of Clarendon Boulevard and North Edgewood Street (as highlighted by the solid rectangular box in figure 59) is 44.5 ft (curb to curb). The walk phase is illuminated for 20 s, and the don’t walk phase is illuminated for 63 s. Figure 60 illustrates what a pedestrian might see as he or she attempts to cross from the south side of Clarendon Boulevard to the north side along North Edgewood Street.

Figure 60. Photo. Illustration of what a pedestrian might see as he or she attempts to cross from the south side to the north side of Clarendon Boulevard along North Edgewood Street.

DATA CODING

For each pedestrian crossing, multiple factors were recorded. The following subsections describe each of these factors and how data were coded.

Crossing Factors

The same crossing factors as phase 1 and phase 2 were used to classify crossing behaviors in the third data collection phase.

Dates/Times Coded

Unlike in phase 1 and phase 2, all data were collected through direct (not video recorded) observation. Data at Location 16 and Location 17 were collected on November, 21, 2012. Data at Location 18 and Location 19 were collected on December 3, 2012. Data at Location 20 were recorded on December 4, 2012. All data in phase 3 were collected midday.

Weather

Table 32 describes the weather and corresponding sunrise/sunset times for each of the days that data were coded.

Table 32. Relevant sunrise, sunset, and weather for each of the coded data collection days.

Date	Sunrise (a.m.)	Sunset (p.m.)	High Temperature (°F)	Low Temperature (°F)	General Weather	Precipitation Accumulation (inches)
11/21/2012	6:07	4:51	57	40	Mostly Sunny	—
12/03/2012	7:10	4:46	70	46	Mostly Sunny	—
12/04/2012	7:11	4:46	69	49	Cloudy	—

— Indicates no recorded precipitation.

RESULTS

The follow subsections describe the overall crossing behavior results from phase 3.

Descriptive Data

Table 33 summarizes the crossing behaviors recorded during the coded data collection times. All values are combined over the five data collection locations. The following subsections explain the basic descriptive data for each of the five locations in further detail.

Table 33. Summary of pedestrian crossings—combined across data collection locations 16–20.

		Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
	Total Crossings	Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	1,082	12	82	—	—	—	1	—	—	—
+traffic flow change	72	—	—	8	—	—	—	—	—	—
Don't Walk	74	—	—	3	—	2	—	—	—	—
+traffic flow change	33	—	—	1	—	—	—	—	—	—
Sum	***1,261***	***12***	***82***	***12***	**—**	***2***	***1***	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	140	3	14	4	—	—	—	—	—	—
+traffic flow change	1	—	—	—	—	—	—	—	—	—
Against Traffic	56	3	7	2	1	—	—	—	—	—
+traffic flow change	6	—	—	—	—	—	—	—	—	—
Sum	***203***	***6***	***21***	***6***	***1***	**—**	**—**	**—**	**—**	**—**
Grand Total	**1,464**	**18**	**103**	**18**	**1**	**2**	**1**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 16

Total Crossings:

There were a total of 280 pedestrian crossings on North Washington Street between King Street and Cameron Street. (See table 34 for a summary of these crossings.) Of these crossings, 262 (or 93.57 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 232 pedestrians crossed in the marked intersection. An additional eight crossings occurred in the marked intersection during the don't walk phase. In addition, 22 crossings occurred in the marked intersection that included a traffic flow change. Of these crossings, 16 began in the walk phase and ended in the don't walk phase. An additional six began in the don't walk phase and concluded in the walk phase.

At Location 16, 18 (or 6.43 percent) of the total 280 crossings took place at the unmarked non-intersection areas. Of these, 14 took place with traffic, and 1 took place against traffic. A portion of the pedestrian crossings that took place at an unmarked non-intersection area involved a traffic flow change. All three of these crossings began against traffic and ended with traffic.

Yielding:

In total, there were 58 yielding behaviors (combined across pedestrians and vehicles). There was a single instance of a pedestrian yielding to a vehicle in an unmarked non-intersection area. In the remaining 57 instances of yielding, the vehicle yielded to the pedestrian. In 55 of these instances, pedestrians were walking in the marked intersection during the walk phase. In the remaining two cases, the vehicle yielded to a pedestrian in the unmarked non-intersection. No other yielding behaviors were observed.

Evasive Pedestrian Actions:

A total of 10 pedestrians took evasive actions at Location 16, and all involved running/accelerated walking. In eight cases, pedestrians began crossing during the walk phase and completed the crossing in the don't walk phase. There was a single instance of pedestrian running/accelerated walking while in the marked intersection entirely during the don't walk phase. In an additional case, a pedestrian began crossing during the don't walk phase and completed the crossing during the walk phase. There were also three instances of pedestrian running/accelerated walking while crossing at and unmarked non-intersection location.

Evasive Vehicle Actions:

There were two recorded evasive vehicle actions at Location 16. In both cases, the vehicle abruptly stopped for a pedestrian crossing in the marked intersection during the don't walk phase.

Table 34. Summary of pedestrian crossings at Location 16.

	Total Crossings	Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
		Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	232	—	55	—	—	—	—	—	—	—
+traffic flow change	16	—	—	8	—	—	—	—	—	—
Don't Walk	8	—	—	1	—	2	—	—	—	—
+traffic flow change	6	—	—	1	—	—	—	—	—	—
Sum	***262***	—	***55***	***10***	—	***2***	—	—	—	—
Unmarked Non-Intersection										
With Traffic	14	1	2	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Against Traffic	1	—	—	—	—	—	—	—	—	—
+traffic flow change	3	—	—	—	—	—	—	—	—	—
Sum	***18***	***1***	***2***	**—**	**—**	**—**	**—**	**—**	**—**	**—**
Grand Total	**280**	**1**	**57**	**10**	**—**	**2**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 17

Total Crossings:

There were a total of 225 pedestrian crossings on King Street between North Washington Street and Saint Asaph Street. (See table 35 for a summary of these crossings.) Of these crossings, 184 (or 81.77 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 165 pedestrians crossed in the marked intersection. An additional 13 crossings occurred in the marked intersection during the don’t walk phase. In addition, six crossings occurred in the marked intersection that included a traffic flow change. Of these crossings, four began in the walk phase and ended in the don’t walk phase. An additional two began in the don’t walk phase and concluded in the walk phase.

At Location 17, 41 (or 18.22 percent) of the total 225 crossings took place at the unmarked non-intersection areas. Of these, 24 took place with traffic, and 17 took place against traffic.

Yielding:

In total, there were 38 yielding behaviors (combined across pedestrians and vehicles). In 15 cases, pedestrians yielded to vehicles. Twelve of these occurred while the pedestrian was in the marked intersection during the walk phase. In the remaining three instances, pedestrians yielded to vehicles while crossing in the unmarked non-intersection area.

There were 23 instances of vehicles yielding to pedestrians. In 16 cases, pedestrians were in the marked intersection during the walk phase. In the remaining seven instances, vehicles yielded to pedestrians crossing in an unmarked non-intersection.

Evasive Pedestrian Actions:

Only a single evasive pedestrian action was recorded at Location 17. During the don’t walk phase of in the marked intersection, a pedestrian was recorded as running/accelerated walking.

Evasive Vehicle Actions:

There was a single recorded evasive vehicle action at Location 17. In this case, the vehicle abruptly stopped for a pedestrian crossing in the marked intersection during the walk phase.

Table 35. Summary of pedestrian crossings at Location 17.

		Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
	Total Crossings	Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	165	12	16	—	—	—	1	—	—	—
+traffic flow change	4	—	—	—	—	—	—	—	—	—
Don't Walk	13	—	—	1	—	2	—	—	—	—
+traffic flow change	2	—	—	—	—	—	—	—	—	—
Sum	***184***	***12***	***16***	***1***	**—**	**—**	***1***	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	24	1	4	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Against Traffic	17	2	3	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Sum	***41***	***3***	***7***	**—**	**—**	**—**	**—**	**—**	**—**	**—**
Grand Total	**225**	**15**	**23**	**1**	**—**	**—**	**1**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 18

Total Crossings:

There were a total of 786 pedestrian crossings on Irving Street Northwest between 14th Street Northwest and Hiatt Place Northwest. (See table 36 for a summary of these crossings.) Of these crossings, 661 (or 84.10 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 574 pedestrians crossed in the marked intersection. An additional 33 crossings occurred in the marked intersection during the don't walk phase. In addition, 54 crossings occurred in the marked intersection that included a traffic flow change. Of these crossings, 43 began in the walk phase and ended in the don't walk phase. An additional 11 began in the don't walk phase and concluded in the walk phase.

At Location 18, 125 (or 15.90 percent) of the total 786 crossings took place at the unmarked non-intersection areas. Of these, 98 took place with traffic, and 26 took place against traffic. In a single case, a pedestrian began crossing in the unmarked non-intersection with traffic and ended against traffic.

Yielding:

In total, 12 yielding behaviors (combined across pedestrians and vehicles) were recorded at Location 18. In all 12 instances, vehicles yielded to pedestrians in an unmarked non-intersection area.

Evasive Pedestrian Actions:

A total of four pedestrians took evasive actions at Location 18; all involved running/accelerated walking. In all four instances, pedestrians were recorded as running/ accelerated walking while crossing at and unmarked non-intersection location.

Evasive Vehicle Actions:

No evasive vehicle actions were recorded at Location 18.

Table 36. Summary of pedestrian crossings at Location 18.

	Total Crossings	Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
		Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	574	—	—	—	—	—	—	—	—	—
+traffic flow change	43	—	—	—	—	—	—	—	—	—
Don't Walk	33	—	—	—	—	—	—	—	—	—
+traffic flow change	11	—	—	—	—	—	—	—	—	—
Sum	***661***	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	98	—	8	3	—	—	—	—	—	—
+traffic flow change	1	—	—	—	—	—	—	—	—	—
Against Traffic	26	—	4	1	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Sum	***125***	**—**	***12***	***4***	**—**	**—**	**—**	**—**	**—**	**—**
Grand Total	**786**	**—**	**12**	**4**	**—**	**—**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 19

Total Crossings:

There were a total of 84 pedestrian crossings on Wisconsin Avenue between Willard Street and Western Avenue. (See table 37 for a summary of these crossings.) Of these crossings, 81 (or 96.43 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 73 pedestrians crossed in the marked intersection. In addition, eight crossings occurred in the marked intersection that included a traffic flow change. Of these crossings, seven began in the walk phase and ended in the don't walk phase. An additional one crossing began in the don't walk phase and concluded in the walk phase.

At Location 19, 3 (or 3.57 percent) of the total 84 crossings took place at the unmarked non-intersection areas. Of these, one took place with traffic, and one took place against traffic. In a single case, a pedestrian began crossing in the unmarked non-intersection against traffic and ended with traffic.

Yielding:

In total, there were 11 yielding behaviors (combined across pedestrians and vehicles) recorded at Location 19. In all 11 instances, vehicles yielded to pedestrians in the marked intersection during the walk phase.

Evasive Pedestrian Actions:

No evasive pedestrian actions were recorded at Location 19.

Evasive Vehicle Actions:

No evasive vehicle actions were recorded at Location 19.

Table 37. Summary of pedestrian crossings at Location 19.

		Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
	Total Crossings	Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	73	—	11	—	—	—	—	—	—	—
+traffic flow change	7	—	—	—	—	—	—	—	—	—
Don't Walk	—	—	—	—	—	—	—	—	—	—
+traffic flow change	1	—	—	—	—	—	—	—	—	—
Sum	***81***	**—**	***11***	**—**	**—**	**—**	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	1	—	—	—	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Against	1	—	—	—	—	—	—	—	—	—
+traffic flow change	1	—	—	—	—	—	—	—	—	—
Sum	***3***	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**
Grand Total	**84**	**—**	**11**	**—**	**—**	**—**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Location 20

Total Crossings:

There were a total of 89 pedestrian crossings on Clarendon Boulevard between North Edgewood Street and North Fillmore Street. (See table 38 for a summary of these crossings.) Of these crossings, 73 (or 82.02 percent) occurred within the marked intersection (i.e., marked crosswalk). These crossings can be broken down into when they occurred during the light phases. During the walk phase, 38 pedestrians crossed in the marked intersection. An additional 20 crossings occurred in the marked intersection during the don't walk phase. In addition, 15 crossings occurred in the marked intersection that included a traffic flow change. Of these crossings, two began in the walk phase and ended in the don't walk phase. An additional 13 crossings began in the don't walk phase and concluded in the "walk phase."

At Location 20, 16 (or 17.98 percent) of the total 89 crossings took place at the unmarked non-intersection areas. Of these, 3 took place with traffic, and 11 took place against traffic. In two instances, pedestrians began crossing in the unmarked non-intersection against traffic and ended with traffic.

Yielding:

In total, there were two yielding behaviors (combined across pedestrians and vehicles) recorded at Location 20. In both instances, pedestrians yielded to vehicles while crossing in the unmarked non-intersection area.

Evasive Pedestrian Actions:

A total of four evasive pedestrian actions were recorded at Location 20. In a single instance, a pedestrian abruptly stopped while crossing in an unmarked non-intersection area. The remaining three evasive actions involved running/accelerated walking. In one instance, the pedestrian accelerated in the marked intersection during the don't walk phase. In the remaining two cases, pedestrians were seen running/accelerated walking in unmarked non-intersection areas.

Evasive Vehicle Actions:

No evasive vehicle actions were recorded at Location 20.

Table 38. Summary of pedestrian crossings at Location 20.

		Yielding		Evasive Pedestrian Actions			Evasive Vehicle Actions			
	Total Crossings	Pedestrian	Vehicle	Running/ Accelerated Walking	Abrupt Stopping	Directional Change	Abrupt Braking (1st Vehicle)	Abrupt Braking (2nd Vehicle)	Directional Change (1st Vehicle)	Directional Change (2nd Vehicle)
Intersection										
Walk	38	—	—	—	—	—	—	—	—	—
+traffic flow change	2	—	—	—	—	—	—	—	—	—
Don't Walk	20	—	—	1	—	—	—	—	—	—
+traffic flow change	13	—	—	—	—	—	—	—	—	—
Sum	***73***	**—**	**—**	***1***	**—**	**—**	**—**	**—**	**—**	**—**
Unmarked Non-Intersection										
With Traffic	3	1	—	1	—	—	—	—	—	—
+traffic flow change	—	—	—	—	—	—	—	—	—	—
Against Traffic	11	1	—	1	1	—	—	—	—	—
+traffic flow change	2	—	—	—	—	—	—	—	—	—
Sum	***16***	***2***	**—**	***2***	***1***	**—**	**—**	**—**	**—**	**—**
Grand Total	**89**	**2**	**—**	**3**	**1**	**—**	**—**	**—**	**—**	**—**

— Indicates no actions of this type were recorded.

Predictive Model

It was hoped that the results of this study might be used to develop a model that would predict whether a pedestrian would cross at a marked intersection or an unmarked non-intersection based on the features of the environment. However, based on the results of the first eight cameras in phase 1 (and similarly low percentages of non-intersection crossings), another predictive modeling attempt was not made for locations 16–20. Instead, a model is presented in the next section that included data from all three data collection phases.

Factor-Specific Analyses

This section evaluates each of the recorded crossing variables in detail.

Crossing Location

Table 39 summarizes the percentage of pedestrians, by location, who crossed at a marked intersection and unmarked non-intersection. The percentage of each type of crossing is presented at each location. For example, at Location 19, 86.90 percent of the total crossings took place in the marked intersection during the walk phase. When the raw values at all locations are combined, the percentage of pedestrians who crossed at the marked intersection is 86.13. The mean percentage of pedestrians crossing at each of the five locations is 87.98 in the marked intersection. None of the locations are outliers.

Table 39. Percentage of pedestrians at each crossing area in each data collection location.

	Location				
	16	**17**	**18**	**19**	**20**
Marked Intersection					
Walk	82.86	73.33	73.03	86.90	42.70
+traffic flow change	5.71	1.78	5.47	8.33	2.25
Don't Walk	2.86	5.78	4.20	—	22.47
+traffic flow change	2.14	.89	1.40	1.19	14.61
Overall in Intersection	***93.57***	***81.78***	***84.10***	***96.43***	***82.02***
Unmarked Non-Intersection					
With Traffic	5.00	1.67	12.47	1.19	3.37
+traffic flow change	—	—	.13	—	—
Against Traffic	.36	7.56	3.31	1.19	12.36
+traffic flow change	1.07	—	—	1.19	2.25
Overall in Unmarked Non-Intersection	***6.43***	***18.22***	***15.90***	***3.57***	***17.98***

— Indicates no actions of this type were recorded.

Pedestrian Yielding

Table 40 summarizes the percentage of pedestrians who yielded to vehicles within each crossing type. As an example, at Location 17, of the 165 total crossings made in the marked intersection during the walk phase, 12 pedestrians yielded to vehicles. This is the equivalent of 7.27 percent of the total crossings in this specific crossing type. The mean percentage of pedestrians yielding to vehicles across each of the five locations is 1.86. If all of the locations are compared with one another, none are outliers.

The mean percentage of pedestrians who yielded to vehicles in the marked intersection was 1.30. If all of the locations are compared with one another, none are outliers (even though Location 17 is the only non-zero value).

Next, the mean percentage of pedestrians who yielded to vehicles in unmarked non-intersections was examined. Overall, the mean percentage of yielding was 5.08. No outliers exist here. In other words, when looking at these five locations alone, none are significantly different in the proportion of pedestrians who yielded to vehicles in unmarked non-intersection areas.

A *t*-test was performed to determine whether the proportion of pedestrian yielding behaviors differed between the marked intersection and the unmarked non-intersection. No significant difference between the two locations was found, $t(4) = -1.56$, $p > .05$. Pedestrian yielding that took place in crossings that occurred within the marked intersection entirely during the walk phase (M = 1.45 percent) were compared with all other crossings (M = 2.20 percent). No significant difference was found, $t(4) = -.71$, $p > .05$.

Table 40. Percentage of pedestrians yielding to vehicles in each crossing area at each data collection location.

	Location				
	16	**17**	**18**	**19**	**20**
Marked Intersection					
Walk	—	7.27	—	—	—
+traffic flow change	—	—	—	—	—
Don't Walk	—	—	—	—	—
+traffic flow change	—	—	—	—	—
Overall in Intersection	—	***6.52***	—	—	—
Unmarked Non-Intersection					
With Traffic	7.14	4.17	—	—	33.33
+traffic flow change	—	—	—	—	—
Against Traffic	—	11.76	—	—	9.09
+traffic flow change	—	—	—	—	—
Overall in Unmarked Non-Intersection	***5.56***	***7.32***	—	—	***12.50***
Grand Percentage	**.36**	**6.67**	—	—	**2.25**

— Indicates no actions of this type were recorded.

Vehicle Yielding

Table 41 summarizes the percentage of vehicles that yielded to pedestrians within each crossing area at each location. As an example, at Location 16, there were 23 instances of vehicles yielding to pedestrians crossing in the walk phase in the marked intersection. This is 23.71 percent of the 232 total walk phase crossings in this location.

The overall percentages of crossings that involved a vehicle yielding to a pedestrian were compared across locations. The mean percentage of crossings that involved vehicle yielding was 9.04. None of the locations were considered to be outliers. These overall yielding behaviors do not provide much information about where vehicles are yielding to pedestrians. As a result, yielding behaviors by crossing area are examined next.

The mean percentage of vehicles that yielded to pedestrians in the marked intersection was 5.57. None of the locations were considered to be outliers.

Next, the mean percentage of vehicles that yielded to pedestrians in unmarked non-intersections was examined. Overall, the mean percentage of yielding was 7.56. No outliers exist here. In other words, when looking at these five locations alone, none are significantly different for the proportion of drivers who yielded to pedestrians in unmarked non-intersection areas.

A *t*-test was performed to determine whether a difference existed in the percentage of vehicle yielding behaviors between the marked intersections and the unmarked non-intersections. No significant difference between the two locations was found, $t(4) = .234$, $p > .05$. Uniquely, in these five locations, the only instances of vehicles yielding to pedestrians in the marked intersection occurred during the walk light phase. Vehicle yielding to pedestrians that crossed within the marked intersection entirely during the walk phase (M = 9.69 percent) were compared with all other crossings (M = 4.30 percent). No significant difference was found, $t(4) = 1.08$, $p > .05$.

Table 41. Percentage of vehicles yielding to pedestrians in each crossing area at each data collection location.

	Location				
	16	**17**	**18**	**19**	**20**
Marked Intersection					
Walk	23.71	9.70	—	15.07	—
+traffic flow change	—	—	—	—	—
Don't Walk	—	—	—	—	—
+traffic flow change	—	—	—	—	—
Overall in Intersection	***20.99***	***8.70***	—	***13.58***	—
Unmarked Non-Intersection					
With Traffic	14.29	16.67	8.16	—	—
+traffic flow change	—	—	—	—	—
Against	—	17.65	15.38	—	—
+traffic flow change	—	—	—	—	—
Overall in Unmarked Non-Intersection	***11.11***	***17.07***	***9.60***	—	—
Grand Percentage	**20.36**	**10.22**	**1.53**	**13.10**	—

— Indicates no actions of this type were recorded.

Yielding Comparison

It is important to understand overall yielding behavior. However, because of the infrequency of observed yielding in phase 3, it is not explored further here. However, a comparison of all 20 locations is examined later.

Evasive Pedestrian Actions

Table 42 summarizes the percentage of pedestrian evasive actions within each crossing area at each of the data collection locations. The three types of evasive actions (running/accelerated walking, abrupt stopping, and directional change) were combined to obtain a better overall perspective on pedestrian evasive actions.

The percentages of crossings that involved pedestrian evasive actions were compared across locations. The mean percentage of crossings that involved a pedestrian evasive action was 1.95. None of the locations had a mean percentage that was more than 2 standard deviations away from this mean. In other words, no outliers existed. These overall values do not provide much information about where pedestrians are making evasive actions. As a result, evasive actions by crossing area are examined next.

The mean percentage of pedestrians who took evasive actions in the marked intersection was 1.30. If all of the locations are compared with one another, none are considered outliers.

Next, the mean percentage of pedestrians who took evasive actions in unmarked non-intersections was examined. Overall, the mean percentage was 4.39. No outliers exist here. In other words, when looking at these five locations, none are significantly different with regard to the proportion of pedestrians who took evasive actions in unmarked non-intersection areas.

A t-test was performed to determine whether a difference existed in the percentage of pedestrian evasive actions between the marked intersection and the unmarked non-intersection. No significant difference between the two locations was found, $t(4) = -.818$, $p > .05$. Interestingly, none of the pedestrian evasive actions took place during the walk phase in the marked intersection. Pedestrian evasive actions that took place in crossings that occurred within the marked intersection entirely during the walk phase (M = 0.00 percent) were compared with all other crossings (M = 7.28 percent). No significant difference was found, $t(4) = -1.57$, $p > .05$.

Table 42. Percentage of pedestrian evasive actions in each crossing area at each data collection location.

	Location				
	16	**17**	**18**	**19**	**20**
Marked Intersection					
Walk	—	—	—	—	—
+traffic flow change	50.00	—	—	—	—
Don't Walk	37.50	7.69	—	—	5.00
+traffic flow change	16.67	—	—	—	—
Overall in Intersection	***4.58***	***.54***	—	—	***1.37***
Unmarked Non-Intersection					
With Traffic	—	—	3.06	—	33.33
+traffic flow change	—	—	—	—	—
Against Traffic	—	—	3.85	—	18.18
+traffic flow change	—	—	—	—	—
Overall in Unmarked Non-Intersection	—	—	***3.20***	—	***18.75***
Grand Percentage	**4.29**	**.44**	**.51**	**—**	**4.49**

— Indicates no actions of this type were recorded.

Evasive Vehicle Actions

Table 43 summarizes the percentage of vehicle evasive actions within each crossing area at each of the data collection locations. Each of the four types of evasive actions (abrupt braking—first vehicle, abrupt braking—second vehicle, directional change—first vehicle, and directional change—second vehicle) were combined to obtain a better overall perspective on vehicle evasive actions.

Location 17 was the only location where evasive actions were observed. As a result, no further analyses were completed.

Table 43. Percentage of vehicle evasive actions in each crossing area at each data collection location.

	Location				
	16	**17**	**18**	**19**	**20**
Marked Intersection					
Walk	—	.61	—	—	—
+traffic flow change	—	—	—	—	—
Don't Walk	—	—	—	—	—
+traffic flow change	—	—	—	—	—
Overall in Intersection	—	***.54***	—	—	-
Unmarked Non-Intersection					
With Traffic	—	—	—	—	—
+traffic flow change	—	—	—	—	—
Against Traffic	—	—	—	-	—
+traffic flow change	—	—	—	—	—
Overall in Unmarked Non-Intersection	—	—	—	—	—
Grand Percentage	—	**.44**	—	—	—

— Indicates no actions of this type were recorded.

Evasive Action Comparison

Because no vehicles took evasive actions, a comparison between vehicle and pedestrian evasive actions was not made.

DISCUSSION

An overarching goal of the present project was to determine which environmental factors influence where pedestrians cross the roadway. Pedestrian crossing behaviors were observed and coded at five different locations in this phase. It was hoped that these data would help to identify factors that influence pedestrians to cross at unmarked non-intersection locations. As was discovered in phase 1 of this study, the number of unmarked non-intersection crossings is overall quite low. As a result, modeling was not attempted for the phase 3 sites alone. Instead all data were combined to create a predictive model. It is discussed in more detail later.

In phase 3, none of the locations were identified as outliers in terms of crossing location, yielding, or evasive actions. Next, all 20 locations (phases 1–3) are compared with one another and environmental factors are explored.

PEDESTRIAN CROSSING BEHAVIORS: COMBINED RESULTS

In all three phases of this study, pedestrian crossing behaviors were examined. Although phase 1 and phase 2 used video capture and phase 3 used in-person observations, the same pedestrian crossing coding guidelines were used in each phase. As a result, crossings are compared across the 20 different locations here. In addition, for ease of reading, data from all three phases are combined and presented again in this section.

The relationship between pedestrian crossings and various environmental factors was examined. A summary of continuous variables can be found in table 44. A summary of categorical variables can be found in table 45. The environmental variables are as follows:

- **Distance (in ft) between marked crossings.** This is the distance between the two marked pedestrian crosswalks at each location.
- **AADT.** Average annual daily traffic expressed in thousands and rounded to the nearest 100.
- **Trip originators**. A scale from 1 (very few) to 5 (a lot) that quantifies the attractions in the area that might generate pedestrian traffic.
- **Walk phase.** The length (in s) that the walk sign is illuminated (this includes the flashing portion of the walk phase that warns pedestrians not to start crossing).
- **Don’t walk phase.** The length (in s) that the don’t walk is illuminated (steady state stable sign only).
- **Width of crossing.** The distance (in ft) pedestrians are required to travel in the roadway to cross in the marked intersection at each location.
- **Travel pace.** The rate (in ft/s) at which pedestrians are required to travel to complete a crossing in the marked intersection entirely during the walk phase.
- **Traffic direction.** Indicator of one-way or two-way vehicular traffic 1 = one way and 2 = two way.
- **Barriers.** Indicator of barrier blocking all or part of the sidewalk from the roadway; 0 = none, 1 = partial block, and 2 = mostly blocked.
- **Bus stops.** Indicator of the location of bus stops; 0 = no bus stop, 1 = enter/exit bus at crosswalk, and 2 = enter/exit bus at non-intersection.
- **Parking present.** Indicator whether parking was present on either side of the street (yes or no).
- **Center turn lane.** Indicator whether a center (non-through traffic) lane was present (yes or no).

- **Dedicated right turn.** Indicator whether a right turn (non-through traffic) lane was present (yes or no).

- **Median.** Indicator of the type of median if it was present; 0 = no median, 1 = hard, raised above traffic level median, and 2 = soft, not raised median (i.e., paint only).

- **Cross streets.** Indicator of a cross street that met with the main travel road between the two marked intersections; 0 = no cross street, 1 = vehicle traffic was light controlled at the cross street, 2 = vehicle traffic was not light controlled at the cross street.

- **Far intersection light controlled.** Indicator whether the far intersection (i.e., the next marked crosswalk) was light controlled (yes or no).

Table 44. Summary of pedestrian crossing locations and their associated environmental factors that were assessed on a continuous scale.

Location	Distance Between Marked Crossings (ft)	AADT	Trip Originators	Walk Phase (s)	Don't Walk (s)	Width of Crossing (ft)	Travel Pace (ft/s)
1	352	15.8	1	20	69	61	3.1
2	530	24.2	1	46	55	81.25	1.8
3	550	26.3	1	46	71	48.25	1.0
4	656	11.3	2	32	45	54.42	1.7
5	391	15.1	3	53	50	61	1.2
6	294	31.5	3	31	56	83	2.7
7	145	11.9	1	44	52	43	1.0
8	433	24.2	1	19	79	70	3.7
9	551	34	4	30	68	109	3.6
10	361	41.8	3	24	75	72.5	3.0
11	193	22.9	1	19	80	68.3	3.6
12	277	19.8	3.5	20	78	64.5	3.2
13	316	15.1	1	10	89	50	5.0
14	338	34.7	1	30	67	68.25	2.3
15	297.5	18.3	1	39	60	45.5	1.2
16	361	28	4	58	73	75	1.3
17	266.5	8.1	5	64	63	43.25	0.7
18	511.25	7.9	4.5	60	40	30	0.5
19	342	23.2	2	30	70	80	2.7
20	339.5	13	3.5	20	63	44.5	2.2

Table 45. Summary of pedestrian crossing locations and their associated environmental factors that were assessed on a categorical scale.

Location	Traffic Direction	Barriers	Bus Stops	Parking Present	Center Turn Lane	Dedicated Right Turn	Median	Cross Streets	Far Intersection Light Controlled
1	2	2	1	Yes	Yes	No	0	0	Yes
2	2	0	0	Yes	No	Yes	2	0	Yes
3	2	1	2	No	Yes	No	1	1	Yes
4	1	0	2	Yes	No	No	0	0	Yes
5	1	0	0	Yes	No	Yes	0	0	Yes
6	2	0	0	No	No	No	0	0	Yes
7	1	1	1	Yes	No	No	0	0	No
8	2	0	0	No	No	No	2	2	No
9	2	0	2	Yes	No	Yes	1	2	Yes
10	2	0	0	Yes	No	No	0	0	Yes
11	2	0	1	No	No	No	0	0	No
12	2	0	1	Yes	No	No	0	0	Yes
13	1	0	2	Yes	No	No	0	0	Yes
14	2	0	0	No	No	No	0	0	Yes
15	1	0	2	No	No	No	0	0	Yes
16	2	0	1	Yes	No	No	1	0	Yes
17	2	0	2	Yes	No	Yes	0	0	Yes
18	1	0	1	No	No	No	0	0	No
19	2	2	2	No	No	No	1	0	Yes
20	1	0	0	Yes	No	Yes	0	0	Yes

The data were analyzed in two different ways. First, data were examined as the full raw dataset, which includes more than 60,000 pedestrian crossings. Second, to handle different levels of pedestrian traffic, data were analyzed in terms of the proportion of crossings within each location.

Full Dataset

Overview of Crossings

Figure 61 through figure 66 depict the breakdown of the total observed crossings across all 20 locations. Because all of the crossings are combined across locations, the proportions of each type of crossing may not be typical of all locations. Because Location 3 was the only location that included crossings at an unmarked intersection, the sum values are not the same in every figure.

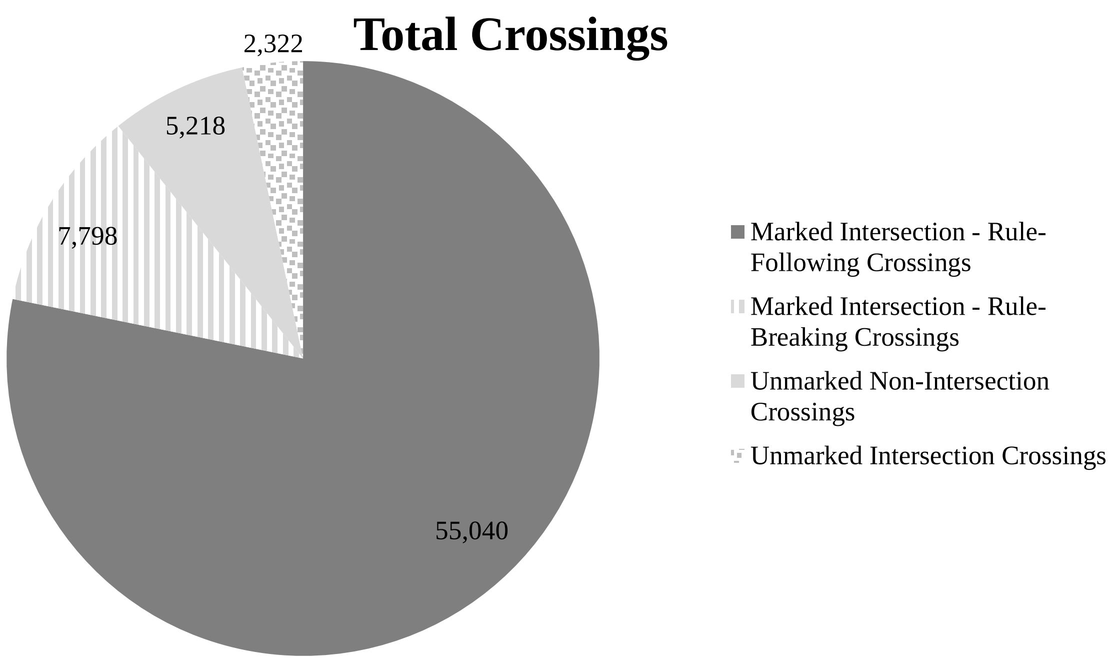


Figure 61. Chart. Distribution of all crossings observed across the 20 different locations by the area in which they took place.

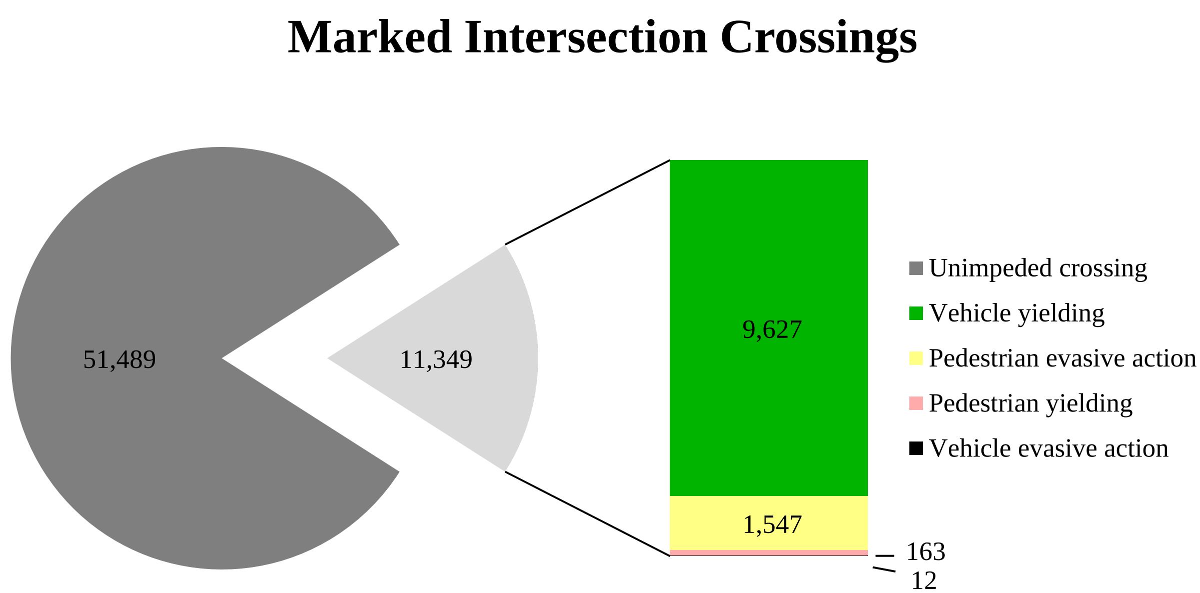


Figure 62. Chart. Distribution of crossings observed across all 20 locations in the marked intersections by circumstances of the crossing.

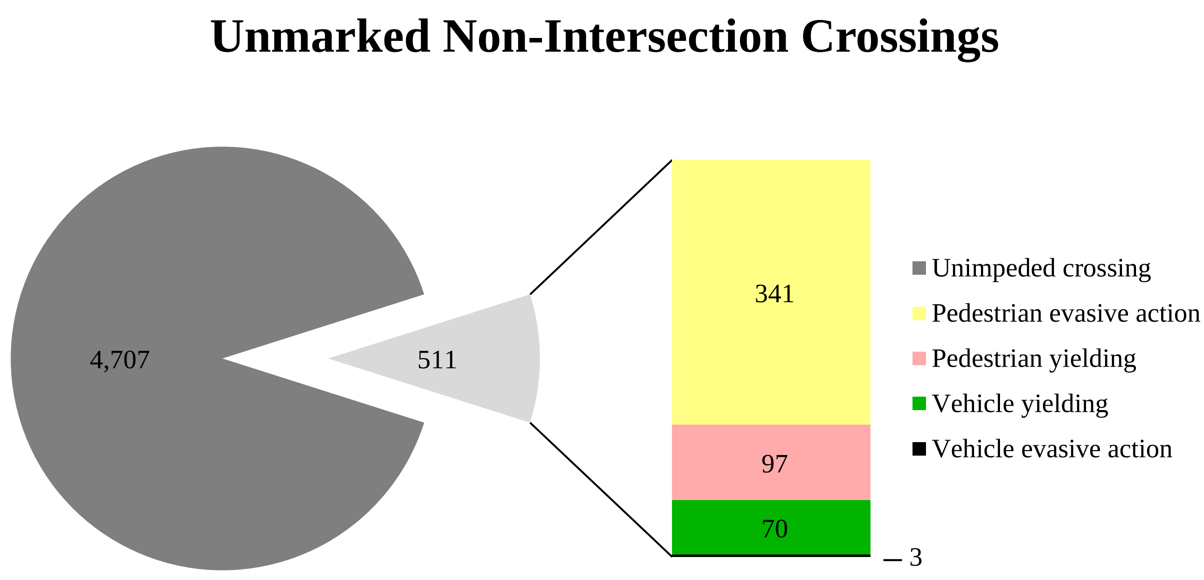


Figure 63. Chart. Distribution of crossings observed across all 20 locations in the unmarked non-intersections by the circumstances of the crossing.

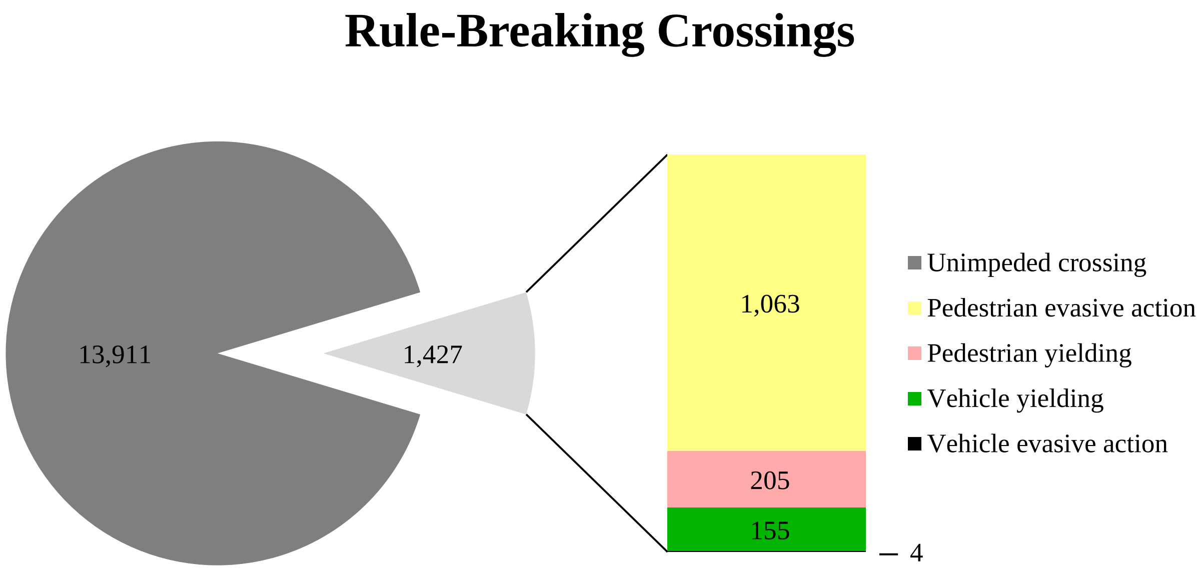


Figure 64. Chart. Distribution of crossings observed across all 20 locations for all rule-breaking crossings by the circumstances of the crossing (including those in the unmarked non-intersections).

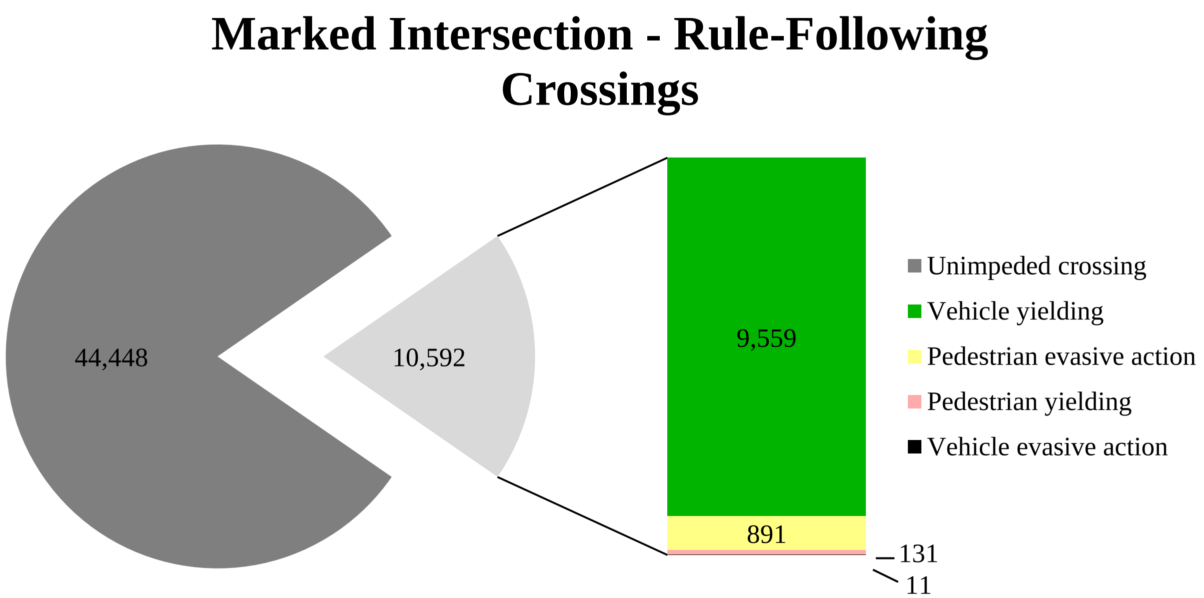


Figure 65. Chart. Distribution of crossings observed across all 20 locations for crossings made entirely during the walk light phase in the marked intersections, by the circumstances of the crossing.

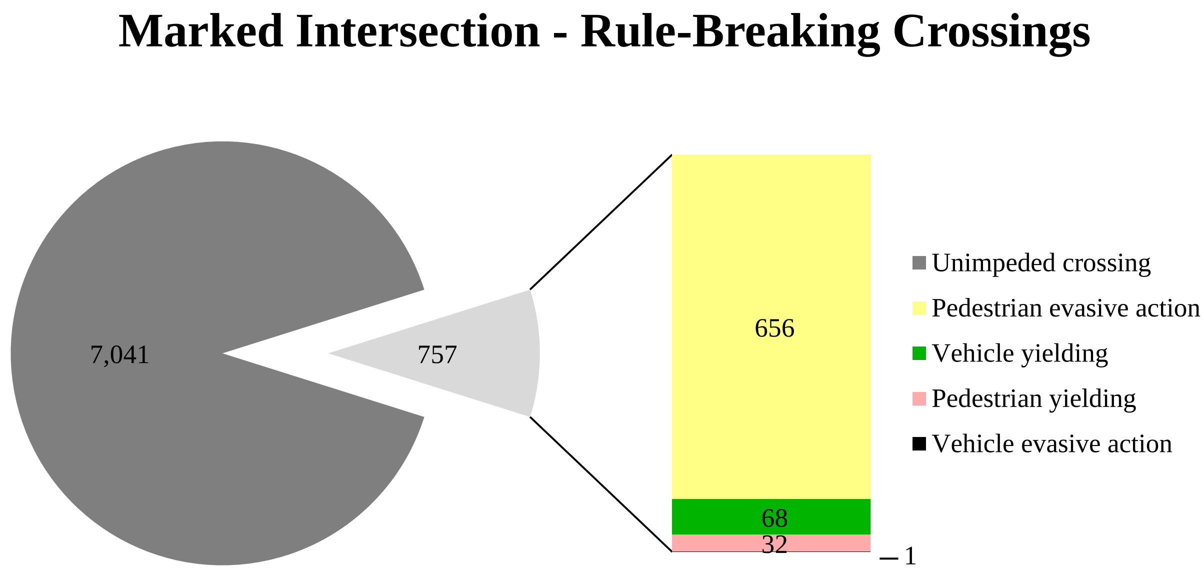


Figure 66. Chart. Distribution of crossings observed across all 20 locations for rule-breaking crossings in marked intersections (i.e., crossings that took place at least partially during the don't walk light phase) by the circumstances of the crossing.

Prediction Model—Crossing Area

Using data from all 20 locations, a model was successfully created in SAS® to predict whether pedestrians would cross at the marked intersection (and not the unmarked non-intersections). There were 68,056 pedestrian crossings among the 20 locations, 62,838 of which occurred at marked intersections. (Note that crossings at the unmarked intersection at Location 3 were not included in the model.) In other words, approximately 92 percent of the crossings occurred at the marked intersections.

First, a factor analysis with an orthogonal varimax rotation was used to describe the underlying relationships among the 16 environmental variables (see table 46). Based on the greater-than-one rule for the eigenvalues, five factors were kept for the rotation. The factor loadings are included. Combined, these factors accounted for approximately 74 percent of the standardized variance in the data.

Table 46. Environmental factors and their labels used to calculate the crossing location prediction model.

Label	Environmental Variable	Coding
A	Distance to the next marked crosswalk	Distance in ft
B	AADT	Expressed in thousands and rounded to the nearest 100
C	One-way or two-way street	1 or 2
D	Presence of physical barriers that might prevent a pedestrian from crossing the roadway	No barrier (0), partial barrier (1), or mostly blocked/large barrier (2)
E	Presence of a bus stop	None (0), bus exit near marked intersection (1), bus exit at Non-Intersection (2)
F	Range of the number of trip originators/ destinations	Range from very few (1) to a lot (5)
G	Presence of parking along the roadway	Yes (1) or no (0)
H	Presence of a center turning lane	Yes (1) or no (0)
I	Presence of a right turn only turning lane	Yes (1) or no (0)
J	Length of walk phase	Time in s
K	Length of don't walk phase	Time in s
L	Curb-to-curb distance	Distance in ft
M	Presence and type of median	No median (0), soft (1), hard (2), soft, not raised median
N	Presence of cross streets between marked crosswalks.	No cross street (0), light-controlled cross street (1), not light-controlled cross street (2)
O	Far marked crosswalk light controlled	Yes (1) or no (0)
P	Travel pace	ft/s

Note: Values in parentheses are the values assigned to categorical variables.

Table 47. Factor loadings for the 16 environmental variables.

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
A	-23	-4	74†	13	21
B	24	86†	11	-9	-6
C	11	86†	13	19	-3
D	2	6	-9	82†	-14
E	7	-39	17	51	16
F	-40	4	-4	-36	51
G	10	-19	-7	-7	79†
H	-2	6	10	86†	-5
I	-25	-3	29	-30	65†
J	-92†	-5	6	-2	9
K	78†	33	-3	13	-2
L	28	75	34	-13	21
M	-2	38	76†	3	-13
N	23	16	84†	-3	-12
O	2	29	-12	29	75†
P	94†	19	8	-8	2

† Indicates a loading of 60 or greater in absolute value.

Each of the five factors is assigned a descriptive label based on its correlations with relative variables:

- Factor 1, Travel Pace and Phasing, is negatively correlated with the length of the walk phase, positively correlated with the length of the do not walk phase, and positively correlated with the travel pace.

- Factor 2, Traffic Throughput, is positively correlated with the AADT, traffic directionality (one- or two-way street), and the curb-to-curb distance (i.e., the width of the street).

- Factor 3, Distance to Safety, is positively correlated with the distance to the next marked crosswalk, the presence and type of median, and the presence of cross streets between marked crosswalks.

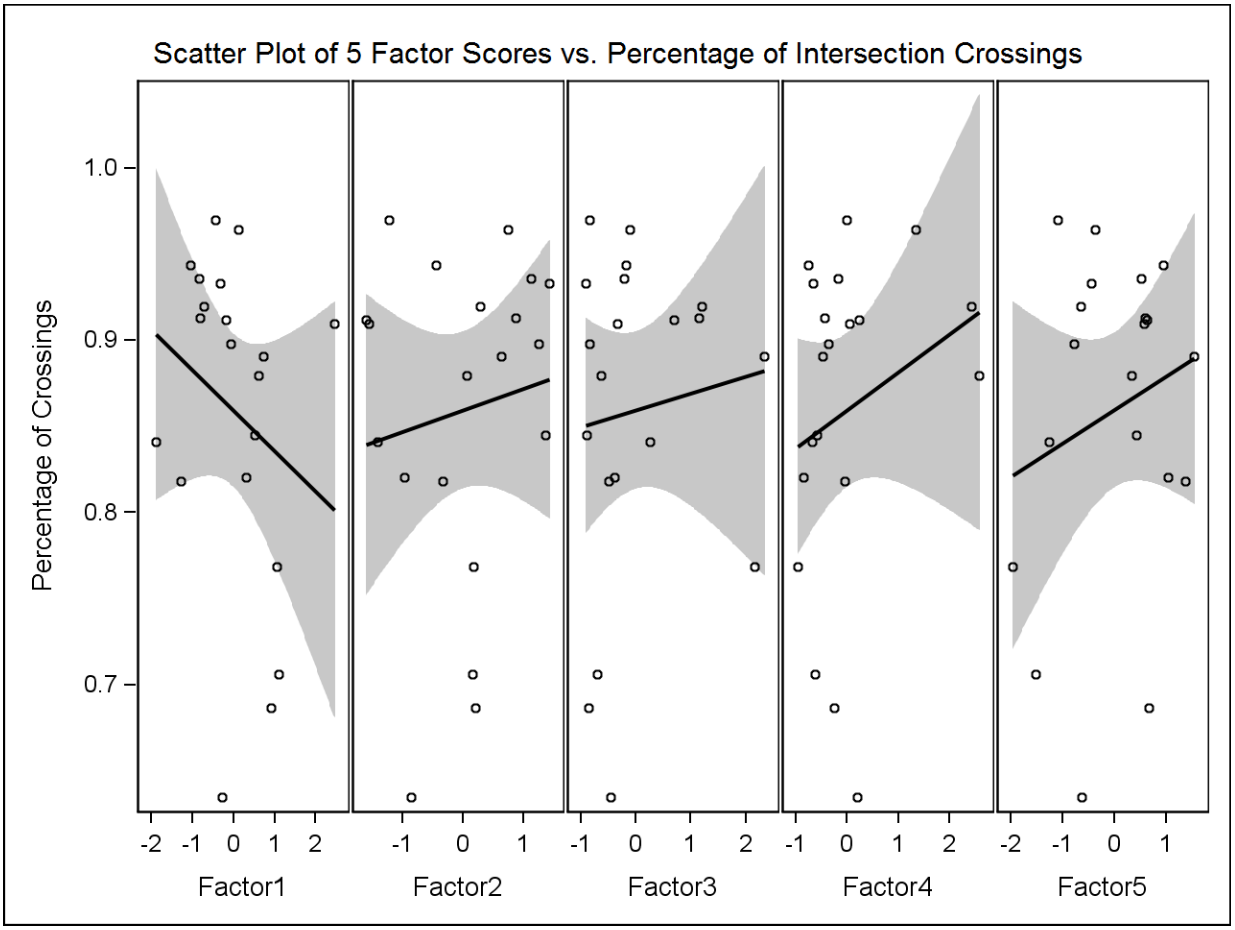
- Factor 4, External Objects (Barriers/Vehicles) in Center of Road, is positively correlated with the presence of physical barriers that might prevent a pedestrian from crossing the roadway and the presence of a center turning lane.

- Factor 5, External Objects (Vehicles) on Sides of Road, is positively correlated with the presence of parking along the roadway, the presence of a right turn only lane, and whether or not the far marked crosswalk is light controlled.

Scores for each of the five factors were generated using the standardized scoring coefficients listed in table 48. These coefficients can only be used with the standardized data and not with the raw, observed values. Each of the five factor scores is graphed against the percentage of intersection crossings for each location in figure 67.

Table 48. Standardized scoring coefficients for the five rotated factors.

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
A	-0.05047	-0.10759	0.38127	0.07187	0.08558
B	-0.04080	0.36229	-0.07173	-0.04503	-0.03821
C	-0.09979	0.38416	-0.07152	0.10124	-0.01225
D	-0.04177	0.05360	-0.06575	0.39620	-0.01480
E	0.09552	-0.22544	0.14359	0.25108	0.12869
F	-0.12612	0.07613	-0.04661	-0.12670	0.20952
G	0.12938	-0.11604	-0.01154	0.01230	0.41212
H	-0.04871	0.03214	0.02615	0.41759	0.02701
I	-0.03224	-0.03729	0.13973	-0.10183	0.29012
J	-0.36946	0.11821	0.00329	0.02802	-0.01769
K	0.26616	0.03607	-0.04015	0.04254	0.04615
L	0.02736	0.25549	0.06317	-0.05440	0.09691
M	-0.05098	0.06517	0.33786	-0.00163	-0.08623
N	0.09721	-0.09803	0.42527	-0.04528	-0.06540
O	-0.00290	0.14773	-0.12528	0.19947	0.39702
P	0.37272	-0.08072	0.04904	-0.06944	0.06522



Notes: The dots remain in consistent locations from box to box.
solid line = regression line, shaded area = 95-percent confidence limits of the regression line).

Figure 67. Chart. Scatterplot of each location's score for each of the five factors against the percentage of intersection crossings at that location.

Next, the scores for the five factors were regressed on the probability of an intersection crossing through logistic regression using forward selection. The model iterated three times after the entrance of an intercept term. The scores for Factor 1, $\chi^2(1) = 176.6$, $p < 0.01$, Factor 2, $\chi^2(1) = 41.6$, $p < 0.01$, and Factor 3, $\chi^2(1) = 402.3$, $p < 0.01$, were statistically significant. The resultant model is shown in figure 68 where π represents the probability of crossing in the marked intersection and **x** is the vector of factor scores for a given location. When using a logit (log odds) model, e^{α} represents the odds of success when all predictors equal zero, and e^{β} represents the multiplicative effect of a one-unit increase in the corresponding x on the odds of success, when the other predictors are held fixed.

$$\text{logit}(\pi(x)) = \log\left[\frac{\pi(x)}{1-\pi(x)}\right] = 2.36 - 0.31\text{ Factor1} - 0.08\text{ Factor2} - 0.27\text{ Factor3}$$

Figure 68. Equation. The logit of crossing at the intersection.

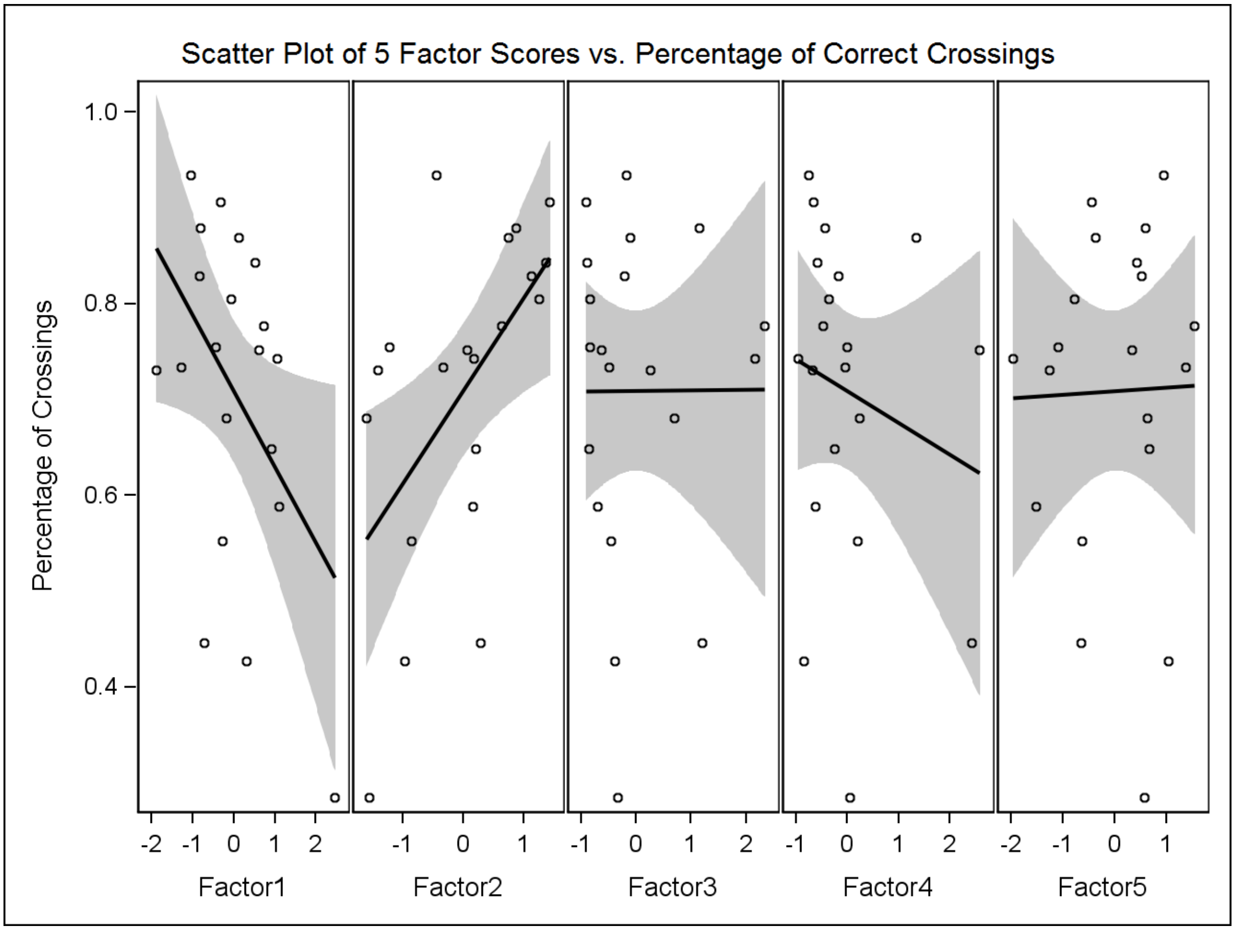
A good probability cutoff point for this data is 0.9, meaning that any future predictions using the model that are 0.9 or greater should be deemed an intersection crossing. With this cutoff, the model can successfully predict approximately 90 percent of the crossings overall. The resultant sensitivity and specificity are about 96 percent and 10 percent, respectively. Sensitivity measures how many events (intersection crossings) were successfully predicted, and specificity measures how many non-events (non-intersection crossings) were successfully predicted. The predicted probabilities of crossing at the intersection for each location are shown in table 49.

Table 49. Probabilities of correctly predicting a crossing at the marked intersection or the unmarked non-intersection by location and the corresponding upper and lower 95-percent confidence limits.

Location	Total Crossings	Estimated Probability	Lower 95 Percent Confidence Limit	Upper 95 Percent Confidence Limit
1	1,110	0.91203	0.90715	0.91668
2	4,631	0.90319	0.89779	0.90834
3	2,878	0.90348	0.89874	0.90802
4	13,199	0.91365	0.90995	0.91721
5	10,635	0.94112	0.93862	0.94353
6	16,418	0.93063	0.92710	0.93400
7	12,958	0.94419	0.94152	0.94675
8	1,574	0.80553	0.79210	0.81829
9	805	0.80876	0.79562	0.82123
10	528	0.91159	0.90585	0.91701
11	17	0.89962	0.89213	0.90664
12	185	0.90793	0.90141	0.91406
13	609	0.85845	0.84056	0.87463
14	205	0.92484	0.92110	0.92842
15	840	0.93348	0.93106	0.93583
16	280	0.93036	0.92719	0.93340
17	225	0.94899	0.94636	0.95150
18	786	0.95218	0.94816	0.95590
19	84	0.90816	0.90462	0.91158
20	89	0.92066	0.91693	0.92424

Prediction Model—Walk Versus All Other Crossings

A second model was developed to predict crossings that occurred entirely during the walk phase in the marked intersection. Crossings were divided into two categories—crossings that occurred within the marked intersection entirely during the walk light phase and all other crossings (e.g., unmarked non-intersection, marked intersection during the don’t walk light phase, etc.). Using this classification system, there were 70,378 pedestrian crossings among the 20 locations, 55,040 of which occurred entirely within the walk phase in the marked intersection. In other words, approximately 78 percent of the crossings were rule-following crossings. Using the factor analysis and standardized scoring coefficients (table 48), each of the five factor scores is graphed against the percentage of rule-following crossings for each location in figure 69.



Notes: The dots remain in consistent locations from box to box.
solid line = regression line, shaded area = 95-percent confidence limits of the regression line).

Figure 69. Chart. Scatterplot of each location's score for each of the five factors against the percentage of intersection crossings at that location.

Next, the scores for the five factors were regressed on the probability of a rule-following crossing through logistic regression using forward selection (see figure 70). The model iterated five times after the entrance of an intercept term. The scores for Factor 1, $\chi^2(1) = 607.6$, $p < 0.01$, Factor 2, $\chi^2(1) = 1224.5$, $p < 0.01$, Factor 3, $\chi^2(1) = 187.4$, Factor 4, $\chi^2(1) = 5783.2$, $p < 0.01$, and Factor 5, $\chi^2(1) = 388.4$, $p < 0.01$, were all statistically significant.

$$\begin{aligned}\text{logit}(\pi(x)) = \log\left[\frac{\pi(x)}{1-\pi(x)}\right] \\ = 1.33 - 0.37\text{ Factor1} + 0.31\text{ Factor2} - 0.23\text{ Factor3} - 0.54\text{ Factor4} \\ + 0.24\text{ Factor5}\end{aligned}$$

Figure 70. Equation. The logit of crossing at the intersection during the walk phase.

A good probability cutoff point for this data is 0.6, meaning that any future predictions using the model that are 0.6 or greater should be deemed a rule-following crossing. With this cutoff, the model can successfully predict approximately 79 percent of the crossings overall. The resultant sensitivity and specificity are about 94 percent and 23 percent, respectively. The predicted probabilities of crossing during the walk phase at the intersection for each location are shown in table 50.

Table 50. Probabilities of correctly predicting a crossing at the marked intersection entirely during the walk phase by location and the corresponding upper and lower 95-percent confidence limits.

Location	Total Crossings	Estimated Probability	Lower 95 Percent Confidence Limit	Upper 95 Percent Confidence Limit
1	1,110	0.7514	0.7251	0.7759
2	4,631	0.8791	0.8694	0.8882
3	2,878	0.4456	0.4321	0.4591
4	13,199	0.6798	0.6718	0.6877
5	10,635	0.9343	0.9295	0.9389
6	16,418	0.9062	0.9017	0.9106
7	12,958	0.7546	0.7471	0.7619
8	1,574	0.7421	0.7199	0.7631
9	805	0.7764	0.7463	0.8039
10	528	0.8431	0.8106	0.8710
11	17	0.6428	0.5546	0.7223
12	185	0.6431	0.5752	0.7057
13	609	0.2855	0.2530	0.3204
14	205	0.8054	0.7656	0.8399
15	840	0.5515	0.5181	0.5845
16	280	0.8286	0.7798	0.8683
17	225	0.7344	0.6730	0.7879
18	786	0.7304	0.6983	0.7603
19	84	0.8690	0.7788	0.9260
20	89	0.4227	0.3397	0.5103

Crossing Proportions

To handle different levels of pedestrian traffic, the next set of analyses examine the data in terms of the proportion of crossings at each location in this section. The proportion of crossings and the types of crossings at each location are examined as a complete group here. In addition, the relationship between environmental factors and the proportions of crossing types are examined.

Crossing Location

Table 51 summarizes the percentage of pedestrians, by location, who crossed at a marked intersection and unmarked non-intersection. An additional column, "rule-breaking," lists the percentage of people within each area whose crossing was not completed entirely during the walk phase in the marked intersection (e.g., an unmarked non-intersection or a marked intersection in the don't walk phase). The percentage of each type of crossing is presented at each location. For example, at Location 19, 86.90 percent of the total crossings took place in the marked intersection during the walk phase. The mean percentage of pedestrians crossing in the marked intersection is 83.88. Location 3 is considered an outlier, with a mean percentage of 50.88 pedestrians crossing at the marked intersection (2.70 standard deviations below the mean). As was noted in phase 1, Location 3 is unique in that there is an unmarked intersection present between the two marked crosswalks.

A mean percentage of 13.89 pedestrians crossed in an unmarked non-intersection area. Location 15 is considered an outlier, with a mean percentage of 36.55 pedestrians crossing at the unmarked non-intersection (2.34 standard deviations above the mean). Location 15 (as described in phase 2) includes a large median that divides traffic. This median provides pedestrians with an opportunity to travel on a more direct (and potentially faster) path between public transit and the neighboring residential area. It is likely that this played a role in the proportion of unmarked non-intersection crossings.

Next, to examine rule-following, crossings made entirely within the walk phase in the marked intersection were compared with all other crossings. (These other crossings are referred to as "rule-breaking." However, note that these crossings are not necessarily against the rules and/or laws in all states. Rather, it is a simple convention for ease of description.) A mean percentage of 70.89 pedestrians crossed entirely during the walk phase in the marked intersections. Location 13 was an outlier at 28.41 percent (2.46 standard deviations below the mean).

A *t*-test was performed to confirm a difference in the percentage of pedestrians crossing the marked intersections (M = 83.88 percent) and the unmarked non-intersections (M = 13.89 percent). A significant difference between the two locations was found, $t(19) = 15.95$, $p < .001$. A second *t*-test examined the percentage of crossings that occurred entirely during the walk phase (M = 70.89 percent) and the percentage that occurred during rule breaking (M = 29.11 percent) crossings. Indeed a difference between the groups was found, $t(19) = 5.40$, $p < .001$.

Table 51. Percentage of pedestrians crossing at each area in each data collection location.

Location	Marked Intersection					Unmarked Non-Intersection					Rule-Breaking
	Walk		*Don't Walk*		*Overall in Intersection*	*With Traffic*		*Against Traffic*		*Overall in Unmarked Non-Intersection*	
	without traffic flow change	+traffic flow change	without traffic flow change	+traffic flow change		without traffic flow change	+traffic flow change	without traffic flow change	+traffic flow change		
1	75.14	0.72	8.47	3.60	87.93	5.23	0.45	5.77	0.63	12.07	24.86
2	87.91	1.12	1.75	0.52	91.30	6.24	0.30	1.60	0.56	8.70	12.09
3	44.56	0.38	5.73	0.21	50.88	1.00	0.15	3.15	0.15	4.46	55.44
4	67.98	0.71	17.89	4.59	91.17	5.38	0.17	2.77	0.52	8.83	32.02
5	93.43	0.37	0.49	0.05	94.33	5.19	0.14	0.33	0.01	5.67	6.57
6	90.63	0.82	0.92	0.90	93.26	4.67	0.27	1.11	0.68	6.74	9.37
7	75.46	1.30	18.69	1.53	96.98	1.81	0.01	1.20	0.00	3.02	24.54
8	74.21	0.64	1.33	0.64	76.81	16.58	0.64	5.46	0.51	23.19	25.79
9	77.64	2.48	4.10	4.84	89.07	3.60	0.50	6.58	0.25	10.93	22.36
10	84.28	0.00	0.00	0.19	84.47	8.71	0.19	6.44	0.19	15.53	15.72
11	58.82	0.00	11.76	0.00	70.59	17.65	0.00	11.76	0.00	29.41	41.18
12	64.86	0.54	3.24	0.00	68.65	15.68	1.08	14.59	0.00	31.35	35.14
13	28.41	10.84	46.80	4.93	90.97	5.09	0.33	3.61	0.00	9.03	71.59
14	80.49	1.46	4.88	2.93	89.76	6.34	0.00	3.41	0.49	10.24	19.51
15	55.24	0.36	6.79	1.07	63.45	28.21	0.83	7.38	0.12	36.55	44.76
16	82.86	5.71	2.86	2.14	93.57	5.00	0.00	0.36	1.07	6.43	17.14
17	73.33	1.78	5.78	0.89	81.78	10.67	0.00	7.56	0.00	18.22	26.67
18	73.03	5.47	4.20	1.40	84.10	12.47	0.13	3.31	0.00	15.90	26.97
19	86.90	8.33	0.00	1.19	96.43	1.19	0.00	1.19	1.19	3.57	13.10
20	42.70	2.25	22.47	14.61	82.02	3.37	0.00	12.36	2.25	17.98	57.30

To better understand influences on crossing behaviors, the relationship between crossing area and the aforementioned environmental factors were examined. Only significant relationships are discussed. A significant correlation was found between the width of the crossing and the percentage of pedestrians crossing entirely during the walk phase in the marked intersection, $r(18) = .504$, $p = .024$. In other words, the greater the travel distance, the more likely pedestrians were to be rule followers; or the shorter the travel distance, the more likely pedestrians were to be "rule breakers."

Interestingly, there was also a significant negative relationship between the length of the walk phase and crossing in the unmarked non-intersection against traffic, $r(18) = -.456$, $p = .043$. In other words, the shorter the time available to cross during the walk phase, the more likely pedestrians were to cross in the unmarked non-intersection against traffic flow.

The presence of physical barriers that might block all or part of the sidewalk from the roadway (away from the marked intersection) were significantly negatively correlated with crossing in the unmarked non-intersection, $r_s(18) = -.496$, $p = .026$. In other words, with more physical barriers present, pedestrians were less likely to cross in unmarked non-intersection areas.

Finally, traffic direction was significantly negatively correlated with crossings in the marked intersection entirely during the don't walk phase, $r_{pb}(18) = -.565$, $p = .005$. In other words, pedestrians were significantly more likely to cross entirely during the don't walk phase on one-way streets (16.76 percent) than on two-way streets (3.91 percent).

Pedestrian Yielding

Table 52 summarizes the percentage of pedestrians who yielded to vehicles within each crossing type. The mean percentage of pedestrians yielding to vehicles across each of the 20 locations is 0.98. Location 17 was an outlier with a mean of 6.67 percent of pedestrian crossings involving yielding to a vehicle (3.60 standard deviations above the mean). This is the result of a high percentage of pedestrians yielding to turning vehicles while crossing in the marked intersection. This is discussed in more detail later.

The mean percentage of pedestrians who yielded to vehicles in the marked intersection was 0.41. Not surprisingly, Location 17 was an outlier again with a percentage of 6.52 (4.22 standard deviations above the mean). All of these yielding behaviors were observed while pedestrians crossed entirely during the walk phase.

Next, the mean percentages of pedestrians who yielded to vehicles in unmarked non-intersections were examined. Overall, the mean percentage of yielding was 3.77. Location 20 is considered an outlier at 12.50 percent (2.03 standard deviations above the mean). However, given that there were only two instances of pedestrians yielding in the unmarked non-intersection, this is not discussed further.

Next, to examine rule-following, crossings made entirely within the walk phase in the marked intersection were compared with all other crossings. A mean percentage of 0.43 pedestrians yielded while crossing entirely during the walk phase in the marked intersections. As previously mentioned, Location 17 was an outlier at 7.27 percent (4.22 standard deviations above the mean). Overall, a mean percentage of 2.58 pedestrians yielded to vehicles while performing a rule-breaking crossing. Location 10 was an outlier at 13.25 percent (3.12 standard deviations above the mean).

A simple *t*-test was performed to determine whether the proportion of pedestrian yielding behaviors differed between the marked intersection (M = 0.41) and the unmarked non-intersection (M = 3.77). A significant difference between the groups was found, $t(19) = -3.52$, $p = .002$. A second *t*-test examined the percentage of yielding behaviors that occurred entirely during the walk phase (M = 0.43) and the percentage that occurred during “rule breaking” (M = 2.58) crossings. Indeed a difference between the groups was found, $t(19) = -2.69$, $p = 0.014$.

Table 52. Percentage of pedestrians yielding to vehicles in each crossing area at each data collection location.

Location	Marked Intersection					Unmarked Non-Intersection					Rule-Breaking	**Grand Percentage**
	Walk		*Don't Walk*		***Overall in Intersection***	*With Traffic*		*Against Traffic*		***Overall in Unmarked Non-Intersection***		
	Without traffic flow change	+traffic flow change	Without traffic flow change	+traffic flow change		Without traffic flow change	+traffic flow change	Without traffic flow change	+traffic flow change			
1	0.12	0.00	0.00	0.00	0.10	3.45	20.00	0.00	14.29	2.99	1.45	0.45
2	0.12	1.92	0.00	25.00	0.28	2.08	7.14	12.16	34.62	6.20	5.71	0.80
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.49	25.00	4.74	3.02	1.67
4	0.17	2.13	0.00	0.50	0.17	0.14	0.00	0.00	0.00	0.09	0.14	0.16
5	0.03	0.00	0.00	0.00	0.03	0.18	0.00	2.86	0.00	0.33	0.29	0.05
6	0.15	0.00	0.00	4.76	0.19	0.65	2.22	8.20	4.50	2.35	2.14	0.33
7	0.74	4.14	0.17	0.51	0.67	0.43	0.00	0.65	0.00	0.51	0.44	0.66
8	0.09	0.00	0.00	0.00	0.08	0.00	10.00	0.00	0.00	0.27	0.25	0.13
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.77	0.00	2.27	1.11	0.25
10	0.00	0.00	0.00	100.00	0.22	2.17	0.00	26.47	0.00	12.20	13.25	2.08
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.52	0.00	8.62	7.69	2.70
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.57	0.00	9.52	5.00	0.98
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	7.14	0.00	0.00	0.00	5.56	2.08	0.36
17	7.27	0.00	0.00	0.00	6.52	4.17	0.00	11.76	0.00	7.32	5.00	6.67
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	33.33	0.00	9.09	0.00	12.50	3.92	2.25

To better understand influences on crossing behaviors, the relationship between crossing location, pedestrian yielding, and the aforementioned environmental factors were examined. A significant correlation was found between the length of the walk phase and the percentage of pedestrians yielding to vehicles both in the marked intersection, $r(18) = .450$, $p = .047$, and crossings that took place entirely during the walk phase in the marked intersection, $r(18) = .450$, $p = .047$. Vehicle traffic, as estimated by AADT, was also significantly correlated with pedestrians yielding during rule-breaking crossings, $r(18) = .478$, $p = .033$.

A significant negative correlation was found between the length of the don't walk phase and pedestrian yielding when the crossing in the marked intersection began during the walk phase, but ended in the don't walk phase, $r(18) = -.451$, $p = .046$.

Several significant correlations were also found between categorical environmental variables and pedestrian yielding locations. There was a significant correlation between whether the next intersection was light controlled (M = 0.00 percent) or stop sign controlled (M = 0.04 percent) and pedestrian yielding to vehicles while crossing entirely during the don't walk phase in the marked intersection, $r_{pb}(18) = -.459$, $p = .042$.

Bus stop location was also correlated with pedestrians yielding while crossing in the unmarked non-intersection against traffic, $r_{pb}(18) = -.452$, $p = .045$. The mean percentages of pedestrian yielding in this scenario were as follows: no bus stop is 12.48 percent, bus stop near the crosswalk is 3.19 percent, and bus stop away from the intersection is 3.00 percent.

Vehicle Yielding

Table 53 summarizes the percentage of vehicles that yielded to pedestrians within each crossing area. The overall percentages of crossings that involved a vehicle yielding to a pedestrian were compared across locations. The mean percentage of crossings that involved vehicle yielding was 8.93. Location 7 was an outlier with 38.69 percent of the crossings involving a vehicle yielding to a pedestrian (2.77 standard deviations above the mean). As was discussed in phase 1, there is both high pedestrian traffic and turning vehicle traffic at this intersection. It is this combination that likely led to the high percentage of vehicles yielding to pedestrians.

The mean percentage of vehicles that yielded to pedestrians in the marked intersection was 9.25. Once again, Location 7 was considered to be an outlier, with 39.80 percent of the crossings in the marked intersection including vehicles yielding to pedestrians (2.64 standard deviations above the mean).

Next, the mean percentage of drivers who yielded to pedestrians in unmarked non-intersections was examined. Overall, the mean percentage of yielding was 3.60. Location 17 was considered an outlier with 17.07 percent (2.80 standard deviations above the mean).

Next, rule-following was examined. A mean of 11.00 percent yielded to pedestrians crossing entirely during the walk phase in the marked intersections. As previously mentioned, Location 7 was an outlier at 50.71 percent (2.87 standard deviations above the mean). Overall, a mean percentage of 2.55 vehicles yielded to pedestrians performing a rule-breaking crossing. Both Location 17 at 11.67 percent (2.77 standard deviations above the mean) and Location 12 at 9.23 percent (2.03 standard deviations above the mean) were classified as outliers.

A *t*-test was performed to determine whether a difference existed in the percentage of vehicle yielding behaviors between the marked intersections (M = 9.25 percent) and the unmarked non-intersections (M = 3.60 percent). A significant difference between the two locations was found, $t(19) = 2.16$, $p = .044$. A second *t*-test examined the percentage of yielding behaviors that occurred entirely during the walk phase (M = 11.00 percent) and the percentage that occurred during rule-breaking (M = 2.55 percent) crossings. Indeed, a difference between the groups was found, $t(19) = 2.72$, $p < .014$.

Table 53. Percentage of vehicles yielding to pedestrians in each crossing area at each data collection location.

Location	Marked Intersection					Unmarked Non-Intersection					Rule-Breaking	**Grand Percentage**
	Walk		*Don't Walk*		***Overall in Intersection***	*With Traffic*		*Against Traffic*		***Overall in Unmarked Non-Intersection***		
	Without traffic flow change	+traffic flow change	Without traffic flow change	+traffic flow change		Without traffic flow change	+traffic flow change	Without traffic flow change	+traffic flow change			
1	4.08	0.00	0.00	0.00	3.48	5.17	0.00	4.69	0.00	4.48	2.17	3.60
2	7.22	0.00	0.00	0.00	6.95	0.00	0.00	0.00	0.00	0.00	0.00	6.35
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.43	0.10	0.35
4	29.88	0.00	0.00	0.99	22.33	0.70	0.00	0.27	0.00	0.52	0.28	20.40
5	0.01	28.21	0.00	0.00	0.12	0.18	6.67	0.00	0.00	0.33	1.86	0.13
6	8.74	0.74	0.00	0.00	8.50	0.13	0.00	0.00	0.00	0.09	0.13	7.93
7	50.71	16.57	0.62	0.51	39.80	2.13	0.00	4.52	0.00	3.07	1.76	38.69
8	0.34	20.00	0.00	0.00	0.50	0.38	10.00	2.33	0.00	1.10	1.48	0.64
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.89	0.00	1.14	0.56	0.12
10	32.81	0.00	0.00	0.00	32.74	0.00	0.00	11.76	0.00	4.88	4.82	28.41
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	10.00	0.00	0.00	0.00	9.45	0.00	0.00	22.22	0.00	10.34	9.23	9.73
13	13.87	0.00	0.00	0.00	4.33	0.00	0.00	4.55	0.00	1.82	0.23	4.11
14	13.94	33.33	0.00	0.00	13.04	7.69	0.00	0.00	0.00	4.76	5.00	12.20
15	0.00	100.00	0.00	0.00	0.56	0.00	0.00	6.45	0.00	1.30	1.86	0.83
16	23.71	0.00	0.00	0.00	20.99	14.29	0.00	0.00	0.00	11.11	4.17	20.36
17	9.70	0.00	0.00	0.00	8.70	16.67	0.00	17.65	0.00	17.07	11.67	10.22
18	0.00	0.00	0.00	0.00	0.00	8.16	0.00	15.38	0.00	9.60	5.66	1.53
19	15.07	0.00	0.00	0.00	13.58	0.00	0.00	0.00	0.00	0.00	0.00	13.10
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

To better understand influences on crossing behaviors, the relationship among crossing location, vehicle yielding, and the aforementioned environmental factors were examined. There were several significant relationships between pedestrian crossing location and environmental factors that included vehicle yielding. First, a significant relationship between the number of trip originators and destinations and pedestrians completing rule-breaking crossings, $r(18) = .586$, $p = .009$ was found. In other words, when looking at instances where pedestrians crossed in a manner other than entirely during the walk phase in the marked intersection, there were more instances of vehicles yielding to pedestrians as the number of trip originators increased.

The length of the walk phase was significantly correlated with the percentage of vehicles yielding to pedestrians crossing in unmarked non-intersections, $r(18) = .475$, $p = .034$. A significant negative relationship was also found between the length of the don't walk light phase and the percentage of vehicles yielding to pedestrians making crossings in the marked intersection that began during the don't walk light phase, but completed during the walk light phase, $r(18) = -.454.$, $p = .044$.

Interestingly, a significant negative correlation was found between the required pedestrian travel pace and yielding to pedestrians crossing in the unmarked non-intersection area with traffic, $r(18)$, = -.456, $p = .043$. This suggests that the faster pedestrians were required to travel (i.e., less time), the more likely they were to experience a vehicle yielding to them while crossing.

Only a single correlation with a categorical environmental variable was found here. A significant relationship was found between vehicles yielding to pedestrians crossing entirely during the don't walk phase and whether the next intersection was light controlled (M = 0.00 percent) or stop sign controlled (M = 0.15 percent), $r_{pb}(18) = -459$, $p = .042$.

Yielding Comparison

It is important to understand overall yielding behavior. Here pedestrian and vehicle yielding are compared. First, yielding behaviors within the marked intersection were compared. A significantly greater percentage of crossings involved vehicle yielding (M = 9.25 percent) than pedestrian yielding (M = 0.41 percent), $t(19) = -3.41$, $p = .003$. Next, yielding behaviors in unmarked non-intersections were examined. No significant difference between vehicle (M = 3.60 percent) and pedestrian (M = 3.77 percent) yielding was found, $t(19) = .145$, $p > .05$.

Next, rule following was examined. When pedestrians crossed in the marked intersection entirely during the walk phase, significantly more vehicles yielded to pedestrians (M = 11.00 percent) than pedestrians yielded to vehicles (M = .43 percent), $t(19) = -3.41$, $p = .003$. When pedestrians made a rule-breaking crossing, there was no significant difference in the percentage of vehicles that yielded to pedestrians (M = 2.57 percent) and pedestrians that yielded to vehicles (M = 2.55 percent), $t(19) = 0.03$, $p > .05$.

Evasive Pedestrian Actions

Table 54 summarizes the percentage of pedestrian evasive actions within each crossing area at each of the data collection locations. The three types of evasive actions (running/accelerated walking, abrupt stopping, and directional change) were combined to obtain a better overall perspective on pedestrian evasive actions.

The overall percentage of crossings that involved a pedestrian evasive action was compared across locations. The mean percentage of crossings that involved a pedestrian evasive action was 3.06. Both Location 1 (8.92 percent; 2.23 standard deviations above the mean) and Location 8 (8.89 percent; 2.22 standard deviations above the mean) were considered to be outliers.

The mean percentage of pedestrians who took evasive actions in the marked intersection was 2.16. Once again, Location 1 was considered an outlier at 6.67 percent (2.29 standard deviations above the mean). Next, the mean percentage of pedestrians who took evasive actions in unmarked non-intersections was examined. Overall, the mean percentage was 7.47. Once again, Location 1 was considered an outlier at 24.63 percent (2.40 standard deviations above the mean).

Next, rule-following was examined. A mean of 1.02 percent of pedestrians took evasive actions while crossing entirely during the walk phase in the marked intersections. Location 2 was an outlier at 4.96 percent (2.66 standard deviations above the mean). Overall, a mean percentage of 8.91 pedestrians took evasive actions while making a rule-breaking crossing. Location 16 was an outlier at 25.00 percent (2.01 standard deviations above the mean).

A *t*-test was performed to determine whether a difference existed in the percentage of pedestrian evasive actions between the marked intersections (M = 2.16 percent) and the unmarked non-intersections (M = 7.47 percent). A significant difference between the two locations was found, $t(19) = -3.82$, $p = .001$. A second *t*-test examined the percentage of evasive actions that occurred entirely during the walk phase (M = 1.02 percent) and the percentage that occurred during rule-breaking (M = 8.91 percent) crossings. Indeed a difference between the groups was found, $t(19) = -4.50$, $p < .001$.

Table 54. Percentage of pedestrian evasive actions in each crossing area at each data collection location.

Location	Marked Intersection					Unmarked Non-Intersection					Rule-Breaking	**Grand Percentage**
	Walk		*Don't Walk*		***Overall in Intersection***	*With Traffic*		*Against Traffic*		***Overall in Unmarked Non-Intersection***		
	Without traffic flow change	+traffic flow change	Without traffic flow change	+traffic flow change		Without traffic flow change	+traffic flow change	Without traffic flow change	+traffic flow change			
1	3.72	12.50	28.72	17.50	6.76	18.97	0.00	31.25	28.57	24.63	24.64	8.92
2	4.96	25.00	19.75	16.67	5.56	4.84	0.00	21.62	26.92	9.18	12.50	5.87
3	0.22	20.00	7.05	0.00	1.13	3.85	0.00	9.15	12.50	7.76	0.94	2.19
4	1.59	12.77	4.57	1.49	2.26	1.41	0.00	1.92	0.00	1.46	3.45	2.19
5	1.70	74.36	36.54	40.00	2.18	2.17	20.00	14.29	0.00	3.32	10.01	2.25
6	1.83	28.15	25.83	7.48	2.36	3.00	24.44	11.48	5.41	5.52	9.68	2.57
7	0.24	14.79	8.42	0.51	2.01	4.68	0.00	14.84	0.00	8.70	8.30	2.21
8	3.42	80.00	42.86	70.00	5.29	13.79	40.00	40.70	12.50	20.82	24.63	8.89
9	0.00	0.00	9.09	2.56	0.56	0.00	0.00	5.66	0.00	3.41	3.89	0.87
10	0.45	0.00	0.00	0.00	0.45	2.17	0.00	23.53	0.00	10.98	10.84	2.08
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	1.67	0.00	33.33	0.00	3.15	0.00	50.00	22.22	0.00	12.07	13.85	5.95
13	0.58	3.03	4.56	3.33	3.07	0.00	0.00	13.64	0.00	5.45	4.36	3.28
14	0.00	0.00	20.00	0.00	1.09	15.38	0.00	0.00	0.00	9.52	10.00	1.95
15	0.00	0.00	5.26	11.11	0.75	0.84	0.00	19.35	0.00	4.56	4.79	2.14
16	0.00	50.00	37.50	16.67	4.58	0.00	0.00	0.00	0.00	0.00	25.00	4.29
17	0.00	0.00	7.69	0.00	0.54	0.00	0.00	0.00	0.00	0.00	1.67	0.44
18	0.00	0.00	0.00	0.00	0.00	3.06	0.00	3.85	0.00	3.20	1.89	0.51
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	5.00	0.00	1.37	33.33	0.00	18.18	0.00	18.75	7.84	4.49

To better understand influences on crossing behaviors, the relationship among crossing location, pedestrian evasive actions, and the aforementioned environmental factors were examined. A significant negative relationship between the length of the walk light phase and evasive actions made by pedestrians crossing in unmarked non-intersections was found, $r(18) = -4.94$, $p = .027$. In other words, the shorter the amount of time that pedestrians had to cross the roadway during the walk phase, the more likely they were to make an evasive maneuver while crossing outside the marked intersection.

A relationship between bus stop location and the percentage of pedestrians taking evasive actions while making a rule-breaking crossing was found, $r_{pb}(18) = -.509$, $p = .022$. The mean percentages of pedestrian evasive actions in this scenario were: no bus stop = 12.22 percent, bus stop near the crosswalk = 12.23 percent, and bus stop away from the intersection = 2.73 percent.

Evasive Vehicle Actions

Table 55 summarizes the percentage of vehicle evasive actions within each crossing area at each of the data collection locations. Each of the four types of evasive actions (abrupt braking—first vehicle, abrupt braking—second vehicle, directional change—first vehicle, and directional change—second vehicle) were combined to obtain a better overall perspective on vehicle evasive actions.

The overall percentage of crossings that involved a vehicle evasive action was compared across locations. The mean percentage of crossings that involved a vehicle evasive action was 0.10. Location 12 had 1.08 percent of the crossings involve a vehicle evasive action, which was an outlier (3.82 standard deviations above the mean).

The mean percentage of pedestrians who took evasive actions in the marked intersection was 0.04. Location 17 was considered an outlier at 0.54 percent (3.83 standard deviations above the mean). Next, the mean percentage of vehicles that took evasive actions in unmarked non-intersections was examined. Overall, the mean percentage was 0.21. Once again, Location 12 was considered an outlier at 3.45 percent (4.15 standard deviations above the mean).

Next, rule-following was examined. A mean of 0.04 percent of vehicles took evasive actions while pedestrians were crossing entirely during the walk phase in the marked intersections. Location 17 was an outlier at .61 percent (3.93 standard deviations above the mean). Overall, a mean percentage of 0.19 vehicles took evasive actions while a pedestrian completed a rule-breaking crossing. Location 12 was an outlier at 3.08 percent (4.13 standard deviations above the mean).

A *t*-test was performed to determine whether a difference existed in the percentage of vehicle evasive actions between the marked intersections (M = 0.04 percent) and the unmarked non-intersections (M = 0.21 percent). No significant difference between the two locations was found, $t(19) = -.929$, $p > .05$. A second *t*-test examined the percentage of evasive actions that occurred entirely during the walk phase (M = 0.04 percent) and the percentage that occurred during "rule breaking" (M = 0.19 percent) crossings. No significant difference between the two locations was found, $t(19) = -.906$, $p > .05$.

Table 55. Percentage of vehicle evasive actions in each crossing area at each data collection location.

Location	Marked Intersection					Unmarked Non-Intersection					Rule-Breaking	**Grand Percentage**
	Walk		*Don't Walk*		***Overall in Intersection***	*With Traffic*		*Against Traffic*		***Overall in Unmarked Non-Intersection***		
	Without traffic flow change	+traffic flow change	Without traffic flow change	+traffic flow change		Without traffic flow change	+traffic flow change	Without traffic flow change	+traffic flow change			
1	0.00	0.00	1.06	0.00	0.10	1.72	0.00	0.00	0.00	0.75	0.72	0.18
2	0.25	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.22
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.41	0.00	3.45	3.08	1.08
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.61	0.00	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.44
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

To better understand influences on crossing behaviors, the relationship among crossing location, vehicle evasive actions, and the aforementioned environmental factors were examined. A significant correlation was found between the length of the walk phase and vehicle evasive actions taken while pedestrians crossed entirely during the walk phase in the marked intersection, $r(18) = .478$, $p = .033$.

Significant relationships between physical barriers and the percentage of evasive vehicle actions were also found in two types of pedestrian crossings. First, a significant relationship was found between physical barriers and the percent of vehicle evasive actions to pedestrians crossing only during the don't walk phase in the marked intersection, $r_s(18) = .513$, $p = .021$. A significant relationship was found between physical barriers and vehicle evasive actions while pedestrians crossed in the unmarked non-intersection with traffic, $r_s(18) = .513$, $p = .021$.

Several significant relationships were found between categorical environmental factors and the percentage of vehicle evasive actions in each crossing type. A significant relationship was found between vehicle evasive actions and locations with a dedicated right turn only lane both while pedestrians crossed entirely in the walk phase in the marked intersection, $r_{pb}(18) = .527$, $p = .017$, and while pedestrians crossed in the marked intersection overall, $r_{pb}(18) = .508$, $p = .022$.

Evasive Action Comparison

It is important to understand overall evasive action behavior. Here, pedestrian and vehicle evasive actions are compared. First, evasive actions behaviors within the marked intersection were compared. A significantly greater percentage of crossings involved pedestrian evasive actions (M = 2.16 percent) than vehicle evasive actions (M = 0.04 percent), $t(19) = -4.70$, $p < .001$. Next, evasive actions in unmarked non-intersections were examined. A significantly greater percentage of crossings involved pedestrian evasive actions (M = 7.47 percent) than vehicle evasive actions (M = 0.21 percent), $t(19) = 4.65$, $p < .001$.

Next, rule-following was examined. When pedestrians crossed in the marked intersection entirely during the walk phase, significantly more pedestrians took evasive actions (M = 1.02 percent) than did vehicles (M = 0.04 percent), $t(19) = 2.96$, $p = .008$. When pedestrians made a rule-breaking crossing, there was a significant difference in the percentage of vehicles that took evasive actions (M = 0.19 percent) and pedestrians that took evasive actions (M = 8.91 percent), $t(19) = 4.97$, $p < .001$.

DISCUSSION

The goal of this work was to explore the factors that influence pedestrians' roadway crossing locations. Factors intrinsic to both humans and the environment were explored. The following describes the findings from literature and phases 1, 2, and 3 of the present study.

Pedestrian Factors

A literature review revealed five traits and factors that influence pedestrians' decisions on when and where to cross the roadway: age, gender, alcohol, self-identity as a safe person, and perceived control. While these influences are intertwined, each is discussed individually here.

Age not only plays a role in the decision on when and where pedestrians might choose to cross the roadway, but also in the outcome of a collision. Children under the age of 15 make up 25 percent of pedestrian injuries, a value larger than any other age group.[7] Given this fact, it may be worthwhile to target special interventions and educational tools to this age group to reduce pedestrian–vehicle collisions. For example, in areas near schools, crosswalk activation buttons may need to be lowered to child level or made visually more attractive to push. Design modifications, coupled with educational tools that incorporate best crossing practices, may be effective in reducing child pedestrian–vehicle collisions.

On the opposite end of the age spectrum, older adults make up about 19 percent of all pedestrian fatalities, but only 8.5 percent of the total injuries.[7] Further, many studies have found that older adults are less likely to attempt dangerous or potentially dangerous crossings.[8,9,10] These data combined suggest that while older adults are less likely to be involved in a pedestrian–vehicle crash, the outcome is likely to be more severe in terms of pedestrian health impact. As such, the safety countermeasures that may be the most beneficial for older adults may not be effective in all areas. For example, in areas near retirement communities, it may be useful to provide for longer crossing times in marked crosswalks or include an opportunity to request (via push button or other movement technology) a longer light protected crossing.

Pedestrian gender has both been associated with both risk crossing and higher pedestrian fatality rates.[6,7,8] These findings are consistent with the general body of literature suggesting that males are more likely to make risky decisions than females.[41] Given the inherent difficultly in designing crosswalks and safety interventions specifically for one gender, time may be better spent on educational interventions. In other words, specific advertisement and educational campaigns can be used to help males better understand crossing risks and the best way to share the roadway as a pedestrian.

As was previously noted, alcohol is involved in a relatively large proportion of fatal vehicle–pedestrian crashes. Obviously, it is not legal to drive while intoxicated. However, walking is generally thought be to be a safe mode of transportation. It is difficult to design pedestrian crossing countermeasures specifically for the intoxicated pedestrian. However, measures can be taken to reduce the fatalities in areas where pedestrians are likely to be intoxicated (e.g., bar districts). For example, railings or shrubbery that separates the sidewalk from vehicular traffic, and road closures might be used. However, these are not likely to be feasible on a widespread basis. As a result, other tactics, such as educational information, public service announcements, or targeted jay-walking enforcement, may reduce less safe pedestrian crossings.

Those people who identify themselves as safe pedestrians are less likely to make risky crossings and accept fewer vehicle gaps as safe for crossing.[10] However, it seems unlikely that one's self-identity can easily be manipulated. In other words, this is likely a stable characteristic that is not easily changed.

Finally, perceived control has also been shown to influence when and where pedestrians are willing to cross the roadway.[9] When pedestrians perceive more behavioral control of the situation, they are more likely to cross (or intend to cross) the roadway. As a result, it is logical that roadways that present less perceived control (or predictability) to pedestrians are less likely to have a high proportion of crossings outside the marked intersection during the walk light phase (where, presumably, control would be the greatest). Along the same lines then, it may be possible to modify roadway design to reduce perceived control away from marked intersections and increase perceived control near marked intersections through affordance modifications. For example, a median might increase control because it allows pedestrians to break up crossings, completing one segment, seeking refuge, and completing the crossing when ready. Another way to increase control is to allow pedestrians to activate walk signals via push button (with feedback of activation initiation). However, one must also account for unintended consequences of affordance modification. For example, if barriers are placed between the sidewalk and roadway, people parking vehicles may not be able to access the sidewalk and may be forced to walk unnecessarily close to vehicular traffic.

Environmental Factors

The remainder of this study focused on which specific environmental factors influence where and when pedestrians cross the roadway. Specifically, pedestrian crossings at 20 different locations in the Washington, DC, metropolitan area were recorded. The area of the crossing (marked crossing or unmarked non-intersection crossing), timing of the crossing (with traffic or against traffic), and other crossing circumstances were recorded (e.g., yielding and evasive actions). For these 20 locations, more than 70,000 crossings were coded. Two different methodologies were used to collect these data. One methodology involved two researchers manually counting and coding pedestrian crossings while observing people in vivo. One advantage of this methodology is that the observers can move about and gain better vantage points as needed. However, in many of the high pedestrian volume areas, it is extremely difficult to obtain accurate counts of pedestrian crossings through in-person observations. To be better able to more accurately code and flexibly collect pedestrian data, a second methodology of video recording was used. This allowed the video to be coded in both slowed and speed motion to maximize accuracy and efficiency. The use of the DDOT traffic management cameras provided a simple and unobtrusive way to capture video. Along with the benefits of this data collection methodology, there were also some challenges. The first challenge is that the primary use of the cameras is for traffic management. As a result, the cameras can be moved at any time and may not be capturing footage from the desired areas. Furthermore, there can be service disruptions with the video equipment (e.g., recording failure, camera failure). Despite these issues, video-based data collection proved to be both fruitful and reliable.

Prediction Models

Coded data from all 20 locations were combined to create two separate crossing prediction models.

Model 1—Intersection Versus Non-Intersection Crossings:

The first model predicts which area of the road pedestrians will cross (marked intersection or unmarked non-intersection) based on the features of the roadway environment. Although many factors were examined, not all were incorporated into the model. The roadway environment variables that were included in the model fell into three categories:

1. Travel Pace and Phasing.
    a. Length of the walk phase.
    b. Length of the do not walk phase.
    c. Travel pace.

2. Traffic Throughput.
    a. AADT.
    b. Traffic directionality (one- or two-way street).
    c. Curb-to-curb distance (i.e., the width of the street).

3. Distance to Safety.
    a. Distance to the next marked crosswalk.
    b. Presence and type of median.
    c. Presence of cross streets between marked crosswalks.

The mean probability of the model correctly predicting a crossing in the marked intersection was .9079. In other words, across the 20 locations, the model correctly predicted an average of 90.79 percent of the crossings. The median prediction accuracy was 91.28 percent with a range of 80.55 percent at Location 8 to 95.22 percent at Location 18. Overall, the model was able to successfully predict crossing location (marked intersection versus unmarked non-intersection) using the features of the roadway environment.

Model 2—Walk Versus All Other Crossings:

It is likely that many of the pedestrians observed making crossings who did not cross in the unmarked non-intersections did not do so simply because the trip did not require a crossing in that specific direction. In other words, pedestrians may not have made an east/west non-intersection crossing because their travel origination and destination only required a north/south path. As a result, general rule-breaking was also examined. Rule-breaking is any crossing that does not take place entirely during the walk light phase in the marked intersection.

Although many factors were examined, not all were incorporated into the model. The roadway environment variables that were included in the model fell into five categories:

1. Travel Pace and Phasing.
    a. Length of the walk phase.
    b. Length of the do not walk phase.
    c. Travel pace

2. Traffic Throughput.
    a. AADT.
    b. Traffic directionality (one or two way street).
    c. Curb-to-curb distance (i.e., the width of the street).

3. Distance to Safety.
    a. Distance to the next marked crosswalk.
    b. Presence and type of median.
    c. Presence of cross streets between marked crosswalks.

4. External Objects (barriers/vehicles) in Center of Road.
   a. Presence of physical barriers that might prevent a pedestrian from crossing the roadway.
   b. Presence of a center turning lane.

5. External Objects (vehicles) on Sides of Road.
   a. Presence of parking along the roadway.
   b. Presence of a right turn only lane.
   c. whether or not the far marked crosswalk is light controlled.

The mean probability of the model correctly predicting a rule-following crossing in the marked intersection was .9079. In other words, across the 20 locations, the model correctly predicted an average of 90.79 percent of the crossings. The median prediction accuracy was 91.28 percent with a range of 80.55 percent at Location 8 to 95.22 percent at Location 18. This model was more successful in predicting rule-following crossings in some locations than in others. However, overall, the model was able to successfully predict rule-following crossings using the features of the roadway environment.

Proportions of Crossing Types and Environmental Factors by Location

To better accommodate the different overall numbers of pedestrian crossings at each of the crossing locations, a series of analyses were performed using proportions of crossings. These proportions were used to examine both crossing type and environmental factors on crossings.

Crossing Location

Overall, the mean percentage of the crossings that took place in the marked intersection was 83.88. (This value was derived by calculating the percentage of crossings that took place in the marked intersection at each location and then these values were taken together to calculate the mean.) The range was 50.88 percent (at Location 3) to 96.98 percent (at Location 7) with a median value of 88.5 percent.

Location 3 is an outlier in this group at 2.70 standard deviations below the mean. Further, when its value is removed, the mean percentage of pedestrians crossing in the marked intersection jumps to 85.61. Yet, when examining the percentage of pedestrians that crossed in unmarked non-intersections, Location 3 does not stand out. In fact, pedestrians were approximately equally likely to cross at the unmarked intersection as the marked intersection. This finding suggests that pedestrians perceive the unmarked intersection to be a safe and acceptable place to cross the roadway. This is likely the result of a few unique characteristics of Location 3. Between the two marked intersections, there is a T-intersection that is light controlled for vehicular traffic (but not for pedestrian traffic). The light phases allow pedestrians travelling to and from the side street to begin crossing, wait on the median, and then complete the crossing when the vehicle light phase changes or an acceptable gap is presented. Given that 41 percent of the crossings at the unmarked intersection involved waiting on the median, it appears that pedestrians were not trapped on the median as previous research has reported. Rather, at this location, pedestrians plan their crossing in phases—crossing a segment, waiting on the median, and then completing the crossing. This is a tactic that presumably increases perceived control. Beyond the ability to divide the crossing into two portions, there are environmental factors that both encourage crossing at the unmarked intersection and discourage traveling to the marked intersection.

This path is likely desirable to pedestrians for several reasons. First, the path to/from the neighboring Metro stop (about 1 block west) and the neighborhood area on the side street is more direct when crossing at the unmarked intersection. Because Rhode Island Avenue Northwest is a diagonal street, pedestrians are required to travel further south and then back north if they elect to cross at the marked intersection. In other words, more travel distance is required. Furthermore, the marked crossing is multipart with variant timing, which means that pedestrians may need to wait on a median/refuge island to complete a crossing, independent of which intersection is used for crossing in this area. To pedestrians, these two factors combined may outweigh the potential benefits of crossing during a protected light phase—especially given the relatively rare occurrence of a vehicle–pedestrian collision. As a result, pedestrians are likely to select to cross at the unmarked intersection as a result of both convenience and a likely perception of more control. Beyond this, the unmarked intersection has several factors that afford a crossing. It is obvious that this is at an intersection; locations where most marked crossings take place. Further, this lies at a junction where it is natural to want to travel. There is Metro station only one block west of the marked intersection, on the north side. As a result, crossing at the unmarked intersection when traveling to/from the Metro station, along Marion Street, is likely the most direct and efficient route. Finally, to the pedestrian, the median in the unmarked intersection looks as though it is a sidewalk (see figure 8). Pedestrians can clearly see a concrete area on the end of the median that is approximately the width of a standard sidewalk (e.g., a firm, raised surface that serves as a barrier from roadway vehicles). As such, this area affords the same things to pedestrians as a standard sidewalk. It is likely that pedestrians interpret this area as they would any other sidewalk area.

Based on these findings, many recommendations can be made for the design of new roadways or the implementation of roadway environment modifications if crossing location (and timing) is a consideration. First, it appears that pedestrians will treat intersections (whether marked with a crosswalk or not) as an acceptable place to cross the roadway. Given sufficient pedestrian volume, protected pedestrian crossings should be taken into account when designing intersections. This is especially important if the intersection is in route to/from a high-density trip originator.

A mean percentage of 13.89 of crossings occurred in unmarked non-intersection areas. This value is especially low considering the percentage of pedestrian fatalities that occur at non-intersection locations (approximately 64 percent). The discrepancy between these two percentages could be the result of several factors. The first possibility is that pedestrians in the Washington, DC, metropolitan area are fundamentally different than other pedestrians. However, this seems unlikely. Another possibility is that because pedestrians infrequently cross outside intersections, drivers do not anticipate pedestrians in these areas. Consequently, drivers are not able to react quickly enough to avoid collision. Furthermore, traffic speeds are most often higher at non-intersections than intersections, thus the outcomes of collisions are more severe.

Rule-following and rule-breaking crossings were explored. A mean percentage of 70.89 pedestrians crossed entirely during the walk phase of the marked intersection. That is, most pedestrians do complete rule-following crossings. Location 13 was an outlier with only

28.41 percent of the crossings completed being rule following. This value is not surprising considering the travel pace required to cross during the walk phase. The walk signal is only illuminated for 10 s and the roadway is approximately 50 ft wide. This requires pedestrians to travel at a rate of 5 ft/s, which is outside the range of comfortable travel for many people. This rate is greater than the MUTCD recommended rate of 3.5 ft/s. Furthermore, the MUTCD states: "Where pedestrians who walk slower than 3.5 feet per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 3.5 feet per second should be considered in determining the pedestrian clearance time." If one is concerned with rule-breaking crossings, the length of the walk phase should be long enough to allow most pedestrians to cross at a reasonable pace and at minimum, meet the MUTCD standards for time provided to cross the roadway.

Analyses also revealed relationships between environmental factors and where pedestrians crossed the roadway. First, a relationship between the width of the crossing and rule-following was found. The wider the crossing, the more likely pedestrians are to make a rule-following crossing. Or, alternatively, pedestrians are more likely to make a rule-breaking crossing when the road is narrow. In addition, the presence of physical barriers along the sidewalk influenced where pedestrians crossed the roadway. Specifically, the more objects that prevent easy access from the sidewalk to the roadway, the less likely pedestrians were to cross at unmarked non-intersection locations. Given these findings, for areas where there might be a problem with dangerous non-intersection crossings, a simple intervention of increasing the barriers along the sidewalk could be made. Placing obstacles like flower planter beds, benches, or other decorative barriers will not eliminate the ability to cross the roadway. However, these barriers will reduce the affordance to cross outside the marked intersection (and maybe even increase the visual esthetic of the area).

Somewhat interestingly, traffic directionality was significantly negatively correlated with crossings made in the marked intersection entirely during the don't walk phase. In other words, pedestrians were more likely to cross entirely during the don't walk light phase signal on one-way streets than on two-way streets. This finding makes sense given that pedestrians are better able to predict traffic that is approaching from one direction rather than two. While changing roadway directionality may not be an appropriate roadway safety intervention, it should be considered when designing/modifying existing road segments. For example, if it is known that pedestrians are more likely to cross a one-way street during the don't walk phase, the speed could be modified to reduce the impact of potential conflicts or pedestrians could be provided with an activation button that triggers the walk phase (increasing perceived control of the crossing).

Pedestrian Yielding:

Of the total crossings at each location, there was a mean percentage of .98 that involved pedestrian yielding. Although pedestrian yielding is discussed, it should not be taken as an indication that there was potential for a collision. Rather, it was simply an action taken by pedestrians to allow vehicles to pass. In the marked intersections, the mean percentage of pedestrians that yielded to vehicles was .41. Similarly, the mean percentage of pedestrians yielding to vehicles during rule-following crossings was .43. Location 17 was an outlier in both cases, with 6.52 percent of the crossings in the marked intersection involving a pedestrian yielding to a vehicle. All of these yielding behaviors were observed while pedestrians crossed entirely during the walk phase, resulting in yielding in 7.27 percent of the rule-following crossings. The exact circumstances of these yielding behaviors were not recorded. However, observational notations indicate that these actions are the result of pedestrians yielding to vehicles turning on to and from the busier main street (North Washington). In other words, pedestrians allowed vehicles to pass, which increased vehicular traffic flow. While patterns such as these show common roadway courtesy and may increase the overall level of user satisfaction, they may lead to unforeseen consequences. For example, if a group of pedestrians yields to a vehicle, the vehicle may proceed to turn to cross the path of the pedestrians. This is not an issue if all pedestrians yield. However, an incident may occur if another pedestrian does not yield to the driver, who is assuming that all pedestrians are yielding.

Overall, Location 10 was an outlier with 13.25 percent rule-breaking crossings involving yielding to a vehicle. Additional notations indicate that some of these yielding behaviors may have been the result of a person parking on one side of the street and seeking a trip destination on the opposite side of the street. That is, pedestrians began crossing somewhere between the two marked intersections and ultimately yielded to a vehicle before completing the crossing. If parking away from a marked intersection does indeed lead people to cross at unmarked non-intersection crossings to reach destinations on the opposite side of the road, it may be difficult to implement interventions to promote crosswalk use. However, items such as barriers that create separation between bi-directional traffic and reduce crossing affordances may be effective (although they have many drawbacks, including cost and feasibility).

As one might expect, there were significantly more instances of pedestrians yielding to vehicles in unmarked non-intersection areas than in marked intersections. Similarly, there were significantly more pedestrian yielding behaviors in rule-breaking crossings than rule-following crossings. These findings suggest that when pedestrians do make rule-breaking crossings, they are prepared to yield to vehicles.

Pedestrian yielding is also significantly correlated with several environmental factors. There was a significant correlation between the length of the walk signal light phase and the percentage of pedestrians that yielded to vehicles in the marked intersection. This is perhaps not surprising. If one thinks about a moderate to heavy volume crossing, pedestrians often group together as they wait for the signal to change. After the initial bulk of pedestrian traffic has crossed the intersection, queued vehicles begin to make turns onto perpendicular streets. As pedestrians, who had not been waiting to cross, reach the intersection, they may yield to allow the vehicles to complete crossing. This serves both to keep vehicular traffic flowing and to provide pedestrians with some control of their safety in the crossing.

Traffic volume, as estimated by AADT, was also significantly correlated with pedestrians yielding during rule-breaking crossings. This is not surprising given that as vehicular traffic increases, there are more opportunities for pedestrians to yield to vehicles. Given these data, it is difficult to say that areas with higher AADT are necessarily more dangerous for pedestrians. Rather, pedestrians are simply more likely to yield to vehicles, which may actually indicate a safer area for pedestrians.

Vehicle Yielding:

Overall, an average of 8.93 pedestrian crossings involved a vehicle yielding to a pedestrian. Location 7 was an outlier, with 38.69 percent of the crossings involving vehicle yielding. This trend remained consistent with both crossings in the marked crossing (39.80 percent) and rule-following crossings (50.71 percent). This area had a substantial number of vehicles turning right and passing through the intersection of interest. As a result of the turning and through traffic having a green light (but not a protected right turn) and the pedestrian signal in the walk phase, vehicles often waited to complete their turn (i.e., yielded) while pedestrians crossed the roadway. These yielding behaviors do not necessarily indicate a safety concern. However, turning traffic in high pedestrian volume areas should be evaluated in intersection design.

Overall, vehicles yielded to 2.55 percent of pedestrians making rule-breaking crossings. Both Location 17 (11.67 percent) and Location 12 (9.23 percent) were outliers. Location 12 is unusual because there were very few rule-breaking crossings overall. As a result, the six observed vehicle yielding behaviors resulted in a high percentage of the total rule-breaking crossings. Location 17 however, is unusual in a different way. This block is in an area known as Old Town Alexandria. In this particular neighborhood, the street is relatively narrow, has parking on both sides of the street, has slow-moving traffic (often looking for parking), and is surrounded by small shops and businesses. This is an area where people move at a leisurely pace. These factors combine to create a unique atmosphere where drivers often stop and "wave" pedestrians to cross the road. Although these specific actions were not measured, they were observed and noted on many crossings. This vehicle yielding in this area may suggest that cultural differences in neighborhood may influence the need (or lack of a need) for different safety interventions.

Overall, significantly greater percentages of vehicles yielded to pedestrians crossing in the marked crossing than in the unmarked non-intersection. The same pattern is true with rule-following and rule-breaking crossings.

A relationship between the number of trip originators and destinations in an area and vehicles yielding to pedestrians making rule-breaking crossings was found. That is, the more trip originators and destinations present, the higher the percentage of pedestrian rule-breaking crossings that involved vehicle yielding. These findings suggest pedestrians may be more motivated to make potentially dangerous rule-breaking crossings to reach a trip destination. It also points out the necessity to take special consideration of pedestrian crossing facilities in areas with a high density of commercial businesses.

Yielding Comparison:

Not surprisingly a significantly greater percentage of vehicles than pedestrians yielded in rule-following crossings. The same is true for crossings taking place in the marked intersection overall. These findings suggest that drivers are respectful of shared road use with pedestrians in the marked intersections. However, it is not known whether this relationship remains true for non-intersection marked crossings (i.e., not light-controlled marked midblock crossings). This specific type of crossing was not explored in the present study. However, vehicles and pedestrians were equally likely to yield in unmarked non-intersection areas. The same remains true in rule-breaking crossings overall.

It is perhaps a bit surprising that there were no significant differences in vehicle and pedestrian yielding outside the marked intersections and in rule-breaking crossings. It might be expected that pedestrians would take a more proactive safety approach when making a rule-breaking crossing. The lack a difference in yielding may also provide insight into the disproportionate percentage of crossings at non-intersection locations and high fatality rates in these areas. This may also indicate that vehicles will yield proactively to allow pedestrians to cross outside the normal rule following crossings and that pedestrians expect vehicles to yield. Both have implications for pedestrian safety and potential collisions.

Evasive Pedestrian Actions:

The mean percentage of crossings that included an evasive pedestrian action was 3.06. Both Location 1 and Location 8 were outliers. Location 8 requires pedestrians to travel at a pace of 3.7 ft/s, faster than the recommended rate of 3.5 ft/s. Given that there is an elementary school approximately two blocks away from this intersection and that there are other small suburban type establishments (including a church, neighborhood market, and library) in the general area, it is likely that there is substantial pedestrian traffic near this intersection that regularly travels at a rate of less than 3.5 ft/s.

While pedestrians were not specifically queried about their crossings, it is possible that pedestrians may feel rushed while crossing at the marked intersection. This rapid pace required to cross at the marked intersection during the walk phase may lead pedestrians to feel hurried and uncomfortable crossing at this location. Furthermore, if pedestrians are not able to complete the crossing during the walk phase, they may be forced to take an evasive action to complete the crossing. This intersection is also just outside a traffic circle. This prevents pedestrians from being able to view traffic from a distance adequate to determine whether it will continue traveling within the traffic circle or exit toward the intersection. Furthermore, this reduces pedestrians' abilities to confidently determine whether the vehicle will cross their potential path during a crossing. At this location, pedestrians may begin a crossing but not be able to clearly view all vehicular traffic. As a result, pedestrians might be forced to take evasive actions to complete the crossing safely.

Location 1 was an outlier both in terms of evasive actions in marked intersections and unmarked non-intersections. At Location 1, there were many instances of "courtesy" acceleration by pedestrians. In other words, it appeared that pedestrians would run, or accelerate, through a crossing to allow turning vehicles to complete their turn during the signal phase. This turning traffic may have also been the cause of the evasive actions made outside the marked intersection. Pedestrians may have started crossing the roadway while no traffic was visible. However, after the pedestrian initiated the crossing, a vehicle could have turned onto the main roadway and forced the pedestrians to take an evasive action to avoid a potential collision. These circumstances were not specifically coded in the data; however, several notes indicated that this did in fact occur. It may not be possible to target a specific intervention for these potential sources of conflict. However, vehicle turning phases (or lack thereof) and pedestrian density should be considered in roadway design.

As one might expect, pedestrians had a significantly greater percentage of crossings in unmarked non-intersection areas that involved an evasive pedestrian action than crossings in the marked intersection. This same pattern is true for rule-following and rule-breaking crossings. In other words, when pedestrians make a rule-breaking crossing, they are more likely to need to take an evasive action to avoid collision.

A significant negative relationship between the percentage of evasive actions taken in unmarked non-intersections and the length of the walk light phase was found. That is, the shorter the walk phase, the more likely that crossings in the unmarked non-intersection will involve an evasive pedestrian action. Thus it appears that light phasing may be an important factor to consider in terms of potential vehicle/pedestrian conflicts. However, light phase timing is also associated with traffic density. As a result, simply increasing the length of the walk signal is not likely to eliminate all pedestrian evasive actions.

Evasive Vehicle Actions:

Overall, the mean percentage of pedestrian crossings that involved an evasive vehicle action was .10. Location 12 was considered an outlier in the percentage of crossings involving an evasive action, both overall and unmarked non-intersection areas. However, only two vehicle evasive actions were recorded at this location. Given the small number, these crossings are not discussed further.

Location 17 is also an outlier in terms of the percentage of evasive vehicle actions made during rule-following crossings and crossings in the marked intersection overall. However, Location 17 only had one recorded evasive vehicle action. As a result, it is not discussed further here.

No significant difference between the percentage of crossings in the marked intersection and the unmarked non-intersection that included a vehicle evasive action was found. No difference in the percentages between rule-following and rule-breaking crossings was found either.

A significant correlation between the length of the walk phase and the percentage of evasive vehicle actions during marked intersection pedestrian crossings was found. In other words, the longer the walk phase, the more likely vehicles were to take an evasive action while pedestrians crossed in the marked intersection. Given the relationship between pedestrian yielding in the marked intersection and the length of the walk phase, this may not be surprising. As discussed in a previous example, it is simple to imagine how pedestrians might group together to wait for a signal to change at a moderate to heavy volume crossing area. After the initial bulk of pedestrian traffic has crossed the intersection, queued vehicles begin to make turns onto perpendicular streets, passing through the marked pedestrian crossing. However, pedestrians who reach the intersection later may come as a surprise to vehicles. As a result, drivers may be forced to make an evasive maneuver to avoid collision.

Evasive Action Comparison:

For crossings made both in the marked intersection and the unmarked non-intersection, pedestrians had a significantly greater percentage of evasive actions than did vehicles. The same pattern is true for rule-following and rule-breaking crossings. This difference can be interpreted in many different ways. In general, it appears as though pedestrians proactively take action to avoid potential collisions. That is, independently of whether pedestrians are making a rule-following or a rule-breaking crossing, they are more likely to take an evasive action to avoid collision than are drivers. Challenges may arise, however, when pedestrians are not able to take an appropriate evasive action, are not aware that one is needed, or when a driver anticipates a pedestrian will take an evasive action and he or she does not.

Summary

The overarching goal of this study was to determine which factors influence when and where pedestrians cross the roadway. Both factors associated with pedestrians and factors associated with the crossing environment were examined. Although factors intrinsic to pedestrians are not easily manipulated, measures that increase safety can be implemented in areas dominated by one specific demographic group (e.g., older adults near a retirement community or smaller children near a school). Furthermore, educational methods can be used to help pedestrians make wiser crossing choices.

Environmental factors were explored at 20 different crossing locations. A model was developed that relatively successfully predicted whether pedestrians would cross within the marked crossing or not. While this model is not 100-percent accurate, it does provide a basis to understand where pedestrians might cross the roadway. This model may prove useful in the design, or renovation, of new roadways and shared use communities. Areas that have a high predicted likelihood of unmarked non-intersection crossings could be proactively targeted to modify the crossing affordances of the environment.

The data here provide insights into some of the specific environmental factors that influence where and when pedestrians cross the road. Some suggestions are provided for ways these factors can be modified to influence pedestrian behavior (e.g., reducing crossing affordances by adding flower beds separating the sidewalk and roadway). Evidence is also provided that suggests modifying environmental affordances to alter perceived control of the crossing will modify where pedestrians cross the roadway. This can be accomplished by both increasing the control of the marked crossing signal (e.g., activated button presses, timed countdowns, traffic flow information) and reducing control outside the marked crossings (e.g., including road barriers, removing medians in bi-directional traffic). However, it should be noted that these modifications can have unintended consequences in crossing behavior and should be evaluated carefully. The exact interaction and interplay of these factors is not fully understood.

An important consideration in environmental factor manipulation is the safety impacts of modifying where pedestrians cross the roadway. It is not known whether pedestrian crossings in the intersection are actually safer than crossings made at non-intersection locations. In fact, of the crossings in the 20 different locations, the only near incident took place in a marked intersection. At Location 7, two pedestrians were about to enter the roadway while at the same time, a vehicle began to make a right turn (passing through the marked intersection). One person pulled the other person back to the curb. Although it is not clear from the video, it appears that the vehicle may have nearly collided with the pedestrian had he or she not be pulled back to the curb. Despite the pedestrian having the right of way in this case, it is easy to understand why the driver continued with the right turn. Prior to the pedestrians attempting to cross the roadway, they stood on the curb facing the opposite crossing direction (i.e., facing north, rather than east). Furthermore, the walk phase had been initiated for more than 10 s prior to the pedestrians attempting to enter the marked intersection. These clues could easily lead a driver not to interpret the pedestrians as a potential hazard. Therefore, it does appear that predictability of pedestrian actions plays a key in driver reaction and potential safety.

In sum, these data help to explain where, when, and why pedestrians cross the road. Through this report, the data and analysis help to promote a better understanding of pedestrian behavior. This information can be used to evaluate the implementation of new roadways and communities, redesign of existing environments, and identification of areas that may benefit from engineering interventions such as crossing-inhibiting designs or pedestrian hybrid beacons.

REFERENCES

1. Fatality Reporting Analysis System (2011). http://www-fars.nhtsa.dot.gov//QueryTool/QuerySection/SelectYear.aspx Accessed November 2011.
2. Jacobs, G., Aeron-Thomas, A., and Astrop, A. (2000). *Estimating Global Road Fatalities*, TRL Report 445, TRL Ltd., Crowthorne, UK.
3. Naci, H., Chisholm, D., and Baker, T.D. (2009). "Distribution of Road Traffic Deaths by Road User Group: A Global Comparison," *Injury Prevention, 15*, 55–59.
4. World Health Organization (2004). *World Report on Road Traffic Injury Prevention*.
5. Karkee, G.J., Pulugurtha, S.S., and Nambisan, S.S. (2009). Statistical Analysis of Pedestrian Crossing Behavior on Streets. Presented at 88th Annual Meeting of the Transportation Research Board, Washington, DC.
6. National Highway Transportation Safety Administration (NHTSA) (2011). Traffic Safety Facts, 2009, U.S. Department of Transportation, Washington, DC.
7. NHTSA (2011). Traffic Safety Facts: Pedestrians. U.S. Department of Transportation, Washington, DC.
8. Holland, C., Hill, R. (2007). "The Effect of Age, Gender, and Driver Status on Pedestrians' Intentions to Cross the Road in Risky Situations," *Accident Analysis and Prevention*, *39*, 224–237.
9. Evans, D. and Norman, P. (1998). "Understanding Pedestrians' Road Crossing Decisions: an Application of the Theory of Planned Behavior," *Health Education Research, Theory and Practice, 13*, 481–489.
10. Holland, C.A., Hill, R., and Cooke, R. (2009). "Understanding the Role of Self-Identity in Habitual Risky Behaviours: Pedestrian Road-Crossing Decisions Across the Lifespan," *Health Education Research*, *24*(4), 674–685.
11. Barton, B.K. and Morrongiello, B.A. (2011). "Examining the Impact of Traffic Environment and Executive Functioning on Children's Pedestrian Behaviors," *Developmental Psychology, 47*, 182–191.
12. Evans, D. and Norman, P. (2003). "Predicting Adolescent Pedestrians' Road-Crossing Intentions: An Application and Extension of the Theory of Planned Behaviour," *Health Education Research*, *18*(3), 267–277.
13. Conner, M. and Sparks, P. (1996). "Theory of Planned Behavior and Health Behaviour," in Conner, M. and Norman, P. (Eds), *Predicting Health Behaviour*. Open University Press, Buckingham, 121–162.
14. Gibson, J.J. (1966). *The Senses Considered as Perceptual Systems*, Houghton Mifflin, Oxford.
15. Tyrrell, R.A., Wood, J.M., Carberry, T.P. (2004). "On-Road Measures of Pedestrians' Estimates of Their Own Nighttime Conspicuity," *Journal of Safety Research*, *35*, 483–490.
16. Norman, D.A. (1988). *The Psychology of Everyday Things*, Basic Books, New York.
17. Retting, R.A, Ferguson, S.A., and McCartt, A.T. (2003). "A Review of Evidence-Based Traffic Engineering Measures Designed to Reduce Pedestrian-Motor Vehicle Crashes," *American Journal of Public Health, 9*, 1,456–1,463.
18. District of Columbia Department of Transportation (2012). Annual Average Daily Traffic, 2010 Traffic Volume Map. http://ddot.dc.gov/DC/DDOT/About+DDOT/Maps/Traffic+Volume+Maps

19. Google®, Inc. (2012) *Map of the intersection of H and 3rd Streets Northeast in Washington, DC*. Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b89bc09737f4f2f2e&msa=0&ll=38.900318,-77.001328&spn=0.016065,0.026071&iwloc=0004b89bc94bb3a1299df)
20. Google®, Inc. (2012) *Map of the intersection of 7th Street and New York Avenue Northwest in Washington, DC*. Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b89bc09737f4f2f2e&msa=0&ll=38.9029,-77.021222&spn=0.002008,0.003259&iwloc=0004b89bcce2495d74a9b)
21. Google®, Inc. (2012) *Map of the intersection of 7th Street and Rhode Island Avenue Northwest in Washington, DC*. Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b89bc09737f4f2f2e&msa=0&ll=38.912142,-77.021354&spn=0.002008,0.003259&iwloc=0004b89bd078124769f02).
22. Google®, Inc. (2012) *Map of the intersection of 13th and I Streets Northwest in Washington, DC*. Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b89bc09737f4f2f2e&msa=0&ll=38.90151,-77.028786&spn=0.002008,0.003259&iwloc=0004b89bd40ef46163777)
23. Google®, Inc. (2012) *Map of the intersection of 14th and H Streets Northwest in Washington, DC*. Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b89bc09737f4f2f2e&msa=0&ll=38.900137,-77.031785&spn=0.002008,0.003259&iwloc=0004b89bd40f0865faecb)
24. Google®, Inc. (2012) *Map of the intersection of 14th Street and New York Avenue Northwest in Washington, DC*. Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b89bc09737f4f2f2e&msa=0&ll=38.899283,-77.031927&spn=0.004016,0.006518&iwloc=0004b89bd7a3b7b5a3fee)
25. Google®, Inc. (2012) *Map of the intersection of 19th Street, H Street, and Pennsylvania Avenue Northwest in Washington, DC*. Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b89bc09737f4f2f2e&msa=0&ll=38.899283,-77.040945&spn=0.004016,0.006518&iwloc=0004b89bd7a3cc098189f)
26. Google®, Inc. (2012) *Map of the intersection of Oliver Street and Connecticut Avenue Northwest in Washington, DC*. Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b89bc09737f4f2f2e&msa=0&ll=38.966412,-77.075964&spn=0.004012,0.006518&iwloc=0004b89bdb3940c0107c2)
27. Cohen, R.A. (2009). “Applications of the GLMSELECT Procedure for Megamodel Selection,” in *Proceedings of the SAS Global Forum 2009 Conference, Cary, NC: SAS Institute Inc.*
28. *Manual on Uniform Traffic Control Devices*. FHWA, U.S. Department of Transportation, Washington, DC, 2009.

29. Google®, Inc. (2012) *Map of the intersection of Connecticut and Florida Avenues Northwest in Washington, DC.* Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b9b739239ddfdbc49&msa=0&iwloc=0004b9b74dba7f6a96117)
30. Google®, Inc. (2012) *Map of the intersection of Connecticut Avenue and Van Ness Street Northwest in Washington, DC.* Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b9b739239ddfdbc49&msa=0&ll=38.943164,-77.062901&spn=0.008027,0.013036&iwloc=0004b9b7514fc6ad1e1fb)
31. Google®, Inc. (2012) *Map of the intersection of Georgia and Arkansas Avenues Northwest in Washington, DC.* Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b9b739239ddfdbc49&msa=0&ll=38.951057,-77.027088&spn=0.004013,0.006518&iwloc=0004b9b758797dd2cd556)
32. Google®, Inc. (2012) *Map of the intersection of Georgia Avenue and Irving Street Northwest in Washington, DC.* Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b9b739239ddfdbc49&msa=0&ll=38.928956,-77.023065&spn=0.004015,0.006518&iwloc=0004b9b766c8b281caacc)
33. Google®, Inc. (2012) *Map of the intersection of H Street and Connecticut Avenue Northwest in Washington, DC.* Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b9b739239ddfdbc49&msa=0&ll=38.899792,-77.03639&spn=0.004016,0.006518&iwloc=0004b9b78366bd4822ba7)
34. Google®, Inc. (2012) *Map of the intersection of Independence and Washington Avenues Southwest in Washington, DC.* Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b9b739239ddfdbc49&msa=0&ll=38.887534,-77.013184&spn=0.004017,0.006518&iwloc=0004b9b78a8fe40fe0aed)
35. Google®, Inc. (2012) *Map of the intersection of Pennsylvania Avenue and 8th Street Southeast in Washington, DC.* Accessed September 19, 2012 (https://maps.google.com/maps/ms?msid=207498904521634712066.0004b9b739239ddfdbc49&msa=0&ll=38.884348,-76.99517&spn=0.004017,0.006518&iwloc=0004b9b744140e0168e29)
36. Virginia Department of Transportation (2012). Annual Average Daily Traffic, 2010 Traffic Volume Map. http://www.virginiadot.org/info/2010_traffic_data_by_jurisdiction.asp
37. Google®, Inc. (2012) *Map of the intersection of King and North Washington Streets in Alexandria, VA.* Accessed September 19, 2012 (https://maps.google.com/maps?q=king+and+north+washington,+alexandria,+va&hl=en&ll=38.804868,-77.046561&spn=0.004022,0.006518&sll=38.925434,-77.035778&sspn=0.128472,0.208569&t=h&hnear=King+St+%26+N+Washington+St,+Alexandria,+Virginia+22314&z=18)

38. Google®, Inc. (2012) *Map of the intersection of Irving and 14th Streets Northwest in Washington, DC*. Accessed September 19, 2012 (https://maps.google.com/maps?q=irving+and+14th+Washington+dc&hl=en&sll=38.804868,-77.046561&sspn=0.004022,0.006518&t=h&hnear=14th+St+NW+%26+Irving+St+NW,+Washington,+District+of+Columbia&z=17)
39. Google®, Inc. (2012) *Map of the intersection of Wisconsin and Western Avenues Northwest in Washington, DC*. Accessed September 19, 2012 (https://maps.google.com/maps?q=willard+ave+and+wisconsin+ave+washington+dc&hl=en&ll=38.959943,-77.085571&spn=0.008026,0.013036&sll=38.928774,-77.03264&sspn=0.008029,0.013036&t=h&hnear=Wisconsin+Ave+%26+Willard+Ave,+7,+Montgomery,+Maryland+20815&z=17)
40. Google®, Inc. (2012) *Map of the intersection of Clarendon Boulevard and North Edgewood Street in Arlington, VA*. Accessed September 19, 2012 (https://maps.google.com/maps?q=North+Fillmore+Street,+Clarendon,+Arlington,+VA&hl=en&ll=38.888127,-77.09188&spn=0.004017,0.006518&sll=38.959943,-77.085571&sspn=0.008026,0.013036&oq=clarendon+north+fillmore&t=h&hnear=N+Fillmore+St,+Arlington,+Virginia+22201&z=18)
41. Wilson, M. and Daly, M. (1985). "Competitiveness, Risk Taking, and Violence: The Young Male Syndrome," *Ethology and Sociobiology, 6,* 59–73.

HRDS-30/01-14(WEB)E