Pedestrian Crosswalk Case Studies: Richmond, Virginia; Buffalo, New York; Stillwater, Minnesota

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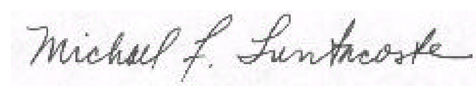
Pedestrian & Bicycle Safety

FOREWORD

The FHWA's Pedestrian and Bicycle Safety Research Program's overall goal is to increase pedestrian and bicycle safety and mobility. From better crosswalks, sidewalks and pedestrian technologies to growing educational and safety programs, the FHWA's Pedestrian and Bicycle Safety Research Program strives to pave the way for a more walkable future.

Crosswalks are among the treatments used to help pedestrians cross streets safely. This study was part of a larger Federal Highway Administration research study investigating the safety effectiveness of crosswalks for pedestrians. This study focused on the effect of crosswalk markings on both pedestrian and driver behavior at unsignalized intersections. It is hoped that readers also will review the reports documenting the results of the related pedestrian crossing studies.

The results of this research will be useful to transportation engineers, planners, and safety professionals who are involved in improving pedestrian safety and mobility.



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16. Abstract

The objective of this research was to determine the effect of crosswalk markings on driver and pedestrian behavior at unsignalized intersections. A before/after evaluation of crosswalk markings was conducted at 11 locations in 4 U.S. cities. Behavior observed included: pedestrian crossing location, vehicle speeds, driver yielding, and pedestrian crossing behavior. It was found that drivers approach a pedestrian in a crosswalk somewhat slower, and that crosswalk usage increases after markings are installed. No evidence was found indicating that pedestrians are less vigilant in a marked crosswalk. No changes were found in driver yielding or pedestrian assertiveness. Overall, it appears that marking pedestrian crosswalks at relatively low-speed, low-volume, unsignalized intersections is a desirable practice, based on the sample of sites used in this study.

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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		
in²	square inches	645.2	square millimeters	mm²
ft²	square feet	0.093	square meters	m²
yd²	square yards	0.836	square meters	m²
ac	acres	0.405	hectares	ha
mi²	square miles	2.59	square kilometers	km²
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft³	cubic feet	0.028	cubic meters	m³
yd³	cubic yards	0.765	cubic meters	m³
NOTE:	Volumes greater than 1000 l shall be shown in m³.			
		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)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m²	cd/m²
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in²	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		
mm²	square millimeters	0.0016	square inches	in²
m²	square meters	10.764	square feet	ft²
m²	square meters	1.195	square yards	yd²
ha	hectares	2.47	acres	ac
km²	square kilometers	0.386	square miles	mi²
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m³	cubic meters	35.71	cubic feet	ft³
m³	cubic meters	1.307	cubic yards	yd³
		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)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m²	candela/m²	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/in²

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

(Revised September 1993)

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OVERVIEW

This research was conducted by the Center for Applied Research, Inc., as part of a subcontract from The University of North Carolina Highway Safety Research Center. Task Order 11, Evaluation of Pedestrian Facilities, was part of Federal Highway Administration research project DTFH61-92-C-00138, Pedestrian and Bicyclist Safety - Administrative and Technical Support.

OBJECTIVES

The overall objective of the research was to determine the effect of crosswalk markings on driver and pedestrian behavior at unsignalized intersections. One aspect of the field data collection effort was to determine if pedestrians were more likely to cross a street within a marked crosswalk. A second aspect of the study was to determine if drivers drove slower and/or yielded more often to pedestrians crossing at a marked location. A final aspect of the study was to determine if pedestrians use more, less, or the same amount of caution when crossing at a marked pedestrian crosswalk compared with an unmarked location.

METHOD

Experimental Sites

Eleven intersections were selected from four cities in different geographical regions of the United States. A before/after evaluation of pedestrian crosswalk markings was conducted. With the exception of one California location, all of the sites were located at previously unmarked crosswalks. All of the crossing locations were on relatively straight and level roadways that allowed excellent sight distance.

Three locations in downtown Sacramento, California, were selected for evaluation. Two of the three sites were located at intersections with unmarked crosswalks. Before and after studies of crosswalk markings were conducted.

The third site in Sacramento was at a “T” intersection in front of the State Capitol building. One through leg had standard solid white parallel line crosswalk markings. The other through leg had no crosswalk markings and No Crossing symbol signs (MUTCD R9-3a) and USE CROSSWALK with arrow signs (MUTCD R9-3b) posted, specifically prohibiting crossing at that location. The city was experiencing difficulty in channeling pedestrian traffic and planned to supplement the existing standard crosswalk markings with a high-visibility upgrade.

Three locations between Virginia Commonwealth University and the community of Uptown, in Richmond, Virginia, were selected. The three unsignalized intersections provided ideal locations for pedestrian and driver observational studies because they experienced heavy traffic and continuous pedestrian activity throughout the day. The chief traffic engineer of Richmond installed standard solid white parallel line crosswalk markings in both crosswalks at each of the three intersections. A before and after study was conducted.

The chief traffic engineer of Buffalo, New York, suggested many locations that could be used in the study. Unfortunately, many of the unsignalized intersections in the city were four-way, stop-controlled offset intersections. Three standard intersections with no traffic signals were selected. Two of the sites were on the south side of the city in an older village with mixed commercial and residential usage. The third site was on the north side of the city in a suburban residential neighborhood. A before and after study was conducted at the three intersections. The city installed standard solid white parallel line crosswalk markings at the three locations.

Two sites were selected for evaluation in Stillwater, Minnesota. One of the sites was a “T” intersection in the downtown district across from the city library. The second intersection was adjacent to one of the town's hospitals. With the cooperation of the city traffic engineer, a before and after study was conducted with high-visibility ladder crosswalk markings installed for the after study.

A detailed description of each of the study intersections follows. Photos showing each location after the crosswalk installation are presented as Figures 1 thru 11.

Sacramento, Site 1: 10th Street at Capitol Mall Drive

The intersection of 10th Street at Capitol Mall Drive is unsignalized. 10th Street is a one-way, three-lane westbound roadway. Capitol Mall Drive is a stop-controlled, two-way roadway with a wide, grassy median that formed a “T” intersection at 10th Street. There is restricted and metered parking along both sides of 10th Street with bus only parking in front of the Capitol Building across from the “T” intersection. Sidewalks are located on both sides of all legs of the intersection. Curb cuts are provided on the east leg of 10th Street and on the cross street. There are no curb cuts on the west leg of 10th Street, and two No Crossing (MUTCD R9-3a) symbol signs were posted on both sides of the roadway. Below the no pedestrian crossing signs there was a Crosswalk sign with directional arrows (MUTCD R9-3b). The arrows pointed to the east leg of the through street where a standard solid white parallel line crosswalk was installed in the roadway. The crosswalk markings were 0.3 m (1 ft) wide and 3 m (10 ft) apart. All legs of the intersection were straight and level and the speed limit was 40 km/h (25 mi/h).

The State Capitol building is located across from the "T" intersection at Capitol Drive. Pedestrian traffic is lightest during morning rush hour, heaviest between 11:00 am and 4:00 pm, and moderate and steady during the afternoon rush hour. Tourists and school children visit the State Capitol building throughout the day, often arriving in buses.

The after study was conducted about 1 month after a novel high-visibility crosswalk was installed. The crosswalk markings were enhanced by adding 0.6-m (2-ft) by 3-m (10-ft) solid white rectangles perpendicular to the standard solid white parallel lines. A total of seven white blocks and six unmarked spaces stretched the width of 10th Street. In addition, seven mono-directional, raised reflective pavement markers were installed in front of the white paint markings facing oncoming traffic.

Sacramento, Site 2: O Street at 14th Street

The intersection of O Street at 14th Street is unsignalized. O Street is a two-way east/west through street with one lane in each direction. The stop-controlled cross street, 14th Street, is also one lane in each direction. There are no additional turn lanes; however, there is space for metered and/or restricted parking on all four legs (both sides) of the intersection. There are sidewalks on all four legs, both sides of the road, with curb cuts at all crossings. All legs of the intersection are straight and level and the posted speed limit is 40 km/h (25 mi/h). The closest intersection eastbound is 108.6 m (356 ft) away and is also an unsignalized intersection. In the westbound direction, O Street ends at a stop-controlled "T" intersection about 108.6 m (356 ft) away. Two restaurants, a market, and a parking lot are located on the corners of the intersection. Mixed residential and office buildings provide a pedestrian volume that peaks during rush hours and lunch time.

The crosswalks were unmarked during the before study. A high-visibility ladder style crosswalk was installed on the west leg of O Street for the after study. The marked crosswalk consisted of 10 bold white lines 3 m (10 ft) by 0.6 m (2 ft) with 0.6-m (2-ft) spacings. Each white line also had two mono-directional, raised reflective pavement markers installed facing oncoming traffic.

Sacramento, Site 3: N Street at 18th Street

The intersection of N Street at 18th Street was unsignalized. N Street is a one-way, eastbound, three-lane roadway. The stop-controlled cross street, 18th St., is a two-way roadway with one lane in each direction. There are no additional turn lanes; however, there is parking on all four legs, both sides, of the roadway. The residential intersection has sidewalks on all four legs with curb cuts at all crossings. The roads are straight and level with a speed limit of 40 km/h (25 mi/h). The closest signalized intersections are at 16th Street and at 19th Street, which are 244 m (800 ft) away.

The crosswalks were unmarked during the before study. A high-visibility ladder style crosswalk was installed on the east leg of N Street for the after study. The marked crosswalk consisted of 11 bold white lines 3.7 m (12 ft) by 0.6 m (2 ft) with 0.6-m (2-ft) spacings. Each white line also had two mono-directional, raised reflective pavement markers installed on the one-way approach to the crosswalk. The intersection is mixed-use residential and commercial with small corner businesses nearby. Pedestrian traffic is light but steady throughout the day.

Richmond, Site 1: Main Street at Granby Street

The intersection of Main Street at Granby Street was unsignalized. Main Street is a one-way, two-lane northbound roadway. There are two additional paved lanes used for parking. Granby Street is a two-way, stop-controlled roadway with one lane in each direction. Parking is permitted at both legs, on both sides of the roadway. There are sidewalks without curb cuts on all four legs, both sides of the roadway, with the exception of the south side of Granby Street, west leg. All legs of the intersection are straight and level and the speed limit is 40 km/h (25 mi/h). The intersection is located within a mixed commercial and residential area where pedestrian traffic is light but steady throughout the day. The closest signalized intersection is located about 97.6 m (320 ft) north of the site.

During the before study, the crosswalks were unmarked. The after study was conducted after standard solid white parallel crosswalk markings were installed at all four crossings of the intersection. The width of the white painted crosswalk markings was 152 mm (6 in).

Richmond, Site 2: Main Street at Plum Street

The intersection of Main Street at Plum Street is unsignalized. Main Street is a one-way, two-lane northbound roadway. There are two additional paved lanes used for parking. Plum Street is a two-way, stop-controlled roadway with one lane in each direction. Parking is permitted on both sides of the roadway on both legs of the intersection. There are sidewalks on all legs of the intersection. Curb cuts are provided on the cross street at both Plum Street crossings. The speed limit is 40 km/h (25 mi/h), and all legs of the intersection are straight and level. The intersection is located within a commercial district made up of restaurants and small service businesses where pedestrian traffic is light but steady throughout the day. The closest signalized intersection is three blocks north of the site.

The crosswalks were unmarked during the before study. Standard solid white parallel crosswalk markings were installed at all four crossings of the intersection for the after study. The width of the white painted crosswalk markings was 152 mm (6 in).

Richmond, Site 3: Main Street at Brunswick Street

Main Street is a two-lane, northbound, one-way roadway. There are two additional lanes for parking. Brunswick Street is a two-way, stop-controlled cross street with one lane in each direction. Parking is permitted on both sides of the roadway, both legs of the intersection. There are sidewalks without curb cuts on all sides of the four legs of the intersection with the exception of the south side of Brunswick, east leg. The speed limit is 40 km/h (25 mi/h), and all legs of the intersection are straight and level. Main and Brunswick Streets are located within a commercial business district that features restaurants and small service and retail-oriented shops. Pedestrian traffic is moderate and steady throughout the day. The closest signalized intersection, located south of the site, is about 61 m (200 ft) away.

The crosswalks were unmarked during the before study. Standard solid white parallel crosswalk markings were installed at all four crossings at the intersection for the after study. The width of the white painted crosswalk markings was 152 mm (6 in). During installation of the crosswalks, curb cuts were also added at the Brunswick Street crossings; however, no additional sidewalks were installed.

Buffalo, Site 1: E. Lovejoy Street at Goethe Street

E. Lovejoy is a two-way east/west street with one travel lane in each direction. Parking is permitted on both sides of the roadway. Goethe Street is a two-way, stop-controlled street with one lane in each direction. Parking is permitted on both sides of Goethe Street. Sidewalks are provided on all legs of the intersection, both sides of the streets. During the before study, curb cuts existed on all crossings except the southwest corner of E. Lovejoy Street. All legs of the intersection are straight and level, and the speed limit is 40 km/h (25 mi/h). The intersection is located within a mostly residential area. There is a bus depot located near one of the corners. Pedestrian traffic is generally light and steady most of the day. The closest intersection, located 76 m (250 ft) east of the site, is also unsignalized. The closest signalized intersection is four blocks away.

During the before study, the crosswalks were unmarked. Standard solid white parallel crosswalk markings were installed at all four crossings of the intersection for the after study. In addition, a curb cut was installed on the southwest corner of E. Lovejoy Street. The width of the painted crosswalk markings was 203 mm (8 in).

Buffalo, Site 2: E. Lovejoy Street at Schiller Street

E. Lovejoy Street is an east/west two-way roadway with one lane in each direction. Parking is permitted on both sides of the street. Schiller Street is a stop-controlled cross street that was two-way with one lane in each direction. Parking is permitted on both sides of Schiller Street. Sidewalks with curb cuts are provided on all legs of the intersection, both sides of the street. The roadways are all straight and level, and the speed limit is 40 km/h (25 mi/h). The intersection is located within a mixed residential and commercial neighborhood. There are private homes and commercial lounges within the same block. Pedestrian traffic is light and steady and becomes moderate during the late afternoon hours. The closest signalized intersection is located 81 km (270 ft) west of the site.

The crosswalks were unmarked during the before study. Standard white parallel crosswalk markings were installed at all four crossings of the intersection for the after study. The width of the painted crosswalk markings was 203 mm (8 in).

Buffalo, Site 3: Tacoma Avenue at Winston Road

Tacoma Avenue is a two-way roadway with one lane in each direction. Winston Road is a stop-controlled, two-way roadway with one lane in each direction. Parking is permitted on all legs of the intersection, both sides of the roadway. Sidewalks without curb cuts are present on all legs of the intersection, both sides of the roadway. The streets are straight and level, and the speed limit is 40 km/h (25 mi/h). The intersection is located in a residential neighborhood where pedestrian traffic is always light. There are no signalized intersections within eight blocks of the site. The closest stop-controlled intersection is located 78 m (256 ft) east of the site where the cross street is controlled and Tacoma Avenue continues uncontrolled.

The crosswalks were unmarked for the before study. Standard solid white painted parallel line crosswalks were installed for the after study. The width of the white painted markings was 203 mm (8 in).

Stillwater, Site 1: 4th Street at W. Mulberry Street

North 4th Street is a two-way roadway with one lane in each direction. Parking is permitted on both sides of the roadway. North 4th Street is an uncontrolled through street that continues for more than a mile in the northern direction and ends at a stop-controlled “T” intersection at W. Myrtle Street more than 305 m (1000 ft) south of the site. Sidewalks are provided on both sides of the roadway, and the speed limit is 40 km/h (25 mi/h). North 4th Street is straight with a slight northbound upgrade.

West Mulberry Street is located 26 m (86 ft) north of North 4th Street. The west side of W. Mulberry Street is a two-way street with one lane in each direction. Parking is permitted on both sides of the street and sidewalks were provided. It is straight with a slight downgrade in the eastbound direction. The east side of W. Mulberry Street is a driveway for library user parking. It is not a through street but drivers enter and exit for parking or dropoff purposes.

The mid-block site was located within a mostly residential neighborhood. City Hall, the police department, and a library are within the study zones. Pedestrian traffic is very light throughout the day, including on weekends.

The crosswalks were unmarked during the before study. A high-visibility ladder type crosswalk was installed mid-block in front of the library, for the after study. The high-visibility crosswalk markings consisted of five white 1.5-m (5-ft) by 0.9-m (3-ft) rectangles.

Stillwater, Site 2: S. Everett Street at W. Anderson Street

The intersection of S. Everett Street at W. Anderson Street is an unsignalized “T” intersection. S. Everett Street is a two-way, two-lane north/south roadway. Parking is not permitted on either side of the street. W. Anderson Street is a two-way roadway that is aligned with the other side of S. Everett Street as an entrance to a hospital parking lot. Parking is not permitted on either side of the stop-controlled leg of W. Anderson Street. The speed limit is 40 km/h (25 mi/h). S. Everett Street is straight with a slight downgrade in the northbound direction. W. Anderson Street is straight and level. There is a sidewalk, without curb cuts, leading to the hospital and clinic and to an adjacent parking lot across from the hospital. There were no sidewalks along S. Everett Street or W. Anderson Street.

Although there is a community hospital and clinic at the site, the neighborhood is primarily residential. The closest signalized intersections are four blocks away. The closest stop-controlled intersection is located more than 91.5 m (300 ft) north of the site at W. Anderson Street and Churchill Street.

The crosswalks were unmarked during the before study. A high-visibility ladder type crosswalk was installed for the after study. The solid white crosswalk markings consisted of six rectangular blocks that measured 1.2 m (4 ft) by 0.6 m (2 ft). Curb cuts were also installed.

SACRAMENTO, CA

Figure 1.

Sacramento Site No. 1

10th Street at
Capitol Mall Drive

Figure 2.

Sacramento Site No. 2

O Street at 14th Street

Figure 3.

Sacramento Site No. 3

N Street at 18th Street

RICHMOND, VA

Figure 4.

Richmond Site No. 1

Main Street at
Granby Street

Figure 5.

Richmond Site No. 2

Main Street at
Plum Street

Figure 6.

Richmond Site No. 3

Main Street at
Brunswick Street

BUFFALO, NY

Figure 7.

Buffalo Site No. 1

E. Lovejoy Street at Goethe Street

Figure 8.

Buffalo Site No. 2

E. Lovejoy Street at Schiller Street

Figure 9.

Buffalo Site No. 3

Tacoma Avenue at Winston Road

STILLWATER, MN

Figure 1O.

Stillwater Site No. 1

4th Street at
W. Mulberry Street

Figure 11.

Stillwater Site No. 2

S. Everett Street at
W. Anderson Street

DATA COLLECTION PROCEDURES

A team of two researchers in each city collected all of the before and after data during the spring, summer, and fall of 1996 and 1997. Data were collected between the hours of 8:00 am and 7:00 pm. The team worked together, one site at a time. Four different types of observational studies were conducted. Each study was scheduled to control for possible time of day and day of week differences.

The data collection team drew detailed site drawings that included measurements of roadway and distances to various buildings, street furniture, and trees. The overall study zones for each site were determined by measuring half the distance to the next intersection on the through street and between 17 m (55 ft) to 24 m (80 ft) on the controlled cross street. Other zones were created and labeled on the data collection forms in order to track pedestrian origin and destination and various pedestrian behaviors. Data were collected using pencil and data forms or by tape recording behavioral observations. The tapes were later transcribed onto data coding forms. Vehicle speeds were recorded at some of the sites using either laser or K-band radar.

Traffic volume counts, including turning movements, were collected hourly, and time headways (traffic gaps) were measured and recorded hourly at each site.

Following is a summary of the four studies that were conducted. For a more comprehensive description of each study, data collection protocol, and sample data collection forms, refer to the Appendix.

Pedestrian Entry/Magnet Study

The objective of the *Pedestrian Entry/Magnet* study was to determine if more pedestrians would cross at or near previously unmarked unsignalized intersections when marked crosswalks were installed.

Researchers recorded the precise location and number of pedestrians entering the roadway to cross. Whether pedestrians were crossing alone or in groups was also recorded. Crossing zones included: at intersection, near intersection, various distances from intersection, mid-block, and diagonally. During data analysis the pedestrian crossing locations were reduced to either in the crosswalk (marked or unmarked) or not in the crosswalk. This was due to the relatively small number of pedestrians observed in some of the original categories.

Right of Way Study

The primary objective of the Right of Way study was to determine how often drivers yielded the right of way to pedestrians attempting to cross at a nonsignalized intersection in unmarked and marked crosswalks. Another objective was to determine how often pedestrians displayed aggressive behavior toward approaching motorists by forcing drivers to yield the right of way. These behaviors were observed while pedestrians were crossing at the intersection.

The following data were recorded on a data collection form for each pedestrian observed crossing the major roadway:

1. Driver yielded to pedestrian in travel way
2. Driver did not yield to pedestrian in travel way
3. Pedestrian showed blatant aggressive behavior toward driver (e.g., crossing behavior that required the driver to slow or stop to avoid a collision)

Driver Speeds/Staged Pedestrian Study

The primary objective of the Speed and Staged Pedestrian study was to determine if drivers slowed down when pedestrians were attempting to cross at a nonsignalized intersection. A before and after study design was used to compare driver speeds at unmarked and marked crosswalks. For each observation, two speeds were measured: one in advance of the intersection and one at the crossing location. By observing two speeds, an assessment could be made about overall speeds and speed change.

Speed measurements were recorded, under three test conditions, using laser radar or K-band radar. The first scenario, used for a baseline, was speeds of drivers approaching the test sites when no pedestrians were present near the intersection. During the second and third test conditions, one team member staged an actual roadway crossing. During these staged conditions, no other pedestrians were present. The same team member always performed as the staged pedestrian in the before and after conditions. The researcher always wore neutral colored casual clothing. A middle-aged man of average height and weight was the staged pedestrian in Sacramento, Richmond, and Stillwater. A middle-aged woman of average height and weight was the staged pedestrian in Buffalo. Time of day and day of week were controlled between the before and after periods.

The second test scenario consisted of the staged pedestrian standing in the crosswalk and looking in the direction of the oncoming traffic. The staged pedestrian was in full view of traffic but not in a travel lane.

For the third test scenario, the staged pedestrian stood in the crosswalk and took one step out into the travel lane as if he were about to cross the street. The stepping movement was timed to the presence of oncoming traffic so that drivers that chose to slow down had the time and distance to do so. Targeted vehicles were randomly selected and were always lone vehicles or the first vehicle in a platoon. Vehicle speeds were recorded when the staged pedestrian was looking or stepping from both sides of the roadway.

The speed study for the two Stillwater, Minnesota, sites was limited to recording vehicle speeds at the actual crosswalk before and after the high-visibility crosswalk markings were installed. This was necessary because parking restrictions made it difficult to collect advance speeds.

Pedestrian Profile Study

One of the objectives of the Pedestrian Profile study was to determine if pedestrians would go out of their way (and how far) in order to use a marked crosswalk at a nonsignalized intersection. Another objective was to identify and record safety measures pedestrians exhibited before and during roadway crossings.

It became clear during pilot testing that frequency of looking behavior was of interest only if traffic was approaching. For example, if no vehicles were within sight in either direction (where there were no visual obstructions to oncoming or turning vehicles and sight distance was several blocks long), the pedestrian who looked 10 times during the crossing of 2 to 3 lanes was no more safe than a pedestrian who looked once in each direction.

This study incorporated the element of approaching traffic, once again, to give a better understanding of the observed pedestrian's gait and travel path before and during the roadway crossing. By tracking particular pedestrians from the location where they entered the study zone, origin and destination information could be recorded. Descriptive information such as age and gender were gathered for each pedestrian observed. Crossing behavior was observed to find out how often the pedestrians checked traffic (looking behavior) and the general speed (in three categories) of their gait. The exact location of the actual roadway crossing was tracked, using established site zones, in order to determine if marked crosswalks not only attracted but also channeled pedestrian crossings.

Observations were repeated during the first half of the crossing and during the second half of crossing. For each pedestrian crossing, observations were also made about the presence of traffic during the entire crossing. One team member recorded on audio tape all pedestrian data items; the other team member simultaneously recorded on data forms vehicle proximity by lane. The following information was observed and recorded for each targeted pedestrian in a before and after study at the unmarked and marked crosswalk sites:

- Pedestrian Age
- Pedestrian Gender
- Pedestrian Travel Path
- Pedestrian Gait, Before Crossing and During Each Lane
- Pedestrian Looking Behavior, At Curb and During Entire Crossing Recorded by Lane of Occurrence
- Vehicle Proximity By Lane While Pedestrian is At Curb, and Crossing Each Lane
- Presence/Absence of Parked Vehicles
- Unusual Driver Behaviors (honking, gesturing, etc.).

RESULTS AND DISCUSSION

The results of the various data collection procedures will be presented in this section. The section has been organized by the various measures of effectiveness (MOEs) that were collected. Thus, the discussion deviates somewhat from the order in which the experimental procedures were described in the previous section.

The following MOEs will be discussed:

- Vehicle Volumes
- Available Gaps in Traffic
- Vehicle Speeds
- Driver and Pedestrian Behavior
- Pedestrian Profile—Looking Behavior

Vehicle Volumes

The purpose of the vehicle volume study was to document if any changes occurred between the before and after periods. Any such changes could have made it difficult to attribute other changes in pedestrian and vehicle behavior solely to the installation of the crosswalk markings.

The vehicle volume data for the street being crossed are shown in Table 1. The vehicle volume data for the cross streets are shown in Table 2. A three-way analysis of variance (period, city, and site within city) for each of the six vehicle volume counts (thru street left turn, thru street right turn, thru street straight, cross street left turn, cross street right turn, and cross street straight) was calculated. There were the expected statistically significant city differences and site differences in all of the analyses. The only statistically significant effect for period was an interaction between period and city. The straight thru vehicle volumes on the cross streets increased in the after period in Sacramento but stayed approximately the same in the other locations, period, $\underline{F}$ (3,366 = 4.961, p = 0.002). As shown in Table 2, the straight cross street traffic volumes increased from 50 vehicles per hour to 70 vehicles per hour. It is not believed that this increase, although statistically significant, was sufficient to affect other behavioral changes that were observed. All other vehicle volume counts remained essentially the same between the before and after periods.

Table 1. Vehicle Volumes on Thru Street Before and After the Installation of Crosswalk Markings.

City/ Site	Period	VEHICLES PER HOUR - THRU STREET								
		Left			Right			Straight		
		N*	Mean*	SD*	N	Mean	SD	N	Mean	SD
Sacramento 1	Before	4	48.00	35.33	N/A			4	343.50	155.64
	After	3	66.00	15.87				3	470.00	121.39
	Î		+18.00						+126.50	
Sacramento 2	Before	4	18.00	10.95	4	24.00	18.97	4	82.50	34.07
	After	5	27.60	9.10	5	25.20	14.32	5	72.00	16.97
	Î		+9.60			+1.20			-10.50	
Sacramento 3	Before	5	13.20	10.73	5	9.60	10.90	5	271.20	170.89
	After	9	12.00	9.49	9	11.33	8.72	9	308.00	135.20
	Î		-1.20			+1.73			+36.80	
All Sacramento	Before	13	25.38	25.12	9	16.00	15.87	13	235.38	168.23
	After	17	26.12	22.54	14	16.29	12.55	17	267.18	177.79
	Î		+0.74			+0.29			+31.80	
Buffalo 1	Before	27	23.78	19.86	27	18.67	10.95	27	198.44	53.77
	After	12	16.00	9.69	12	8.50	5.40	12	166.00	48.29
	Î		-7.78			-10.17			-32.44	
Buffalo 2	Before	19	16.42	12.94	19	14.53	10.83	19	210.95	50.96
	After	15	14.40	11.06	15	14.00	11.49	15	196.40	50.22
	Î		-2.02			-0.53			-14.55	
Buffalo 3	Before	26	6.23	5.49	26	9.92	7.39	26	72.92	26.92
	After	17	3.88	4.21	17	7.76	9.43	17	69.88	21.42
	Î		-2.35			-2.16			-3.04	
All Buffalo	Before	72	15.50	15.98	72	14.42	10.35	72	156.42	77.41
	After	44	10.77	10.07	44	10.09	9.58	44	139.23	69.50
	Î		-4.73			-4.33			-17.19	
Richmond 1	Before	10	6.00	7.48	10	2.40	3.10	10	813.00	255.66
	After	16	5.25	7.86	16	6.75	6.15	16	787.13	262.30
	Î		-0.75			+4.35			-25.87	
Richmond 2	Before	16	12.75	9.26	16	8.25	8.45	16	780.38	207.91
	After	14	12.00	7.81	14	13.29	9.75	14	867.86	236.82
	Î		-0.75			+5.04			+87.48	
Richmond 3	Before	14	24.00	20.52	14	6.43	6.85	14	818.14	209.39
	After	10	16.80	12.90	10	7.80	2.90	10	858.00	157.00
	Î		-7.20			+1.37			+39.86	
All Richmond	Before	40	15.00	15.43	40	6.15	7.12	40	801.75	215.96
	After	40	10.50	10.24	40	9.30	7.56	40	833.10	228.70
	Î		-4.50			+3.15			+31.35	
Stillwater 1	Before	27	10.22	8.12	27	8.89	6.08	27	84.22	19.93
	After	46	9.65	10.84	46	12.91	11.31	46	97.57	28.18
	Î		-0.57			+4.02			+13.35	
Stillwater 2	Before	35	7.37	7.29	35	19.37	13.26	35	88.46	34.08
	After	59	5.90	6.05	59	19.42	11.65	59	88.07	31.50
	Î		-1.47			+0.05			-0.39	
All Stillwater	Before	62	8.61	7.73	62	14.81	11.89	62	86.61	28.65
	After	105	7.54	8.65	105	16.57	11.90	105	92.23	30.32
	Î		-1.07			+1.76			+5.62	
All Sites	Before	187	13.80	15.08	183	12.82	11.12	187	276.80	302.01
	After	206	10.34	11.98	203	13.71	11.18	206	260.56	309.09
			-3.46			+0.89			-16.24	

* N = number of 10-minute data collection periods
Mean = average vehicles per hour
SD = standard deviation

Table 2. Vehicle Volumes on Cross Street Before and After the Installation of Crosswalk Markings.

City/ Site	Period	VEHICLES PER HOUR - CROSS STREET								
		Left			Right			Straight		
		N*	Mean*	SD*	N	Mean	SD	N	Mean	SD
Sacramento 1	Before	4	78.00	52.54						
	After	3	92.00	9.17						
	Î		+14.00							
Sacramento 2	Before	4	12.00	12.00	4	22.50	10.25	4	28.50	5.74
	After	5	18.00	14.70	5	19.20	14.32	5	40.80	16.65
	Î		+6.00			-3.30			+12.30	
Sacramento 3	Before				5	24.00	9.46	5	67.20	29.82
	After				9	19.33	7.21	9	86.00	19.67
	Î					-4.67			+18.80	
All Sacramento	Before	8	45.00	49.89	9	23.33	9.22	9	50.00	29.55
	After	8	45.75	40.18	14	19.29	9.75	14	69.86	28.79
	Î		+0.75			-4.04			+19.86	
Buffalo 1	Before	27	10.22	9.24	27	16.22	11.39	27	7.56	6.14
	After	12	12.00	8.49	12	20.50	12.91	12	4.50	5.20
	Î		+1.78			+4.28			-3.06	
Buffalo 2	Before	19	10.42	7.96	19	19.89	11.67	19	8.53	7.02
	After	15	6.40	4.79	15	20.00	8.38	15	6.80	8.44
	Î		-4.02			+0.11			-1.73	
Buffalo 3	Before	26	6.92	6.93	26	8.77	8.69	26	16.38	11.95
	After	17	6.71	6.67	17	9.18	6.75	17	16.94	8.55
	Î		-0.21			+0.41			+0.56	
All Buffalo	Before	72	9.08	8.18	72	14.50	11.38	72	11.00	9.66
	After	44	8.05	6.96	44	15.95	10.59	44	10.09	9.40
	Î		-1.03			+1.45			-0.91	
Richmond 1	Before	10	22.20	12.98	10	9.60	7.59	10	12.60	8.22
	After	16	20.25	13.48	16	13.88	8.41	16	16.13	14.15
	Î		-1.95			+4.28			+3.53	
Richmond 2	Before	16	21.38	8.19	16	12.00	8.20	16	14.25	8.73
	After	14	22.71	9.75	14	14.14	9.59	14	14.57	9.03
	Î		+1.33			+2.14			+0.32	
Richmond 3	Before	14	13.29	9.47	14	23.14	11.49	14	17.57	12.77
	After	10	16.20	10.22	10	25.80	13.87	10	11.40	9.98
	Î		+2.91			+2.66			-6.17	
All Richmond	Before	40	18.75	10.54	40	15.30	10.87	40	15.00	10.17
	After	40	20.10	11.49	40	16.95	11.36	40	14.40	11.43
	Î		+1.35			+1.65			-0.60	
Stillwater 1	Before	27	8.89	7.13	27	8.67	6.52	27	1.78	4.34
	After	46	10.17	7.25	46	9.13	7.13	46	3.39	4.32
	Î		+1.28			+0.46			+1.61	
Stillwater 2	Before	35	9.43	8.27	35	4.97	6.59	35	11.31	9.95
	After	59	9.36	8.93	59	5.39	6.27	59	9.25	7.75
	Î		-0.07			+0.42			-2.06	
All Stillwater	Before	62	9.19	7.74	62	6.58	6.76	62	7.16	9.27
	After	105	9.71	8.21	105	7.03	6.88	105	6.69	7.08
	Î		+0.52			+0.45			-0.47	
All Sites	Before	182	12.82	15.17	183	12.43	10.77	183	12.49	14.40
	After	197	12.91	13.99	203	11.76	10.20	203	13.30	19.24
			+0.09			-0.67			+0.81	

* N = number of 10-minute data collection periods
Mean = average vehicles per hour
SD = standard deviation

With vehicle volumes of about 800 vehicles per hour, the three Richmond sites were, by far, the busiest roadways in the study. These high traffic volumes reduced the available pedestrian crossing opportunities.

Available Gaps in Traffic

The purpose of the traffic gaps study (like the vehicle volume study) was to document if any changes in traffic flow between the before and after periods could have been responsible for any of the other changes in either pedestrian or vehicle behavior that were observed in the other studies. It was hypothesized that there would be no changes in available gaps between the before and after periods. It this were the case, then we could more confidently conclude that observed changes in pedestrian behavior were due to the installation of crosswalk markings and <u>not</u> due to changes in available gaps for crossing.

The available gaps in traffic before and after the installation of crosswalk markings are shown in Table 3.

The percentage of gaps adequate for a safe pedestrian crossing before and after crosswalk markings were analyzed using chi-squares. A 2X2 contingency table of period (before, after) by gap (adequate, inadequate) was completed for each site, each city, and overall. Differences in each table were tested for significance using $\div^2$ corrected for continuity.

At the 11 sites where gap data were collected, 8 showed a nonsignificant $\div^2$ while 3 showed a significant $\div^2$. All three of the significant changes were due to increases in available gap.   Seven of the eight nonsignificant differences involved reductions in available gap. Overall, across all sites, there was a significant (3.3 percent) increase in the percentage of gaps adequate for safe crossing at a 3.5 ft/s walking speed. Although statistically significant, this change is not believed to be large enough to have affected any of the changes observed in pedestrian behavior. With the exception of the sites in Richmond, all of the study locations had relatively high percentages of adequate gaps. At all three of the Richmond sites, less than 10 percent of the available gaps were adequate for a safe crossing at 3.5 ft/s. As was shown in Table 1, the Richmond sites also had much higher vehicle volumes. It is not known what effect the high traffic volumes and low percentage of adequate gaps may have had on other driver and pedestrian behavior observed in Richmond (i.e., approach and crosswalk speeds).

Table 3. Available Gaps in Traffic Before and After the Installation of Crosswalk Markings.

City/ Site	Period	Total Number of Gaps Measured	Percentage of Gaps Adequate for Safe Crossing at 3.5 ft/s Walking Speed	Signif (?)
Sacramento 1	Before After	202 241	25.2 9.9 -5.3	NS
Sacramento 2	Before After	81 71	65.4 64.8 -0.6	NS
Sacramento 3	Before After	203 474	33.0 25.9 -7.1	NS
All Sacramento	Before After	486 786	35.2 27.6 -7.6	0.005
Buffalo 1	Before After	1109 404	46.1 53.2 +7.1	0.016
Buffalo 2	Before After	746 601	46.1 42.8 -3.3	NS
Buffalo 3	Before After	448 240	59.8 69.2 +9.4	0.019
All Buffalo	Before After	2303 1245	48.8 51.2 +2.4	NS
Richmond 1	Before After	1264 2012	9.5 9.1 -0.4	NS
Richmond 2	Before After	2196 1834	8.0 8.1 +0.1	NS
Richmond 3	Before After	1965 1328	6.4 8.5 +2.1	0.023
All Richmond	Before After	5425 5174	7.8 8.6 +0.8	NS
Stillwater 1	Before After	512 1040	66.4 62.6 -3.8	NS
Stillwater 2	Before After	653 1249	70.0 72.7 +2.7	NS
All Stillwater	Before After	1165 2289	68.4 68.1 -0.3	NS
All Sites	Before After	9378 9494	26.8 30.1 +3.3	0.000

Vehicle Speeds/Staged Pedestrian Study

The vehicle speed and staged pedestrian study involved a comparison of vehicle speeds before and after crosswalk markings were installed. The purpose of the study was to determine if crosswalk markings had an effect on vehicle speeds. Vehicle speeds were measured at two different locations under each of three separate stated pedestrian conditions. Vehicle speeds were measured as the vehicle approached the crosswalk (approach speed) and when the vehicle arrived at the crosswalk (crosswalk speed). The three separate pedestrian conditions included: (1) no pedestrian present (no ped); (2) a staged pedestrian standing in the crosswalk looking in the direction of oncoming traffic (ped looks); and (3) a staged pedestrian in the crosswalk making a stepping motion as if he/she were about to step into the roadway (ped steps).

Vehicle approach speeds for the three staged pedestrian conditions are shown in Table 4. A three-way analysis of variance (period, city, site within city) of vehicle approach speed was calculated for each of the three staged pedestrian conditions (no ped, ped looks, and ped steps). For the no ped condition, there was no significant difference between the before (no crosswalk markings) and the after (crosswalk markings installed) conditions. There were, not surprisingly, significant differences between cities, F (2,916) = 95.119, p = 0.000 and between sites, F (4,916) = 13.156, p = 0.000.

For the ped looks staged condition, there were significant differences between the before and after periods, F (1,928) = 8.163, p = 0.004. The approach speeds were significantly lower in the after (markings installed) period. There were also statistically significant differences between cities, F (2,928) = 94.720, p = 0.000, and between sites, F (4,928) = 7.366, p = 0.000.

The ped steps condition also produced statistically significant differences between cities, F (2,894) = 118.059, p = 0.000 and between sites, F (4,894) = 17.528, p = 0.000. In addition, the ped steps condition resulted in a statistically significant period by city interaction, F (2,894) = 4.117, p = 0.017. The approach speeds in both Sacramento and Buffalo decreased significantly while the approach speeds in Richmond increased significantly between the before and after periods.

The analysis of vehicle approach speeds shows that there were differences between the various study areas (cities) and study locations (sites) within the study areas. This is not unexpected since travel speeds tend to vary by location and no attempt was made to match the experimental sites by travel speed. There was also no difference in approach speed when no pedestrian was present. This was also expected since there is no need for a driver to slow down when approaching a crosswalk unless a pedestrian is present. It is also important to remember that the absolute amount of the speed reduction is not critical. The purpose of the crosswalk marking is to produce a change in driver awareness. The markings should be telling the driver that pedestrians may be present and if they are present, they may cross the road at that location. Basically, the

Table 4. Vehicle Approach Speeds Before and After the Installation of of Crosswalk Markings.

City/ Site	Period	VEHICLE APPROACH SPEEDS (km/h)								
		No Ped			Ped Looks			Ped Steps		
		N*	Mean*	SD*	N	Mean	SD	N	Mean	SD
Sacramento 1	Before	14	25.71	3.05	15	28.20	4.26	17	24.94	3.73
	After	19	25.89	3.63	17	26.12	4.68	16	25.31	4.64
	Î		+0.18			-2.08			+0.37	
Sacramento 3	Before	30	31.67	4.92	20	32.80	4.31	24	33.50	3.91
	After	31	31.84	2.88	24	30.79	5.30	22	31.41	4.71
	Î		+0.17			-2.01			-2.09	
All Sacramento	Before	44	29.77	5.20	35	30.83	4.82	41	29.95	5.71
	After	50	29.58	4.29	41	28.85	5.51	38	28.84	5.53
	Î		-0.19			-1.98			-1.11	
Buffalo 1	Before	80	28.84	4.44	96	28.45	4.68	96	27.85	4.16
	After	128	27.86	4.18	128	27.89	4.10	128	27.22	4.27
	Î		-0.98			-0.56			-0.63	
Buffalo 2	Before	112	27.47	4.44	120	27.75	4.13	113	26.96	4.26
	After	122	28.25	4.23	128	27.61	3.91	128	26.56	3.60
	Î		+0.78			-0.14			-0.40	
Buffalo 3	Before	60	26.42	4.53	59	28.03	4.09	52	27.85	4.24
	After	78	27.15	3.48	79	26.27	3.26	80	25.85	3.15
	Î		+0.73			-1.76			-2.00	
All Buffalo	Before	252	27.65	4.53	275	28.05	4.32	261	27.46	4.23
	After	328	27.84	4.05	335	27.40	3.89	336	26.64	3.80
	Î		+0.19			-0.65			-0.82	
Richmond 1	Before	64	32.64	4.49	64	32.33	4.02	64	32.39	3.76
	After	64	32.63	4.92	64	32.19	3.67	56	33.11	5.38
	Î		-0.01			-0.14			+0.72	
Richmond 2	Before	64	32.00	4.83	64	31.95	4.70	48	30.92	4.45
	After	64	31.56	4.76	64	31.38	4.22	64	31.91	4.55
	Î		-0.44			-0.57			+0.99	
All Richmond	Before	128	32.32	4.65	128	32.14	4.36	112	31.76	4.11
	After	128	32.09	4.85	128	31.78	3.96	120	32.47	4.97
	Î		-0.23			-0.36			+0.71	
All Sites	Before	424	29.28	5.08	438	29.47	4.74	414	28.87	4.75
	After	506	29.09	4.66	504	28.63	4.47	494	28.23	4.92
	Î		-0.19			-0.84			-0.64	

* N = number of 10-minute data collection periods
Mean = mean or average vehicle approach speed
SD = standard deviation

desired driver response is to a marked crosswalk is: “There may be a pedestrian here; I need to be careful” or “If I see pedestrian here, they may cross; I need to be careful.” It is not essential that the driver slow down. Unfortunately, there is no way to observe or measure driver awareness, so vehicle speed is used as a kind of surrogate measure.

An examination of the approach speed before/after differences in the no ped condition in Table 4 shows very small differences, less than 1 mi/h (1.6 km/h) at all sites. In the ped looks condition it could be hypothesized that the presence of crosswalk markings would cause approaching drivers to be more careful (e.g., slow down). In fact, speed reductions were found at all locations. The magnitude of the speed reductions varied from 2.08 mi/h (3.33 km/h) at Site 1 in Sacramento to 0.14 mi/h (0.22 km/h) at Site 2 in Buffalo and Site 1 in Richmond. The overall speed reduction across all sites was 0.84 mi/h (1.34 km/h). In the ped steps condition we could also hypothesize that the presence of crosswalk markings would also cause approaching drivers to slow down. This was the case in both Sacramento and Buffalo. The speed reductions ranged from 2.09 mi/h (3.34 km/h) at Site 3 in Sacramento to 0.37 mi/h (0.59 km/h) at Site 1 in Sacramento. However, the approach speeds increased at both of the Richmond sites. Overall, across all sites in all three cities there was a decrease in approach speed of 0.64 mi/h (1.02 km/h). In general, it appears that crosswalk markings have a beneficial effect on the speeds of drivers approaching a pedestrian in a crosswalk.

Vehicle speeds in the crosswalk for the three staged pedestrian conditions are shown in Table 5.

A three-way analysis of variance (period, city, site within city) of crosswalk speed was planned for each of the three conditions (no ped, ped looks, ped steps). One of the assumptions of this statistical test is homogeneity of variance, especially important when the number of observations in each group varies greatly. This assumption was checked using Levene’s Test, and in each condition this assumption was not met. Since the number of observations per site within each city was similar, each city was analyzed separately. Therefore, a two-way analysis of variance (period, site) was performed for each city for each condition.

For the no ped condition, the crosswalk vehicle speeds showed the same patterns as the approach speed. In Sacramento there were statistically significant differences between sites $F(1,90) = 21.552$, $p = 0.000$. In Buffalo there were statistically significant differences between sites $F(2, 574) = 5.208$, $p = 0.006$. In Richmond there were no significant differences. In Stillwater there was a statistically significant difference between sites, $F(1, 3464) = 685.933$, $p = 0.000$ as well as a period by site interaction, $F(1, 3464) = 10.855$, $p = 0.001$. This interaction resulted from an increase in speed at Site 2 and a decrease in speed at Site 1. Overall, we would not expect that crosswalk markings, in the absence of a pedestrian, would produce a change in vehicle speeds, and only one was found.

Table 5. Vehicle Speeds in Crosswalk Before and After the Installation of Crosswalk Markings.

City/ Site	Period	VEHICLE CROSSWALK SPEEDS (km/h)								
		No Ped			Ped Looks			Ped Steps		
		N*	Mean*	SD*	N	Mean	SD	N	Mean	SD
Sacramento 1	Before	14	26.14	4.69	15	27.07	8.45	17	22.76	9.02
	After	19	26.63	3.90	17	20.29	14.00	16	15.44	14.31
	Î		+0.49			-6.78			-7.32	
Sacramento 3	Before	30	31.13	5.12	20	30.35	8.13	24	31.67	8.09
	After	31	30.10	2.91	24	26.50	11.41	22	29.41	8.09
	Î		-1.03			-3.85			-2.26	
All Sacramento	Before	44	29.55	5.46	35	28.94	8.31	41	27.98	9.48
	After	50	28.78	3.70	41	23.93	12.76	38	23.53	13.00
	Î		-0.77			-5.01			-4.45	
Buffalo 1	Before	80	28.39	4.65	96	28.23	4.61	96	27.32	3.98
	After	128	28.00	3.86	128	27.73	4.90	128	26.24	5.95
	Î		-0.39			-0.50			-1.08	
Buffalo 2	Before	112	27.79	5.98	120	27.53	4.49	113	26.20	5.48
	After	122	28.25	4.87	128	27.49	4.62	128	26.50	4.35
	Î		+0.46			-0.04			+0.30	
Buffalo 3	Before	60	27.18	5.75	59	27.90	6.12	52	27.81	6.34
	After	78	25.49	8.43	79	25.80	5.55	80	24.34	7.95
	Î		-1.69			-2.10			-3.47	
All Buffalo	Before	252	27.84	5.53	275	27.85	4.91	261	26.93	5.20
	After	328	27.49	5.71	335	27.18	5.00	336	25.89	6.02
	Î		-0.35			-0.67			-1.04	
Richmond 1	Before	64	32.11	4.42	64	31.86	3.77	64	31.69	3.56
	After	64	31.80	4.74	64	31.27	3.90	56	32.11	5.14
	Î		-0.31			-0.59			+0.42	
Richmond 2	Before	64	32.05	4.73	64	32.08	4.54	48	30.19	4.11
	After	64	31.33	4.47	64	30.84	4.28	64	31.25	4.64
	Î		-0.72			-1.24			+1.06	
All Richmond	Before	128	32.08	4.56	128	31.97	4.16	112	31.04	3.86
	After	128	31.56	4.59	128	31.05	4.08	120	31.65	4.88
	Î		-0.52			-0.92			+0.61	
Stillwater 1	Before	439	26.75	4.87						
	After	1079	26.20	4.99						
	Î		-0.55							
Stillwater 2	Before	624	22.20	3.53						
	After	1326	22.67	3.29						
	Î		+0.47							
All Stillwater	Before	1063	24.08	4.70						
	After	2405	24.25	4.50						
	Î		+0.17							
All Sites	Before	1487	25.57	5.49	438	29.14	5.38	414	28.15	5.74
	After	2911	25.02	4.98	504	27.90	6.16	494	27.11	7.08
	Î		-0.55			-1.24			-1.04	

N = number of 10-minute data collection periods
Mean = mean or average vehicle speed in the crosswalk
SD = standard deviation

For the ped looks condition, it was hypothesized that crosswalk markings would result in a speed reduction, and that was the case in two of the three study cities. In Sacramento there was a significant difference between periods, F (1,72) = 4.464, p = 0.038. In Buffalo there was also a significant difference between periods, F (1,604) = 4.453, p = 0.035. In both cases speeds were slower during the after period. In Richmond speeds were also lower, but the difference was not statistically significant.

For the ped steps condition, it was hypothesized that the crosswalk markings would result in a speed reduction in response to the staged pedestrian stepping into the roadway. This was not usually the case. In Sacramento there was a statistically significant difference between sites, F (1,75) = 25.945, p = 0.000. In Buffalo there was a statistically significant difference between periods, F (1,591) = 8.534, p = 0.004 and a period by site interaction, F (2,591) = 4.608, p = 0.010. The interaction was due to decreased speeds at Sites 1 and 3 and increased speeds at Site 2. In Richmond there was a statistically significant difference between sites, F (1,228) = 4.114, p = 0.044. Overall, speeds decreased at four of the sites and increased at three of the sites, but only Buffalo had a significant period effect.

Driver and Pedestrian Behavior

The purpose of the driver and pedestrian behavior study was to document changes in specific driver and pedestrian behaviors that could be attributed to the installation of crosswalk markings at the study sites. The specific driver and pedestrian behaviors observed were: (1) drivers yielding to pedestrians; (2) drivers not yielding to pedestrians; (3) pedestrian exhibiting aggressive behavior (behavior that caused the driver to slow or stop); and (4) number of pedestrians crossing in the crosswalk (pedestrians per hour). The results of the study are shown in Table 6.

A three-way analysis of variance (period, city, site within city) was calculated for each of the four specific behaviors observed. There were statistically significant city differences in two of the analyses and site differences in two of the analyses. There were no statistically significant differences between the before and after periods in any of the four behaviors observed. There were also no significant interactions, indicating that period, city and site within city did not affect the behaviors observed. Apparently, crosswalk markings do not have any effect on the yielding behavior of drivers, the blatant aggressive behavior of pedestrians, or the total number of pedestrians crossing.

Additional data were collected on the crossing location of pedestrians who were either alone or in a group. The percentage of the pedestrians, either alone or in a group, who were crossing in the crosswalk is shown in Table 7.

Table 6. Driver and Pedestrian Behavior Before and After the Installation of Crosswalk Markings.

City/ Site	Period	Drivers, per Hour, Yielding to Ped in Crosswalk			Drivers, per Hour, NOT Yielding to Ped in Crosswalk			Pedestrians, per Hour, Exhibiting Blatant Aggressive Behavior			Pedestrians, per Hour, Crossing in Crosswalk		
		N*	**Mean***	**SD***	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Sacramento 1	Before	6	7.00	11.01	6	4.00	7.27	6	0.00	0.00	6	67.00	85.06
	After	4	10.50	13.30	4	4.50	3.00	4	0.00	0.00	4	81.00	77.85
	Î		+3.50			+0.50			0.00			+14.00	
Sacramento 2	Before	16	1.13	2.42	16	0.75	2.05	16	0.00	0.00	16	21.38	22.45
	After	22	1.36	2.57	22	0.82	2.11	22	0.00	0.00	22	23.45	21.90
	Î		+0.23			+0.07			0.00			+2.07	
Sacramento 3	Before	20	0.00	0.00	20	1.50	3.83	20	0.00	0.00	20	14.70	10.92
	After	20	0.60	1.85	20	1.20	4.18	20	0.00	0.00	20	23.40	17.18
	Î		+0.60			-0.30			0.00			+8.70	
All Sacramento	Before	42	1.43	4.74	42	1.57	3.99	42	0.00	0.00	42	24.71	37.91
	After	46	1.83	4.88	46	1.30	3.33	46	0.00	0.00	46	28.43	31.96
	Î		+0.40			-0.27			0.00			+3.72	
Buffalo 1	Before	4	3.00	3.46	4	4.50	5.74	4	1.50	3.00	4	22.50	5.74
	After	4	1.50	3.00	4	1.50	3.00	4	1.50	3.00	4	10.50	13.30
	Î		-1.50			-3.00			0.00			-12.00	
Buffalo 2	Before	7	0.86	2.27	7	6.00	8.49	7	0.86	2.27	7	12.86	5.40
	After	10	1.20	2.53	10	2.40	4.20	10	1.80	2.90	10	5.40	7.18
	Î		+0.34			-3.60			+0.94			-7.46	
Buffalo 3	Before	5	1.20	2.68	5	3.60	5.37	5	2.40	3.29	5	10.80	2.68
	After	5	2.40	3.29	5	0.00	0.00	5	0.00	0.00	5	15.60	25.31
	Î		+1.20			-3.60			-2.40			+4.80	
All Buffalo	Before	16	1.50	2.68	16	4.88	6.65	16	1.50	2.68	16	14.63	6.56
	After	19	1.58	2.71	19	1.58	3.37	19	1.26	2.51	19	9.16	14.75
	Î		+0.08			-3.30			-0.24			-5.47	
All Sites	Before	58	1.45	4.25	58	2.48	5.03	58	0.41	1.53	58	21.93	32.64
	After	65	1.75	4.34	65	1.38	3.32	65	0.37	1.45	65	22.80	29.28
	Î		+0.30			-1.10			-0.04			+0.87	

* N = number of 10-minute data collection periods
Mean = mean or average number of specific behaviors observed per hour
SD = standard deviation

Table 7. Pedestrian Crossing Location—Peds in Crosswalk
Before and After the Installation of Crosswalk Markings.

City/ Site	Period	PERCENTAGE OF PEDESTRIANS – IN CROSSWALK								
		Alone			In Groups			Total		
		N*	Mean*	SD*	N	Mean	SD	N	Mean	SD
Sacramento 1	Before	4	49.68	18.35	4	72.93	14.64	4	64.25	16.68
	After	4	65.73	15.16	4	80.30	15.51	4	74.93	8.00
	Î		+16.05			+7.37			+10.68	
Sacramento 2	Before	4	37.03	6.47	4	51.48	20.85	4	41.33	6.66
	After	6	42.92	12.64	6	60.03	22.36	6	49.32	10.73
	Î		+5.89			+8.55			+7.99	
Sacramento 3	Before	6	44.02	17.68	4	62.50	47.87	6	47.20	19.88
	After	7	45.60	18.60	6	63.48	36.11	7	50.91	22.12
	Î		+1.58			+0.98			+3.71	
All Sacramento	Before	14	43.64	15.24	12	62.30	29.76	14	50.39	17.76
	After	17	49.39	17.65	16	66.39	26.85	17	56.00	18.68
	Î		+5.75			+4.09			+5.61	
Buffalo 1	Before	19	57.34	38.35	12	80.80	32.08	19	62.03	36.81
	After	18	54.63	41.93	15	100.00	0.00	20	76.84	27.30
	Î		-2.71			+19.20			+14.81	
Buffalo 2	Before	21	59.18	27.19	15	60.80	38.32	21	60.88	23.91
	After	21	70.64	23.58	22	97.73	10.66	24	84.06	17.37
	Î		+11.46			+36.93			+23.18	
Buffalo 3	Before	18	78.33	30.11	13	92.31	27.74	19	86.81	19.90
	After	13	91.02	22.18	13	81.54	37.83	19	83.33	30.94
	Î		+12.69			-10.77			-3.48	
All Buffalo	Before	58	64.52	32.89	40	77.04	35.18	59	69.60	29.73
	After	52	70.19	33.41	50	94.20	21.39	63	81.55	25.08
	Î		+5.67			+17.16			+11.95	
Richmond 1	Before	17	11.85	22.14	9	28.38	42.71	17	13.81	18.92
	After	20	20.42	27.38	4	25.00	50.00	21	20.08	28.34
	Î		+8.57			-3.38			+6.27	
Richmond 2	Before	27	19.42	25.40	11	41.82	44.00	28	21.76	26.49
	After	27	26.64	27.59	9	27.11	33.31	27	31.00	27.69
	Î		+7.22			-14.71			+9.24	
Richmond 3	Before	44	31.71	28.61	25	35.57	41.63	44	32.23	26.88
	After	46	48.76	29.61	17	44.51	45.17	47	46.79	29.91
	Î		+17.05			+8.94			+14.56	
All Richmond	Before	88	24.11	27.44	45	35.66	41.68	89	25.42	26.21
	After	93	36.24	30.96	30	36.69	42.11	95	36.40	30.70
	Î		+12.13			+1.03			+10.98	
Stillwater 1	Before	26	14.25	23.42	7	6.13	16.22	26	14.69	23.74
	After	45	14.61	21.68	12	24.31	34.36	45	13.93	21.63
	Î		+0.36			+18.18			-0.76	
Stillwater 2	Before	33	48.67	25.43	18	49.12	43.18	33	50.70	25.73
	After	59	50.22	19.74	37	56.58	45.36	59	51.92	17.70
	Î		+1.55			+7.46			+1.22	
All Stillwater	Before	59	33.50	29.84	25	37.08	42.13	59	34.83	30.55
	After	104	34.81	27.10	49	48.68	44.83	104	35.48	27.10
	Î		+1.31			+11.60			+0.65	
All Sites	Before	219	38.59	33.26	122	52.14	42.73	221	41.31	33.25
	After	266	43.16	32.28	145	63.85	42.55	279	47.45	33.38
	Î		+4.57			+11.71			+6.14	

* N = number of 10-minute data collection periods
Mean = mean or average percentage of peds observed in crosswalk
SD = standard deviation

A three-way analysis of variance (period, city, site within city) of the percentage of pedestrians crossing in the crosswalk was performed for three different categories of pedestrians: pedestrians alone, pedestrians in groups, and total pedestrians. Preliminary checks on the data indicated that the assumption of homogeneity of variance was not met. Analysis of variance is relatively robust with respect to departures from homogeneity of variance; however, when the number of observations in each cell varies greatly, there is possibility of bias in the results. Since the number of observations per site within each city were similar, each city was analyzed separately. The final analysis was a two-way analysis of variance (period, site) for each city for each category of pedestrians (i.e., single pedestrians, pedestrians in groups and all pedestrians combined).

The data showing the percentage of either single pedestrians or pedestrians in groups that completed all or part of their crossing within the unmarked (before) or marked (after) crosswalk is shown in Table 7. The same size crosswalk was used in both the before and after observations.

Single Pedestrians

Although there was an increase in crosswalk usage at all three Sacramento sites, there were no statistically significant differences. One of the three Buffalo sites showed a small (2.7 percent) decrease in crosswalk usage while the other two Buffalo sites had 11.46 percent and 12.69 percent increases. Although there was a statistically significant difference between sites, F (2,104) = 7.075, p = 0.001, the before/after differences were not statistically significant.

All three Richmond sites showed before/after increases in crosswalk usage by single pedestrians. They ranged from a 7.22 percent to a 17.05 percent increase in the number of pedestrians crossing alone in the crosswalk. In Richmond there was a statistically significant difference between sites, F (2,175) = 12.545, p = 0.001 and a statistically significant difference between periods, F (1,175) = 6.227, p = 0.014. The percentage of single pedestrians who were in the crosswalk increased after the crosswalks were marked. In Stillwater the only significant difference was between sites, F (1,159) = 93.007, p = 0.000.

Pedestrians Crossing in Groups

The data for pedestrians observed who were with at least one other pedestrian are also shown in Table 7. There were no significant differences in Sacramento or Richmond. Buffalo had a statistically significant period by site interaction, F (2,84 = 5.940, p = 0.004. At Sites 1 and 2 the percentages of pedestrians in groups who were in the crosswalk increased from the before to after periods, while at Site 3 the percentage decreased. Stillwater had only a significant difference between sites, F (1,70) = 10.672, p = 0.002. It appears that the marking of crosswalks has less effect on the crossing location of pedestrians traveling in groups.

All Pedestrians

The data for all pedestrians (single pedestrian plus those in groups) are shown in Table 7. Although all three Sacramento sites had an increase in crosswalk usage, the only statistically significant difference was between sites, F (2,25) = 5.578, p = 0.010. Buffalo also had a significant difference between sites F (2,116) = 3.801, p = 0.025 but more interestingly had a statistically significant difference between periods, F (1,116) = 5.720, p = 0.018. The percentage of total pedestrians in the crosswalk increased from before to after. Richmond had effects comparable to those found in Buffalo. There was a statistically significant difference between sites, F (2,178) = 10.166, p = 0.000, as well as a statistically significant difference between periods, F (1,178) = 5.427, p = 0.021. The percentage of total pedestrians in the crosswalk increased after the markings were installed. The total pedestrian data in Stillwater, like the alone and group data, showed only a significant difference between sites, F (1,159) = 108.980, p = 0.000.

Pedestrian Profile—Looking Behavior

The pedestrian profile study involved observing the looking behavior of pedestrians both in the crosswalk and not in the crosswalk. Simultaneously, a second observer noted the presence of an approaching vehicle or vehicles. Because of the relatively small sample size in each of the four study locations, it was not possible to do an analysis of each location separately. This data set was aggregated across the four cities for analysis. The pedestrian profile looking behavior is presented in Table 8.

Table 8. Pedestrian Profile: Pedestrian Looking Behavior.

Pedestrian Location	Period	PERCENTAGE OF PEDESTRIANS LOOKING					
		No Vehicle Present			Vehicle Present		
		At Curb	During Crossing	Either at Curb or During Crossing	At Curb	During Crossing	Either at Curb or During Crossing
In Crosswalk	Before	66.7% *	74.5% *	95.7%	48.2%	91.9%	96.5%
	After	54.5% *	85.2% *	97.5%	42..7%	95.8%	99.3%
Not in Crosswalk	Before	53.5%	76.3%	95.9%	66.0%	81.9%	98.6%
	After	51.6%	79.0%	98.8%	65.0%	89.4%	99.5%

* Denotes significant before/after differences

In all cases pedestrian looking behavior at the curb was less frequently observed than was pedestrian looking behavior during the crossing. This is probably because the amount of head movement needed for a pedestrian to scan for approaching vehicles increases as the pedestrian gets closer to the roadway. A pedestrian approaching the roadway only needs to turn slightly, if at all, to scan up and down the road for approaching vehicles. Once in the crosswalk a much more profound and, therefore, much more observable, head movement is needed. The “at curb” looking behavior was, in all cases, less after the crosswalks were marked. However, only the difference for pedestrians in the crosswalk when no vehicle was present, a decrease from 66.7 percent to 54.5 percent, was statistically significant (1,N = 403) = 5.404, p = 0.020. None of the other, much smaller, decreases even approached being statistically significant.

Pedestrian looking behavior during the crossing was, in all cases, more frequently observed than at curb looking. Also, in all cases, there was an increase in looking behavior after the crosswalks were marked. These increases varied from 2.7 percent to 10.7 percent.

When there was an approaching vehicle, pedestrian looking behavior during the crossing increased to more than 90 percent for pedestrians in the crosswalk and to more than 80 percent for pedestrians not in the crosswalk. A Chi-Square Test (1,N = 404) = 6.448, p = 0.011 was used to examine the before/after differences in pedestrian looking behavior. The only statistically significant difference found after the installation of the crosswalk markings was the 10.7 percent change found for pedestrians in the crosswalk when no vehicle was approaching. The increase in looking behavior from 74.5 percent to 85.2 percent was significant at the 0.011 level.

The third column in the table shows the percentage of pedestrians who were observed looking either at the curb or during the crossing. Virtually all of the pedestrians (at least 95 percent in all situations) were seen to look either while at the curb or during the crossing. Although looking behavior was more frequent in all cases after the crosswalks were marked, the increases were not significant. There appears to be absolutely no evidence that the installation of crosswalk markings causes pedestrians to be less vigilant during their crossing; in fact, the installation of markings resulted in no significant change in pedestrian looking behavior.

SUMMARY AND CONCLUSIONS

A field study examined the effect of crosswalk markings on driver and pedestrian behavior at 11 unsignalized intersections in four different cities. A before/after experimental design was used to evaluate the effect of crosswalk markings. Data were collected on vehicle and pedestrian volumes, available crossing gaps, vehicle speeds, driver behavior, and pedestrian behavior.

Table 9 contains a tabular summary of the primary research results. The first column in the table lists the six hypotheses that were addressed by the experimental effort. The hypotheses represent both desirable and undesirable effects that might be associated with the installation of crosswalk markings. The second column lists the dependent variables or MOEs that were collected to prove each of the hypotheses. The last column summarizes the conclusions that were presented in the previous section. In general, crosswalk markings at unsignalized intersections appear to have several positive effects and no observed negative effects. Specifically, drivers appear to be aware that pedestrians are in a marked crosswalk and drive slightly slower. Crosswalks also have the positive benefit of channeling pedestrians to the intersection. Also, there appears to be no evidence to support the contention that pedestrians feel protected in marked crosswalks and act more carelessly. In conclusion, it appears that marking pedestrian crosswalks at relatively narrow, low-speed, unsignalized intersections is a desirable practice.

Table 9. Summary of Research Results.

Hypothesis	Measurement of Effectiveness (MOE)	Conclusion
1. Before/after differences are due to the installation of the crosswalk markings and not other factors.	Vehicle Volumes Traffic Gaps	No meaningful before/after changes were found in either vehicle volumes or traffic gaps.
	Pedestrian Volumes	No meaningful before/after changes were found in pedestrian volumes. Lack of before/after changes in overall vehicle and pedestrian activity means that changes can be more confidently attributed to the installation of the marked crosswalks.
2. Crosswalk markings do not affect the way drivers respond to pedestrians	Vehicle Speed (approaching and at crosswalk)	Although the magnitude of the observed speed changes were small, drivers appear to respond differently (e.g., drive slower, when approaching a pedestrian in a marked crosswalk).
3. Crosswalk markings disrupt traffic flow because some drivers will stop and yield to crossing pedestrians.	Driver Yielding Behavior	No changes in driver yielding were observed. Drivers are not either more or less likely to yield to a pedestrian in a marked crosswalk.
4. Pedestrians feel protected by marked crosswalks and act more aggressively when crossing.	Aggressive Pedestrian Behavior	No change in blatantly aggressive pedestrian behavior indicates that pedestrians do not feel overly protected by crosswalk markings.
5. Pedestrians will not use marked crosswalks.	Percentage of Crossing Pedestrians in the Crosswalk	Pedestrians walking alone tend to use marked crosswalks especially at busier intersections. Pedestrians walking in groups do not tend to use marked crosswalks. Overall, crosswalk usage increased after the installation of the crosswalk markings.

APPENDIX—DATA COLLECTION PROTOCOL

Pedestrian Entry/Magnet Study - Data Collection Protocol
Right of Way Study - Data Collection Protocol
Driver Speeds/Staged Pedestrian Study - Data Collection Protocol
Pedestrian Profile Study - Data Collection Protocol
Vehicle Volume Counts and Traffic Gaps
Field Studies Definitions and Exceptions

PEDESTRIAN ENTRY/MAGNET STUDY
DATA COLLECTION PROTOCOL

OBJECTIVE OF STUDY

Determine if pedestrians are more likely to cross at or near marked crosswalks instead of at mid-block or at intersections without crosswalk markings.

PROTOCOL

The data collection form consisted of copies of the specific site drawing with measured zones. Before the marked crosswalk was installed, markings or reference points were established to indicate where the crosswalk zone would be located in the after study. Data were written directly onto the data form using a colored pencil.

A team of two observers divided the site in half so that each observer could continually observe their half of the site.

Each observer recorded a tick mark within the zone where each pedestrian stepped off the curb and entered the roadway. When pedestrians entered the roadway as a group, the appropriate number of tick marks was recorded and circled to indicate a group.

When a group of pedestrians included one or more of the "exclusions," the group was counted, minus all exclusions. For example, a group of pedestrians composed of five people, with one pedestrian carrying a child, was recorded by four circled tick marks.

All pedestrians were counted as they entered the roadway even if they returned to the curb and/or aborted their crossing. Pedestrians who were getting out of parked cars were not included.

Data collection lasted a minimum of 30 minutes per period. A new data collection sheet was started every 10 minutes.

At the conclusion of the day, all tick marks were tallied by zone and recorded on the Pedestrian Entry/Magnet Study Data Reduction Form.

It was occasionally possible for one data collector to observe the entire site when pedestrian volumes were light. It was also possible to record the entries directly onto the data reduction form by keeping the site drawing nearby.

RIGHT OF WAY STUDY
DATA COLLECTION PROTOCOL

OBJECTIVE OF STUDY

To determine the effect of crosswalk markings on drivers yielding and not yielding to pedestrians and on aggressive pedestrian behavior.

PROTOCOL

All pedestrians using the marked (future) crosswalk were observed. No distinction was made for groups or lone pedestrians. Both crosswalks on the uncontrolled street were observed simultaneously*. Some pedestrians began or ended their crossing outside of the crosswalk; data were collected if pedestrians crossed in the general area of the designated crosswalk.

Tick marks were recorded on the Right of Way data form for each category of driver or pedestrian behavior:

1. Drivers who yielded to pedestrian/s in the travelway in the process of or getting ready to cross.

2. Extremely aggressive pedestrian behavior; behavior that required a driver to slow or stop to avoid a collision with a pedestrian crossing the roadway.

3. Drivers who did not stop or slow for pedestrian/s in the travelway already in the process of crossing.

Data were collected for 10-minute periods. One data form was used for the entire observation day.

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* Note: Because of the high pedestrian volumes at Sacramento Site No. 1, two data collections were needed to observe the crosswalks. At all other sites one observer was able to tally observations on both crosswalks simultaneously.

DRIVER SPEEDS/STAGED PEDESTRIAN STUDY
DATA COLLECTION PROTOCOL

OBJECTIVE OF STUDY

To demonstrate the effect of crosswalk markings on driver behavior in the presence of pedestrians at nonsignalized intersections.

PROTOCOL

Speeds of free flow vehicles or first in a platoon of vehicles were measured under three conditions:

1. No pedestrian present

2. Staged pedestrian looking at oncoming traffic E or N side of roadway and W or S side of roadway

3. Staged pedestrian stepping out into travelway E or N side of roadway and W or S side of roadway

The speed study required a team of two data collectors. One person observed vehicle speeds and the other team member served as the staged pedestrian (SP).

Using a laser speed detection device, the operator obtained speeds of drivers in the lane <u>nearest</u> the SP. All vehicle types with the exceptions of motorcycles and commercial trucks were observed. Buses were recorded with the notation "B" next to the recorded speeds.

The laser operator worked from within a mini van, with the back hatch open, pointing the device toward oncoming traffic. The position of the observation vehicle varied from site to site.

Two speeds were obtained for each observed vehicle. The location where the first speed point was obtained varied from site to site and was measured and recorded on the speed data form. Once the speed point was established for a particular site, that distance was used throughout the course of the study. In order to measure any change in speed, the first speed point was approximately 45.8 m (150 ft) to 61 m (200 ft) before the future crosswalk markings. The second speed point was located at the approximate point where the near intersection crosswalk markings were installed. Both speeds were recorded on the data collection form in the appropriate column. Speeds were obtained only when no pedestrians were present at or near the crosswalk or intersection, (condition number 1) or when the SP was alone in the crosswalk area. If pedestrians entered the crosswalk area, exited or entered a vehicle parked in the study zone, or appeared anywhere near the targeted vehicle, speeds were not collected.

When both team members were ready, the SP watched for a vehicle in the appropriate lane and continually looked at oncoming traffic until the target vehicle crossed the future/marked crosswalk (condition 2). For condition 3, the SP took one small, but obvious step, out into the travelway while looking at the oncoming traffic. Both staged pedestrian behaviors were displayed after the targeted vehicle passed the first speed target. For safety purposes, the step was not near the line of traffic.

Some drivers yielded to the SP coming to a stop or near stop. When this happened, the speed was noted with the letter "Y" for yield on the data form. If drivers yielded to the SP, the SP crossed the road and began staging data collection from the other side of the roadway.

The SP always wore neutral colored clothing that was season appropriate.

Speed data were collected for a minimum of 15 minutes or 16 observations under each of the 3 conditions per observation period.

PEDESTRIAN PROFILE STUDY
DATA COLLECTION PROTOCOL

OBJECTIVE OF STUDY

To determine the effect of crosswalk markings on pedestrian path and location, pedestrian crossing behavior, and pedestrian looking behavior.

PROTOCOL

Pedestrians walking alone were observed by a team of two data collectors. One team member was responsible for observing pedestrian identifying information and vehicle data items. The other team member observed pedestrian travel path and crossing behavior.

Pedestrian identifying information and vehicle data items were recorded directly onto the data collection form. Pedestrian travel path and crossing behavior was recorded onto audio tape by using a cassette tape recorder. At the conclusion of data collection, the information on the tape was transcribed onto the data collection form. Team members identified each profile with the same identification number.

A map of the site location was drawn and zones created to capture the entire study area. This area began at the marked crosswalk (future crosswalk) and continued half the distance, in each direction, to the next intersection. That distance was not more than 76 m (250 ft) in each direction. A zone of approximately 17 m (55 ft) was created on the controlled legs of the intersection so pedestrians who entered the study area from the cross street were included in the study. Each zone was identified with an alpha, and each lane of vehicle travel was identified with a numeric.

The data collector responsible for observing travel path data points referred to the zoned site map while recording information onto a tape recorder.

An observation began when the first lone pedestrian entered the study zone. Pedestrian identifying information was written directly on the data form. Gender was coded as M or F, and age was coded as the actual numeric.

Travel path was observed to include the pedestrian's zone of origin into the study area, entry into the roadway, path during the crossing, zone at the end of the crossing, and path to the end of the study area. When the pedestrian arrived at the curb, the data collector recorded the number of times the pedestrian looked for traffic at the curb and the number of times the pedestrian looked during the crossing while in each lane. The looking codes were: none=0, once=1 and more than once=2. Looking observations were recorded at the curb and during each lane of crossing.

Pedestrian walking gait and any change in gait during each profile observation were recorded. The codes for gait were: 1=slow, 2=typical, 3=run/jog, 4=adjusted speed faster, 5=adjusted speed slower, 6=4 and 5, 7=stopped during the crossing, 8=reversal during the crossing, and 9=stopped at the curb.

When the pedestrian began crossing the roadway, the data collector responsible for traffic observations coded the number of vehicles in the study zone, by lane. Two traffic observations were recorded: once during the first half of the pedestrian crossing and once during the second half of the pedestrian crossing. The codes were: none=0, at least one vehicle in study zones=1, and congested—no free flow traffic=2.

Any unusual driver behavior was recorded using the following codes: 0=none, 1=yield to pedestrian, 2=obvious slowing, 3=hard braking, and 4=horn, swerve, driver yells or gestures.

All vehicles parked within 4.6 m (15 ft) of the marked crosswalk were recorded by zone on the data form. Any changes during the observation period were recorded as they occurred.

To avoid selecting the targeted pedestrian to be observed, some of the observations included people who entered the study zones but never crossed the roadway. These observations were part of the data set.

VEHICLE VOLUME COUNTS AND TRAFFIC GAPS

OBJECTIVE

To provide general traffic volume and density information, by time of day. This will allow proper comparison between the before (unmarked crosswalk) and the after (marked crosswalk) periods (i.e., by isolating any changes due to the markings and not due to changes in traffic volume).

PROTOCOL

Vehicle Volume Counts

Using the Traffic Volume Counts data form, the number of vehicles, by leg and turning movement, that crossed the marked (future) crosswalk were counted.

Identifying leg numbers by N/S ordinates as they relate to each site were established.

Bank counters or paper and pencil tick marks were used for 10 minutes per hour of data collection. All identifying information at the top of the form was completed. The "notes and comments" section at the bottom of the data collection form was used for any relevant information about the roadway (i.e., one-way street, "T" intersection, etc.).

Time Headways/Traffic Gaps

A 100-interval memory stop watch was activated each time a vehicle, in any lane, crossed the crosswalk marking nearest the intersection. After 10 minutes the gap times were tallied on the data form. For gaps of more than 25 seconds, the exact time of each gap was recorded on the lower half of the data form.

FIELD STUDIES DEFINITIONS AND EXCEPTIONS

DEFINITIONS

Group:	Two or more pedestrians known or unknown to each other who walk within arm's reach; about 0.9 m (3 ft) on either side.
Roadway:	Any part of paved road where vehicles drive or park.
Travelway:	That part of the roadway where vehicles can proceed. Parking lanes and medians are not part of the travelway.
Gait, slow:	Walking at a pace that would be equivalent to about 0.6 m (2 ft) per second.
Gait, typical:	Walking at a pace that is faster than 0.6 m (2 ft) per second but not as fast as a jog or run.
Gait, fast:	Running or jogging.
Yield:	Driver stops or slows long enough to allow pedestrian to cross roadway at a typical gait, even if the pedestrian chooses to run.
Congested:	No free flow traffic.

EXCEPTIONS

In general, the following pedestrians were not observed during the field studies. There were a few sites where bikers and skaters were found in abundance. At these locations, special codes were developed and these individuals were noted.

- People who used roller blades, skates, skateboards
- People who rode or walked bikes
- People who were in wheel chairs
- People who used walkers
- People who carried children of any age
- People who pushed baby stroller, cart, walked dogs
- People who were blind or who led blind pedestrians