Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations:

Executive Summary and Recommended Guidelines

FHWA-RD-01-075

U.S. Department of Transportation
Federal Highway Administration
Research and Development
Turner-Fairbank Highway Research Center
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Pedestrian & Bicycle Safety

FOREWORD

The Federal Highway Administration's (FHWA) 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 expanding public educational and safety programs, the FHWA's Pedestrian and Bicycle Safety Research Program strives to pave the way for a more walkable future.

The following document summarizes the results of a study that examined the safety of crosswalks at uncontrolled crossing locations and provides recommended guidelines for pedestrian crossings. The crosswalk study was part of a large FHWA study "Evaluation of Pedestrian Facilities" that has produced a number of other documents regarding the safety of pedestrian crossings and the effectiveness of innovative engineering treatments on pedestrian safety. It is hoped that readers also will read the reports documenting the results of the related pedestrian safety 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.

Michael F. Trentacoste
Director, Office of Safety
Research and Development

NOTICE

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16. Abstract

Pedestrians are legitimate users of the transportation system, and they should, therefore, be able to use this system safely. Pedestrian needs in crossing streets should be identified, and appropriate solutions should be selected to improve pedestrian safety and access. Deciding where to mark crosswalks is only one consideration in meeting that objective. This study involved an analysis of 5 years of pedestrian crashes at 1,000 marked crosswalks and 1,000 matched unmarked comparison sites. All sites in this study had no traffic signal or stop sign on the approaches. Detailed data were collected on traffic volume, pedestrian exposure, number of lanes, median type, speed limit, and other site variables. Poisson and negative binomial regressive models were used.

The study results revealed that on two-lane roads, the presence of a marked crosswalk alone at an uncontrolled location was associated with no difference in pedestrian crash rate, compared to an unmarked crosswalk. Further, on multi-lane roads with traffic volumes above about 12,000 vehicles per day, having a marked crosswalk alone (without other substantial improvements) was associated with a higher pedestrian crash rate (after controlling for other site factors) compared to an unmarked crosswalk. Raised medians provided significantly lower pedestrian crash rates on multi-lane roads, compared to roads with no raised median. Older pedestrians had crashes that were high relative to their crossing exposure.

More substantial improvements were recommended to provide for safer pedestrian crossings on certain roads, such as adding traffic signals with pedestrian signals when warranted, providing raised medians, speed-reducing measures, and others.

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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		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	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.

Symbol	When You Know	Multiply By	To Find	Symbol
		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/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	35.71	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)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		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 September 1993)

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BACKGROUND AND INTRODUCTION

Pedestrians are legitimate users of the transportation system, and they should, therefore, be able to use this system safely and without unreasonable delay (figure 1). Pedestrians have a right to cross roads safely and, therefore, planners and engineers have a professional responsibility to plan, design, and install safe crossing facilities. Pedestrians should be included as “design users” for all streets.

As a starting point, roads should be designed with the premise that there will be pedestrians, that they are going be able to cross the street, and that they will be able to do it safely. The design question is “How can this task be best accomplished?”

Providing marked crosswalks has traditionally been one measure used in an attempt to facilitate crossings. They are commonly used at uncontrolled locations and sometimes at midblock locations. However, there have been conflicting studies and much controversy regarding the safety effects of marked crosswalks. This study evaluated marked crosswalks at uncontrolled locations and offers guidelines for their use.

Figure 1. Pedestrians have a right to facilities where they can cross the road safely and without unreasonable delay.

How to Use This Study

Marked crosswalks are one tool to get pedestrians safely across the street. When considering marked crosswalks at uncontrolled locations, the question should not simply be: “Should I provide a marked crosswalk or not?” Instead, the question should be: “Is this an appropriate tool for getting pedestrians across the street?” Regardless of whether marked crosswalks are used, there remains the fundamental obligation to get pedestrians safely across the street.

In most cases, marked crosswalks are best used in combination with other treatments (e.g., curb extensions, raised crossing islands, traffic signals, roadway narrowing, enhanced overhead lighting, traffic calming measures etc.). Think of marked crosswalks as one option in a progression of design treatments. If one treatment does not adequately accomplish the task, then move on to the next one. Failure of one particular treatment is not a license to give up and do nothing. In all cases, the final design must accomplish the goal of getting pedestrians across the road safely.

What Is the Legal Definition of a Crosswalk?

The 1992 Uniform Vehicle Code (Section 1-112) defines a crosswalk as:[1]

(a) That part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs, or in the absence of curbs, from the edges of the traversable roadway; and in the absence of a sidewalk on one side of the roadway, the part of a roadway included within the extension of the lateral lines of the existing sidewalk at right angles to the centerline.

(b) Any portion of a roadway at an intersection or elsewhere distinctly indicated for pedestrian crossing by lines or other markings on the surface.

Thus, legal crosswalks exist at all public intersections where there is a sidewalk on at least one side of the street. The only way a crosswalk can exist at a midblock location is if it is marked. Furthermore, according to the *Manual on Uniform Traffic Control Devices* (MUTCD) (Section 3B-18), a crosswalk may be marked with paint, thermoplastic materials, and plastic tape, among other materials.[2]

Specifically, crosswalks serve as the pedestrian right-of-way across a street. The level of connectivity between pedestrian facilities is directly related to the placement and consistency of street crossings.

Why Are Marked Crosswalks Controversial?

There has been considerable controversy in the United States regarding whether providing marked crosswalks will increase or decrease pedestrian safety at crossing locations that are not controlled by a traffic signal or stop sign. Many pedestrians consider marked crosswalks as a tool to enhance pedestrian safety and mobility. They view the markings as proof that they have a right to share the roadway, and in their opinion, the more the better. Many pedestrians do not understand the legal definition of a crosswalk and think that there is no crosswalk unless it is marked. They may also think that the driver will be able to see the crosswalk markings as well as they do, and they assume that it will be safer to cross where drivers can see the white crosswalk lines.

When citizens request the installation of marked crosswalks, some engineers and planners still refer to the 1972 study by Bruce Herms[3] as justification for not installing marked crosswalks at uncontrolled locations. That study found an increased incidence of pedestrian collisions in marked crosswalks, compared to unmarked crosswalks, at 400 uncontrolled intersections in San Diego, California. Questions have been asked about the validity of that study, and the study results have sometimes been misquoted or misused. Some have misinterpreted the results of that study. The study **did not** conclude that all marked crosswalks are “unsafe” and it did not include school crosswalks. A few other studies have also tried to address this issue since the completion of the Herms study. Some were not conclusive because of their methodology or sample size problems, while others have fueled the disagreements and confusion on this matter.

Furthermore, most of the previous crosswalk studies have analyzed the overall safety effects of marked crosswalks but did not investigate their effects for various numbers of lanes, traffic volumes, or other roadway features. Like other traffic control devices, crosswalks should not be expected to be equally effective or appropriate under all roadway conditions.

Where Are Crosswalks Typically Installed?

The practice of where to install crosswalks differs considerably from one jurisdiction to another across the United States, and engineers have been left with using their own judgment (sometimes influenced by political and/or public pressure) in reaching decisions. Some cities have developed their own guidelines on where marked crosswalks should or should not be installed. At a minimum, many cities tend to install marked crosswalks at signalized intersections, particularly urban areas where there is a considerable amount of pedestrian activity. Many jurisdictions also commonly install marked crosswalks at school crossing locations (such as where adult crossing guards are used) and they are more likely to mark crosswalks at intersections controlled by a stop sign. At uncontrolled locations (i.e., sites not controlled by a traffic signal or stop sign), some agencies rarely, if ever, choose to install marked crosswalks, while other agencies have installed marked crosswalks at selected pedestrian crossing locations, particularly in downtown areas. Some towns and cities have also chosen to supplement selected crosswalks with advance overhead or post-mounted pedestrian warning signs, flashing lights, STOP FOR PEDESTRIANS IN CROSSWALK signs mounted at the street centerline (or mounted along the side of the street or overhead), and/or supplemental pavement markings.

STUDY PURPOSE AND OBJECTIVE

Many highway agencies routinely mark crosswalks at school crossings and signalized intersections. While questions have been raised concerning marking criteria at these sites, most of the controversy on whether to mark crosswalks has pertained to the many uncontrolled locations in U.S. towns and cities. The purpose of this study was to determine whether marked crosswalks at uncontrolled locations (i.e., locations with no traffic signal or stop sign on the approach) are safer than unmarked crosswalks under various traffic and roadway conditions. Another objective was to provide recommendations on how to provide safer crossings for pedestrians. This includes providing assistance to engineers and planners when making decisions on:

- Where crosswalks may be installed.
- Where an existing crosswalk, by itself, is acceptable.
- Where an existing crosswalk should be supplemented with additional improvements.
- Where one or more other engineering treatments (e.g., raised median, traffic signal with pedestrian signal) should be considered instead of having only a marked crosswalk.
- Where marked crosswalks are not appropriate.

The results of this study should not be misused as justification to do nothing to help pedestrians to safely cross streets. Instead, pedestrian crossing problems and needs should be routinely identified, and appropriate solutions should be selected to improve pedestrian safety and access. Deciding where to mark or not mark crosswalks is only one consideration in meeting that objective.

This Executive Summary is based on a major study for the Federal Highway Administration on the safety effects of marked crosswalks vs. matched unmarked crossings that was conducted by the University of North Carolina's Highway Safety Research Center.[(4)]

DATA COLLECTION AND ANALYSIS METHODOLOGY

An ideal study design would involve removing all crosswalks in several test cities and randomly assigning sites for crosswalk markings and also to serve as unmarked control sites. However, it would be impossible to get the level of cooperation from the cities that is needed to conduct such a study due to liability considerations. Also, such random assignment of crosswalk marking locations would result in many crosswalks not being marked at the most appropriate locations.

Thus, because of such real-world constraints, a treatment and matched comparison site methodology was used to quantify the pedestrian crash risk of marked vs. unmarked crosswalks. This allowed for selection of a large sample of study sites in cities throughout the United States where marked crosswalks and similar unmarked comparison sites were available. At intersections, the unmarked crosswalk comparison site was typically the opposite leg of the same intersection as the selected marked crosswalk site. For each marked midblock crosswalk, a nearby midblock *crossing* location was chosen as the comparison site on the same street (usually a block or two away) where pedestrians were observed to cross. (Even though an unmarked midblock crossing is not technically or legally a "crosswalk," it was a suitable comparison site for a midblock crosswalk). The selection of a matched comparison site for each crosswalk site (typically on the same route and very near the crosswalk site) helped to control for the effects of vehicle speeds, traffic mix, and a variety of other traffic and roadway features.

A before/after experiment was not considered to be practical because of regression-to-the-mean problems, limited sample sizes of new crosswalk installations, etc. A total of 1,000 marked crosswalk sites and 1,000 matched unmarked (comparison) crossing sites in 30 cities across the United States (see figure 2) were selected for analysis. Test sites were chosen without any prior knowledge of their crash history. School crossings were not included in this study because of crossing guards and/or special school signs and markings that may increase the difficulty of quantifying the safety effects of crosswalk markings.

Figure 2. Cities and States used for study sample.

Test sites were selected from the following cities:

- East: Cambridge, MA; Baltimore, MD (city and county); Pittsburgh, PA; Cleveland, OH; Cincinnati, OH.
- Central: Kansas City, MO; Topeka, KS; Milwaukee, WI; Madison, WI; St. Louis, MO (city and county).
- South: Gainesville, FL; Orlando, FL; Winter Park, FL; New Orleans, LA; Raleigh, NC; Durham, NC.
- West: San Francisco, CA; Oakland, CA; Salt Lake City, UT; Portland, OR; Seattle, WA.
- Southwest: Austin, TX; Ft. Worth, TX; Phoenix, AZ; Scottsdale, AZ; Glendale, AZ; Tucson, AZ; Tempe, AZ.

Detailed information was collected at each of the 2,000 sites, including pedestrian crash history (average of 5 years per site), daily pedestrian volume estimates, average daily traffic (ADT) volume, number of lanes, speed limit, area type, type of median, type and condition of crosswalk marking patterns, location type (midblock vs. intersection), and other site characteristics. Various crosswalk marking patterns are given in the MUTCD.[2] All of the 1,000 marked crosswalks had one of the marking patterns shown in figure 3 (i.e., none had a brick pattern for the crosswalk). Very few of the marked crosswalks had any type of supplemental pedestrian warning signs. Furthermore, none of the test sites had traffic-calming measures or special pedestrian devices (e.g., in-pavement flashing lights). Estimates of daily pedestrian volumes at each crosswalk site and unmarked comparison site were determined based on pedestrian volume counts at each site, which were expanded to estimated daily pedestrian volume counts based on hourly adjustment factors. Specifically, at each of the 2,000 crossing locations, trained data collectors conducted on-site counts of pedestrian crossings and classified pedestrians by age group based on observations. Pedestrian counts were collected simultaneously for 1 hour at each of the crosswalk and comparison sites. Full-day (8-to 12-h) counts were conducted at a sample of the sites and were used to develop adjustment factors by area type (urban, suburban, fringe) and by time of day. The adjustment factors were then used to determine estimated daily pedestrian volumes in a manner similar to that used by many cities and States to expand short-term traffic counts to average annual daily traffic (AADT). Collecting the volume counts simultaneously at each crosswalk site and its matched comparison site helped to control for time-related influences on pedestrian exposure.

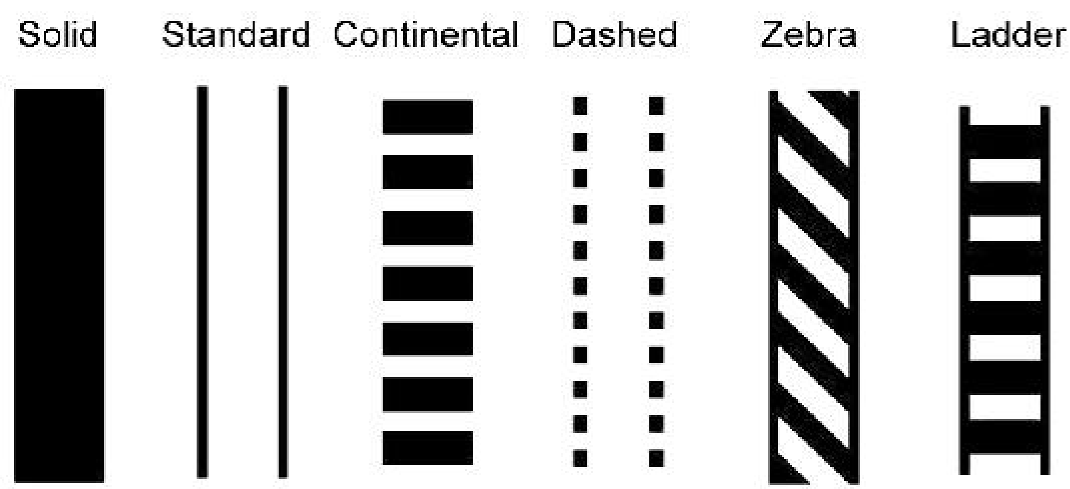


Figure 3. Crosswalk marking patterns.

This methodology was intended as a measure at the crosswalk and comparison sites for use as a control variable in the analysis. Collecting the volume counts simultaneously helped to control for time-related influences on pedestrian exposure.

The crash data periods varied somewhat from city to city and averaged approximately 5 years per site (typically from about January 1, 1994 to December 31, 1998). Police crash reports were obtained from each of the cities, except for Seattle, where detailed printouts were obtained for each crash. Crashes were carefully reviewed to assign a crash type and to ensure accurate matching of the correct location (and whether the crash occurred at the location, i.e., at or within 20 ft (6.1 m) of the marked or unmarked crossing of interest).

Standard pedestrian crash typology was used to review police crash reports and determine the appropriate pedestrian crash types (e.g., multiple threat, midblock dartout, intersection dash), as discussed later. All treatment (crosswalk) and comparison sites were chosen without prior knowledge of crash history. **All sites used in this study were intersection or midblock locations with no traffic signals or stop signs on the main road approach (i.e., uncontrolled locations).** This study focused on pedestrian safety and, therefore, data were not collected for vehicle-vehicle or single-vehicle collisions, even though it is recog- nized that marking crosswalks may increase vehicle stopping, which may also affect these collision types.

The selected analysis techniques were deemed to be appropriate for the type of data in the sample. Due to relatively low numbers of pedestrian crashes at a given site (e.g., there were many sites with zero pedestrian crashes in a 5-year period), Poisson modeling and negative binomial regression were used in the analysis of the data. Using these analysis techniques allowed for determining statistically valid safety relationships. In fact, there were a total of 229 pedestrian crashes at the 2,000 crossing sites over an average of 5 years per site. This translates to an overall average of one pedestrian crash per crosswalk site every 43.7 years.

All analyses of crash rates at marked and unmarked crosswalks took into account traffic volume, pedestrian exposure, and other roadway features (e.g., number of lanes). To supplement the pedestrian crash analysis, a corresponding study by Knoblauch, et al.[5] was also conducted on pedestrian and driver behavior before and after marked crosswalks were installed at selected sites in California, Minnesota, New York, and Virginia, as discussed in more detail later in this publication.

STUDY RESULTS

Significant Variables

1. Poisson and negative binomial regression models were fit to pedestrian crash data at marked and unmarked crosswalks. These analyses showed that several factors in addition to crosswalk markings were associated with pedestrian crashes. Traffic and roadway factors found to be related to a greater frequency of pedestrian crashes included higher pedestrian volumes, higher traffic ADT, and a greater number of lanes (i.e., multi-lane roads with three or more lanes had higher pedestrian crash rates than two-lane roads). For this study, a center two-way left-turn lane was considered to be a travel lane and not a median.

2. Surprisingly, after controlling for other factors (e.g., pedestrian volume, traffic volume, number of lanes, median type), speed limit was not significantly related to pedestrian crash frequency. Certainly, one would expect that higher vehicle speed would be associated with an increased probability of a pedestrian crash (all else being equal). However, the lack of association found in this

analysis between speed limit and pedestrian crashes may be due to the fact that there was not a lot of variation in the range of vehicle speed or speed limit at the study sites (i.e., 93 percent of the study sites had speed limits of 25 to 35 mi/h [40.2 to 56.3 km/h]). Another possible explanation, as hypothesized by Garder,[6] is that pedestrians may be more careful when crossing streets with higher speeds; that is, they may avoid short gaps on high-speed roads, which may minimize the effect of vehicle speed on pedestrian crash rates.[6] In terms of speed and crash severity, the analysis showed that speed limits of 35 mi/h (56.3 km/h) and greater were associated with a higher percentage of fatal and Type A injuries (43 percent) compared to sites having lower speed limits (23 percent of the crashes resulting in fatal or Type A injuries).

3. The presence of a raised median (or raised crossing island) was associated with a significantly lower pedestrian crash rate at multi-lane sites with both marked and unmarked crosswalks. These results were in basic agreement with a major study by Bowman and Vecellio[7] and also a study by Garder[8] that found safety benefits for pedestrians due to raised medians and refuge islands, respectively. Furthermore, on multi-lane roads, medians that were painted (but not raised) and also center two-way left-turn lanes **did not** offer significant safety benefits to pedestrians, compared to multi-lane roads with no median at all.

4. There was also a significant regional effect; that is, sites in western U.S. cities had a significantly higher pedestrian crash rate than eastern U.S. cities (after controlling for pedestrian exposure, number of lanes, median type, and other site conditions). The reason(s) for these regional differences in pedestrian crash rate is not known, although it could be related to regional differences in driver and pedestrian behavior, higher vehicle speeds in western cities, differences in pedestrian-related laws, variations in roadway design features, and/or other factors.

5. All of the variables related to pedestrian crashes (i.e., pedestrian volume, traffic ADT, number of lanes, existence of median and median type, and region of the country) were then included in the models for determining the effects of marked vs. unmarked sites. Factors having *no* significant effect on pedestrian crash rate included: area (e.g., residential, central business district [CBD]), location (i.e., intersection vs. midblock), speed limit, traffic operation (one-way or two-way), condition of crosswalk marking (excellent, good, fair, or poor), and crosswalk marking pattern (e.g., parallel lines, ladder type, zebra stripes). One may expect that crosswalk marking condition may not necessarily be related to pedestrian crash rate, since the condition of the markings may have varied over the 5-year analysis period, and the condition of the markings was observed only once. Furthermore, in some regions, the crosswalk markings may be less visible during or after rain or snow storms. It is also recognized, however, that some agencies may maintain and restripe crosswalks more often than other agencies included in the study sample.

Marked vs. Unmarked Crosswalk Comparisons

6. The results revealed that on **two-lane** roads, there were no significant differences in pedestrian crashes for marked vs. unmarked crosswalk sites. In other words, pedestrian safety on two-lane roads was not found to be different, whether the crosswalk was marked or unmarked. This conclusion is based on a sample size of 914 crossing sites on two-lane roads (out of 2,000 total sites). Specifically, binomial comparison of pedestrian crash rates for marked vs. unmarked sites within subsets by ADT, median type, and number of lanes are shown in figure 4.

7. **On multi-lane roads with ADTs of 12,000 or less,** there were also no differences in pedestrian crash rates between marked and unmarked sites. On multi-lane roads with **no raised medians** and ADT's greater than 12,000, sites with marked crosswalks had higher pedestrian crash rates than

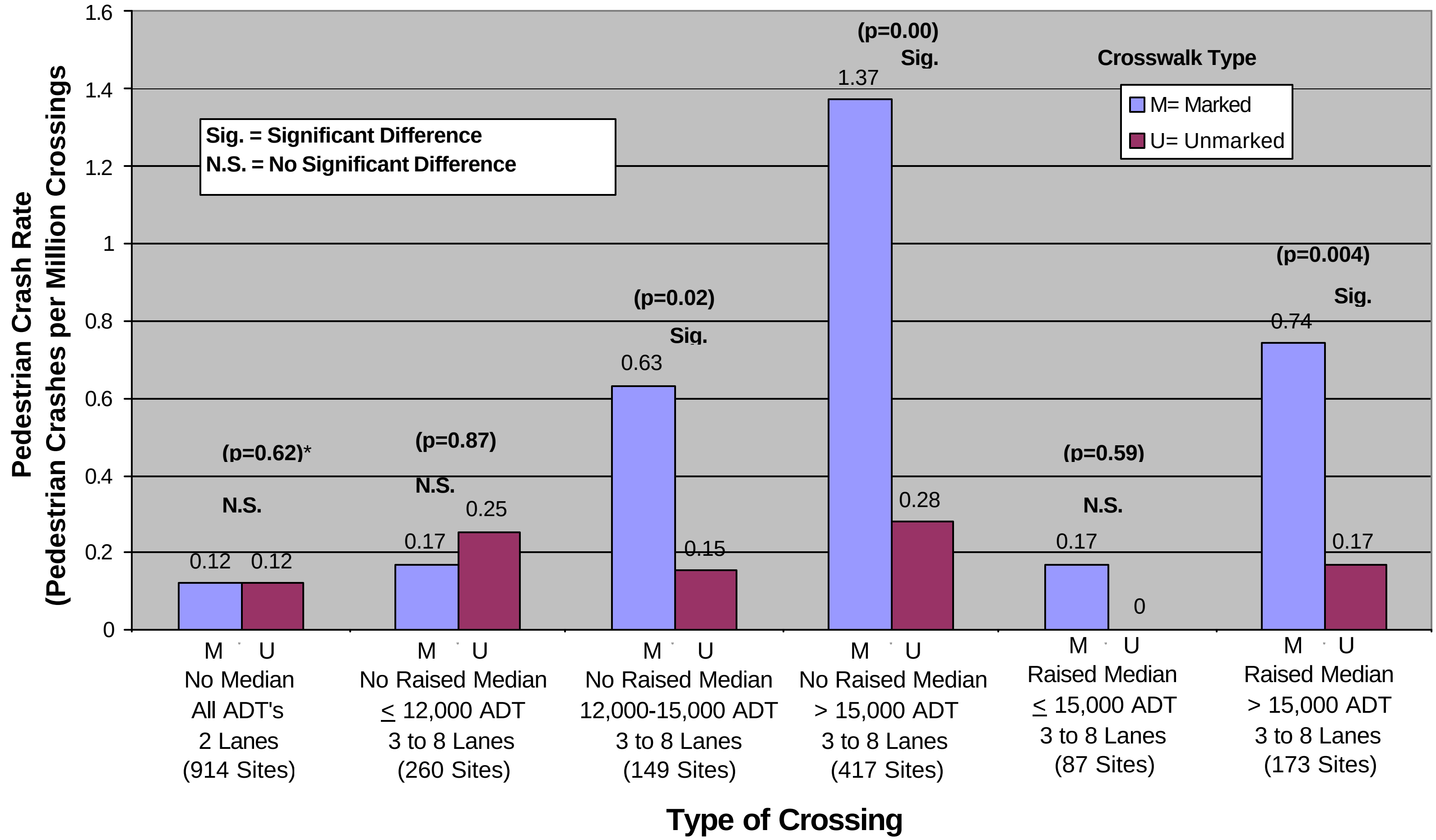


Figure 4. Pedestrian crash rate vs. type of crossing.

unmarked crossings. On multi-lane roads (roads with 3 to 8 lanes) with **raised medians** and vehicle ADT's greater than 15,000, a significantly higher pedestrian crash rate was associated with marked crosswalk sites compared to unmarked sites.

8. Best-fit curves on multi-lane undivided roads were produced for pedestrian crashes (per million pedestrian crossings) at marked and unmarked crosswalks as a function of vehicle volume (ADT), as shown in figure 5. Similar analyses were conducted for multi-lane divided roads. This analysis for multi-lane undivided roads revealed that:

- For traffic volumes (ADT's) of about 10,000 or less, pedestrian crash rates were about the same (i.e., less than 0.25 pedestrian crashes per million pedestrian crossings) between marked and unmarked crosswalks.

- For ADT's greater than 10,000, the pedestrian crash rate for marked crosswalks became increasingly worse as ADT increased. The crash rate at unmarked crossings increased only slightly as ADT increased.

Note that each point on the graph represents dozens of sites, that is, all of the sites corresponding to the given ADT group. For example, the data point for marked crosswalks with ADT's greater than 15,000 corresponds to more than 400 sites. All analyses in this study took into account differences in pedestrian crossing volume, traffic volume, and other important site variables.

The results given above may be somewhat expected. Wide, multi-lane streets are difficult for many pedestrians to cross, particularly if there is an insufficient number of adequate gaps in traffic due to heavy traffic volume and high vehicle speed. Furthermore, while marked crosswalks in themselves may not increase measurable unsafe pedestrian or motorist behavior (based on the Knoblauch et al. study),[5] one possible explanation is that installing a marked crosswalk may increase the number of at-risk pedestrians (particularly children and older adults) who choose to cross there instead of at the nearest signal-controlled crossing.

The pedestrian crossing counts at the 1,000 marked crosswalks and 1,000 unmarked comparison crossings from this study may partially explain the difference. Overall, 66.1 percent of the observed pedestrians crossed at marked crosswalks vs. 33.9 percent at unmarked crossings. More than 70 percent of pedestrians under age 12 and above age 64 crossed at marked crosswalks, while about 35 percent of pedestrians in the 19- to 35-year-old range crossed at unmarked crossings, as shown in figure 6. The age group of pedestrians was determined from on-site observation.

An even greater percentage of older adults (81.3 percent) and young children (76.0 percent) chose to cross in marked crosswalks on multi-lane roads compared to two-lane roads. Thus, installing a marked crosswalk at an already undesirable crossing location (i.e., wide, high-volume street) may increase the chance of a pedestrian crash occurring at such a site if a few at-risk pedestrians are encouraged to cross where other adequate crossing facilities are not provided. This explanation might be evidenced by the many calls to traffic engineers from citizens who state: "Please install a marked crosswalk so that we can cross the dangerous street near our house." Unfortunately, simply installing a marked crosswalk without other more substantial crossing facilities often does not result in the majority of motorists stopping and yielding to pedestrians, contrary to the expectations of many pedestrians.

9. On three-lane roads (i.e., one lane in each direction with a center two-way left-turn lane), the crash risk was slightly higher for marked crosswalks compared to unmarked crosswalks, but this difference was not significant (based on a sample size of 148 sites).

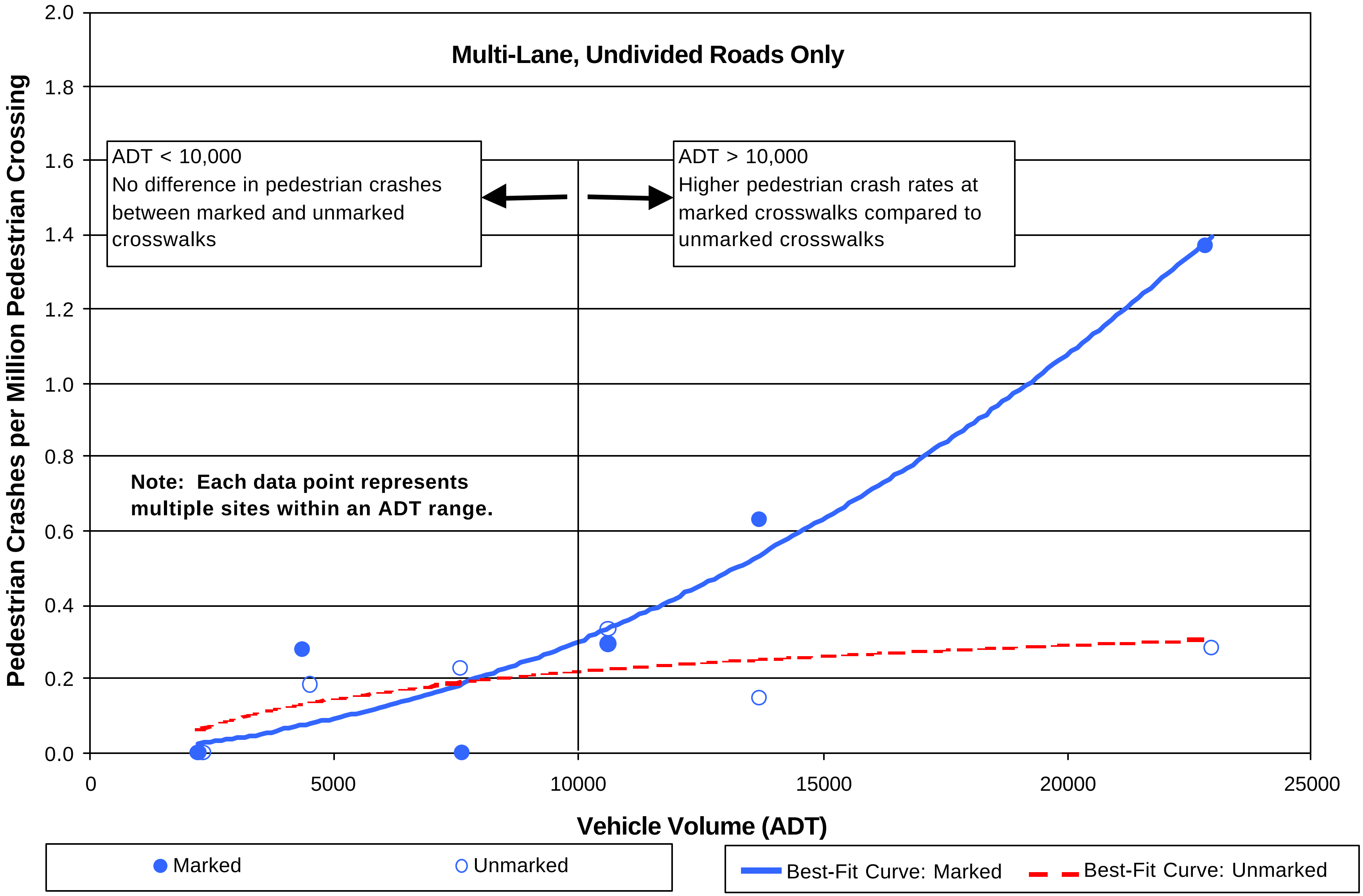
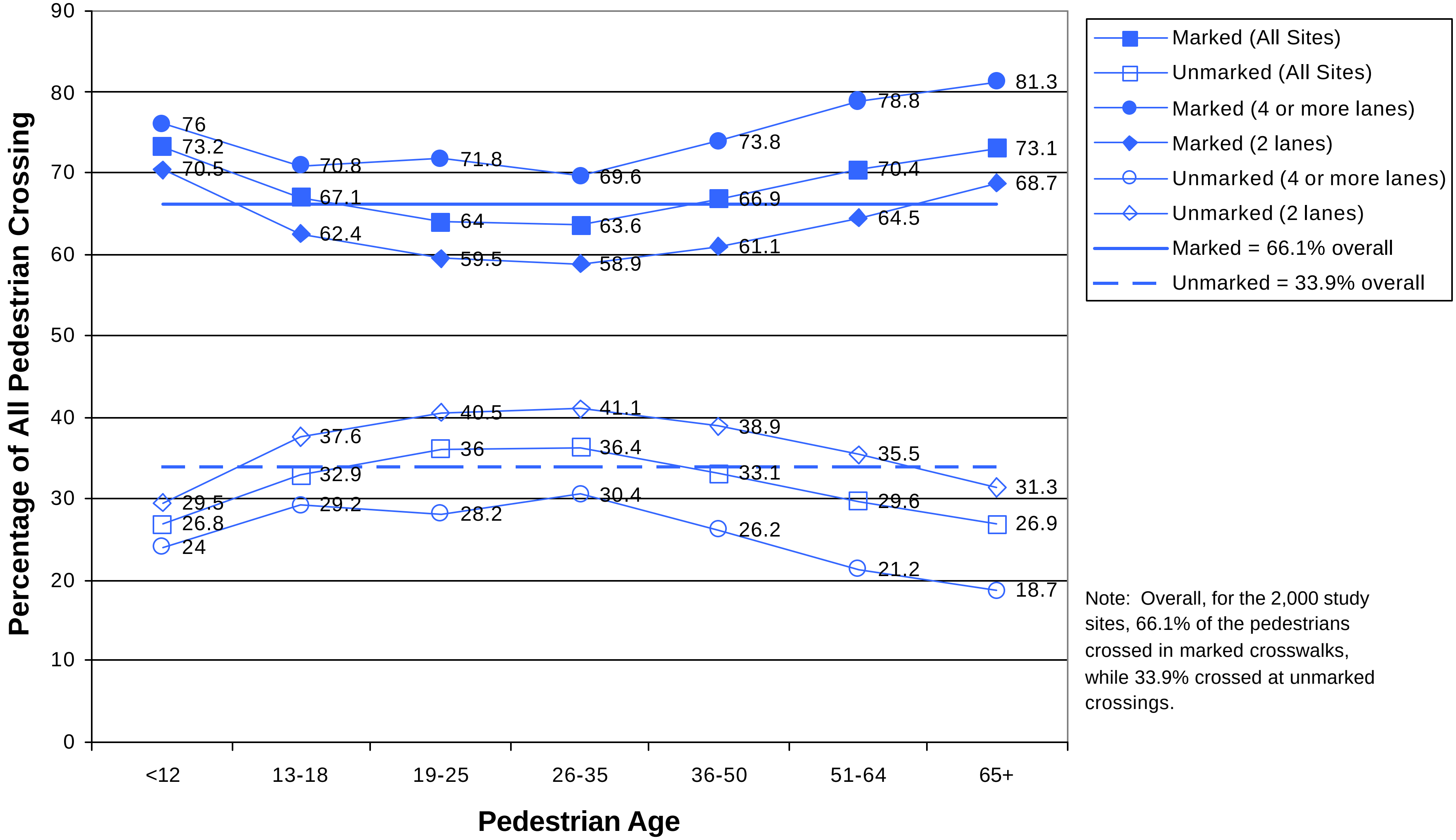


Figure 5. Pedestrian crash rates by traffic volume for multi-lane crossings with no raised medians — marked vs. unmarked crosswalks.



Note: Overall, for the 2,000 study sites, 66.1% of the pedestrians crossed in marked crosswalks, while 33.9% crossed at unmarked crossings.

Figure 6. Percentage of pedestrians crossing at marked and unmarked crosswalks by age group and road type.

Pedestrian Crash Types

10. The greatest difference in pedestrian crash types between marked and unmarked crosswalks involved "multiple-threat" crashes. A multiple-threat crash involves a driver stopping in one lane of a multi-lane road to permit pedestrians to cross, and an oncoming vehicle (in the same direction) strikes the pedestrian who is crossing in front of the stopped vehicle. This crash type involves both the pedestrian and driver failing to see each other in time in order to avoid the collision (see figure 7). To avoid multiple-threat collisions, drivers should slow down and look around stopped vehicles in the travel lane, and pedestrians should stop at the outer edge of a stopped vehicle and look into the oncoming lane for approaching vehicles before stepping into the lane.

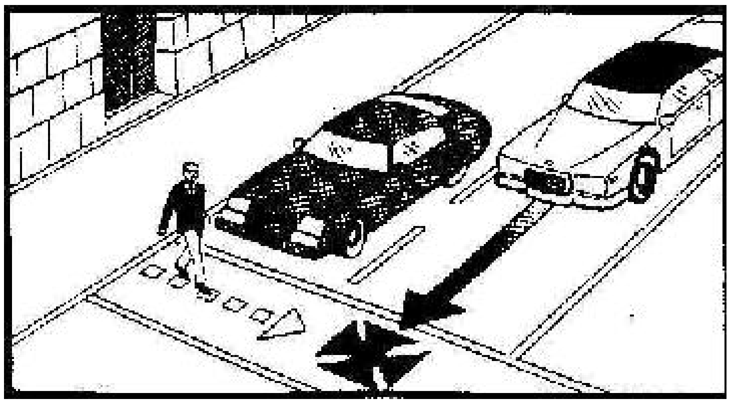


Figure 7. Illustration of multiple-threat pedestrian crash.

A total of 17.6 percent (33 out of 188) of the pedestrian crashes in marked crosswalks were classified as multiple threat. None of the 41 pedestrian crashes in unmarked crosswalks were multiple threat. This finding may be the result of one or more of the following:

- Drivers may be more likely to stop and yield to pedestrians in marked crosswalks compared to unmarked crossings, since at least one motorist must stop for a pedestrian in order to set up a multiple-threat pedestrian collision. Also, pedestrians may be more likely to step out in front of oncoming traffic in a marked crosswalk than at an unmarked location in some instances.

- A second explanation is related to the fact that most of the total pedestrians who are crossing multi-lane roads are crossing in a marked crosswalk (66.1 percent), as shown earlier in figure 5. Furthermore, of the pedestrian age groups most at risk (the young and the old), an even greater proportion of these pedestrians are choosing to cross multi-lane roads in marked crosswalks (76 percent and 81.3 percent, respectively).

- Another possible explanation could be that some pedestrians crossing in a marked crosswalk may be less likely to search properly for vehicles (compared to an unmarked crossing) when stepping out past a stopped vehicle and into an adjacent lane (i.e., pedestrians not realizing that they need to search for other oncoming vehicles after one motorist stops for them).

Further research on pedestrian and motorist behavior could help to gain a better understanding of the causes and potential effects of countermeasures (e.g., advance stop lines) related to these crashes. There is also a need to examine the current laws (and a possible need for changes in the laws) on motorist responsibility to yield to pedestrians and how these laws differ between States. A distribution of pedestrian crash types is shown in figure 8, which includes all of the 229 pedestrian collisions at the 2,000 study sites.

11. Motorists failing to yield (on through movements) represented a large percentage of pedestrian crashes in marked crosswalks (41.5 percent) and unmarked crosswalks (31.7 percent). Likewise, vehicle turn and merge crashes, also generally the fault of the driver, accounted for 19.2 percent (marked crosswalks) and 12.2 percent (unmarked crosswalks) (see figure 8). These results indicate a strong need for improved driver enforcement and education programs that emphasize the importance of yielding to or stopping for pedestrians. More pedestrian-friendly roadway designs may also be helpful in reducing such crashes by slowing vehicles, providing pedestrian refuge (e.g., using raised medians), and/or better warning to motorists about pedestrian crossings.

12. A substantial proportion of pedestrian crashes involved dartout, dash, and other types of crashes in which the pedestrian stepped or ran in front of an oncoming vehicle at unmarked crosswalks (23 of 41, or 56.1 percent) and a lesser proportion occurred at marked crosswalks (41 of 188, or 21.8 percent). Police officers sometimes unjustifiably assign fault to the pedestrian, which suggests the need for more police training. Specifically, it may be questioned why so many pedestrian crashes were designated by the police officer as "pedestrian fails to yield," since in most States, motorists are legally required to yield the right-of-way to pedestrians who are crossing in marked or unmarked crosswalks. Of course, some state ordinances do specify that pedestrians also bear some responsibility for avoiding a collision by not stepping out into the street directly into the path of an oncoming motorist who is too close to the crosswalk to stop in time to avoid a collision. It is likely that police officers often rely largely on the statement of the motorist (e.g., "the pedestrian ran out in front of me" or "came out of nowhere") in determining fault in such crashes, particularly when the driver was not paying proper attention to the road, the pedestrian is unconscious, and there are no other witnesses at the scene. However, it is also true that a major contributing factor is the unsafe behavior of pedestrians. Keeping that in mind, dartouts, dashes, and failure of the pedestrians to yield were indicated by police officers as contributing causes in 27.9 percent (64 of 229) of the pedestrian crashes at the study sites. These results are indicative of a need for improved pedestrian educational programs, which is in agreement with recommendations in other important studies related to improving the safety of vulnerable road users.[9] Furthermore, speeding drivers often contribute to dartout crashes, in addition to unsafe pedestrian behaviors. Creating more pedestrian-friendly crossings, by including curb extensions, traffic-calming measures, etc. may also be useful in reducing many of these crashes, as discussed later.

Pedestrian Crash Severity

13. An analysis was conducted to compare pedestrian crash severity on marked vs. unmarked crosswalks. Crash severity did not differ significantly between marked and unmarked crosswalks on two-lane roads. On multi-lane roads, there was evidence of more fatal and Type A injury pedestrian crashes at marked crosswalks compared to unmarked crosswalks. This result is probably due to older pedestrians being more likely than other age groups to walk in marked rather than unmarked crosswalks. Furthermore, they are much more likely to sustain fatal and serious injuries than younger pedestrians. As mentioned earlier, speed limits of 35 mi/h (56.3 km/h) and higher were associated with a greater percentage of fatal and Type A injuries (43 percent); whereas sites with lower speed limits had 23 percent of pedestrian crashes resulting in fatal or Type A injuries.

Lighting and Time of Day

14. Nighttime pedestrian crash percentages were about the same at marked and unmarked crosswalks (approximately 30 percent). In terms of time of day, the percentage of pedestrian crashes in

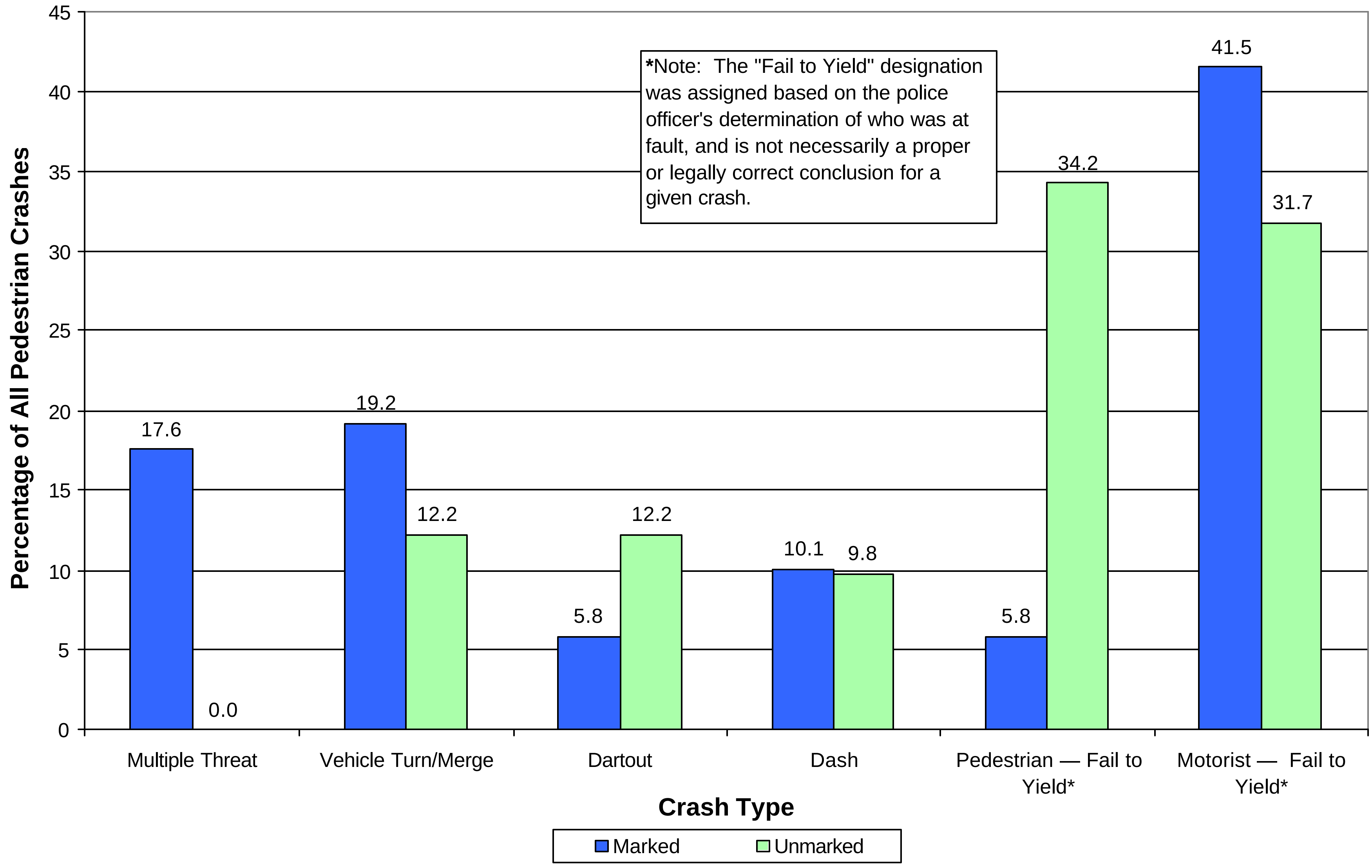


Figure 8. Pedestrian crash types at uncontrolled marked and unmarked crosswalks.

marked crosswalks tended to be higher than for unmarked crosswalks during the morning (6 to 10 a.m.) and afternoon (3 to 7 p.m.) peak periods, but lower in the midday (10 a.m. to 3 p.m.) and evening (7 p.m. to midnight) periods. This is probably because pedestrians are more likely to cross in marked crosswalks than in unmarked crossings during peak traffic periods (e.g., walking to and from work) than at other times. Adequate nighttime lighting should be provided at marked crosswalks to enhance the safety of pedestrians crossing at night.

Age Effects

15. A separate analysis of pedestrian crashes and crossing volumes by age of pedestrian was conducted. For virtually every situation studied (i.e., marked and unmarked crossings on two-lane and multi-lane roads), pedestrians age 65 and older were overrepresented in pedestrian crashes compared to their relative crossing volumes. Figure 9 shows the relative proportion of crashes and exposure for various age groups for marked crosswalks on two-lane and multi-lane roads. For a given age group, when the proportion of crashes exceeds the proportion of exposure, then crashes are overrepresented; that is, pedestrians in that population group are at greater risk of being in a pedestrian crash than would be expected from their volume alone.

The pedestrian age groups younger than 65 showed no clear increase in crash risk compared to their crossing volumes. One possible reason that young pedestrians were not overinvolved in crash occurrence is the fact that many crashes involving young pedestrians (particularly ages 5 to 9) occur on residential streets, whereas this study did not include school crossings and most sites were drawn from collector and arterial streets (where marked crosswalks exist), which are less likely to be frequented by unescorted young children.

Also, some of the young children counted in this study were crossing with their parents or other adults, which may have reduced their risk of a crash. Some of the possible reasons that older pedestrians are at greater risk when crossing streets compared to other age groups are that older adults are more likely (as an overall group) than younger pedestrians to have:

- Slower walking speeds (and thus greater exposure time).
- Visual and/or hearing impairments.
- Difficulty in judging the distance and speed of on-coming traffic.
- More difficulty keeping track of vehicles coming from different directions, including turning vehicles.
- Inability to react (e.g., stop, dodge, or run) as quickly as younger pedestrians in order to avoid a collision under emergency conditions (in some cases, due to prescription medication, which may affect judgment and/or the ability to react to motor vehicles).

Driver and Pedestrian Behavior at Crosswalks

16. A complementary study was conducted by Knoblauch et al.(5) on pedestrian and motorist behavior and also vehicle speed before and after crosswalk installation at sites in California, Minnesota, New York, and Virginia (on two-lane and three-lane streets) to help gain a better understanding of the effects of marked crosswalks vs. unmarked crossings. The study results revealed that very few motorists stopped or yielded to pedestrians either before or after marked crosswalks were installed. After marked crosswalks were installed, there was a small increase in pedestrian scanning behavior (before stepping out into the street). Also, there was approximately a 1-mi/h (1.6-km/h) reduction in vehicle speed after the marked crosswalks were installed.(5) These behavioral results from the Knoblauch et al. study tend to contradict the "false sense of security" claims attributed to marked

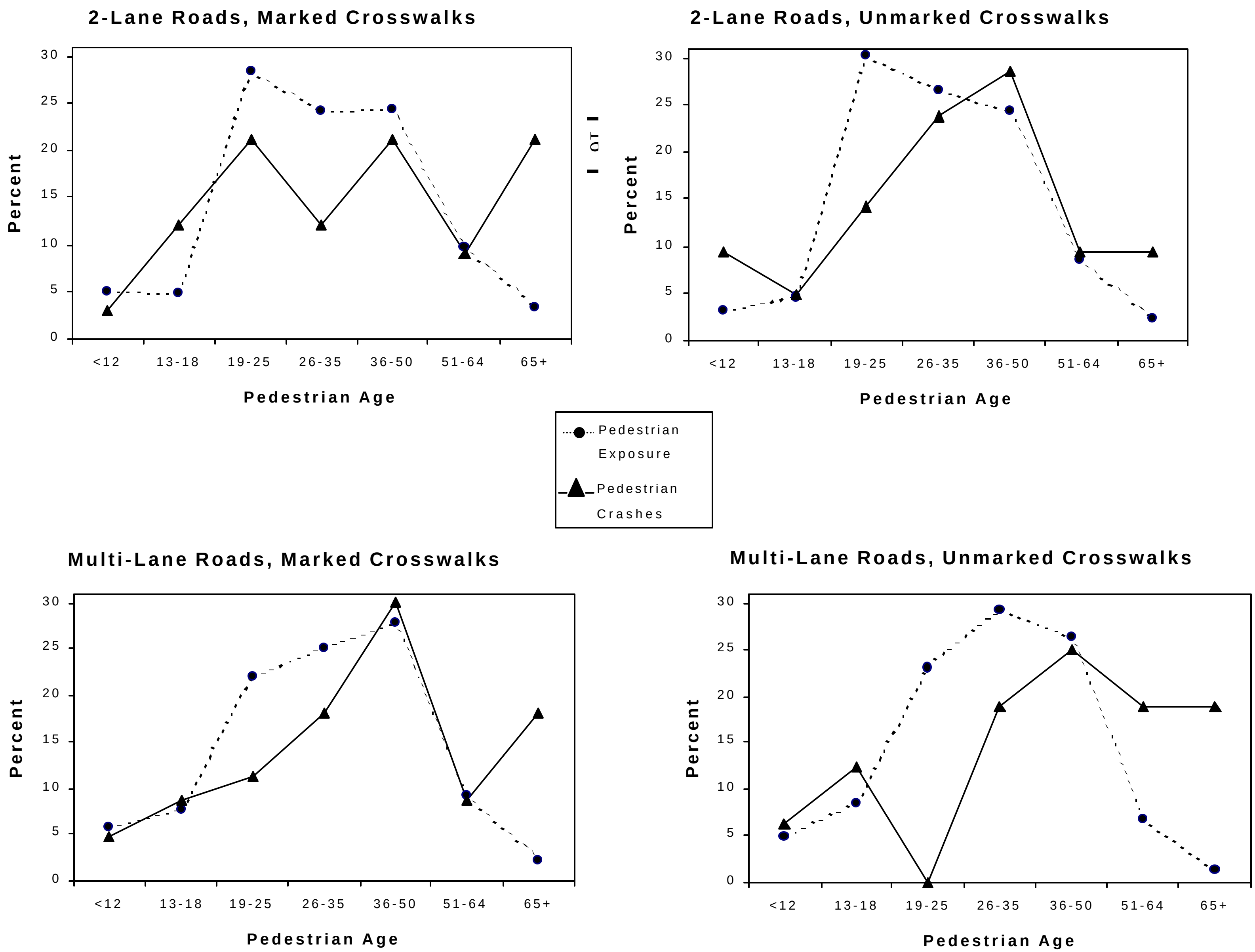


Figure 9. Percentage of crashes and exposure by pedestrian age group and roadway type at uncontrolled marked and unmarked crosswalks.

crosswalks, since observed pedestrian behavior actually improved after marked crosswalks were installed at the study sites. However, it should also be remembered that measures such as “pedestrian awareness” and “expectation that motorists will stop for them” cannot be collected by field observation alone. It should be mentioned that installing marked crosswalks or other measures can affect pedestrian level of service if the measures increase the number of motorists who stop and yield to pedestrians. Future studies using focus groups of pedestrians and also questionnaires completed by pedestrians in the field could shed light on such measures.

STUDY CONCLUSIONS AND RECOMMENDATIONS

Pedestrians are legitimate users of the transportation system and they should, therefore, be able to use this system safely. Pedestrian needs in crossing streets should routinely be identified, and appropriate solutions should be selected to improve pedestrian safety and access. Deciding where to mark crosswalks is only one consideration in meeting that objective. The study results revealed that under no condition was the presence of a marked crosswalk alone at an uncontrolled location associated with a significantly lower pedestrian crash rate compared to an unmarked crosswalk. Furthermore, on multi-lane roads with traffic volumes greater than 12,000 vehicles per day, having a marked crosswalk was associated with a higher pedestrian crash rate (after controlling for other site factors) compared to an unmarked crossing. Therefore, adding marked crosswalks alone (i.e., with no engineering, enforcement, or education enhancement) is not expected to reduce pedestrian crashes for any of the conditions included in the study. On many roadways, particularly multi-lane and high-speed crossing locations, more substantial improvements are often needed for safer pedestrian crossings, such as providing raised medians, installing traffic signals (with pedestrian signals) when warranted, implementing speed-reducing measures, and/or other practices. In addition, development patterns that reduce the speed and number of multi-lane roads should be encouraged.

Street crossing locations should be routinely reviewed to consider the following available options:

- Option 1 - No special provisions needed.
- Option 2 - Provide a marked crosswalk alone.
- Option 3 - Install other crossing improvements (with or without a marked crosswalk) to reduce vehicle speeds, shorten crossing distance, or increase the likelihood of motorists stopping and yielding.

Since sites in this study were confined to those having no traffic signal or stop sign on the main road approaches, it follows that these results do not apply to crossings controlled by traffic signals, stop or yield signs, traffic-calming treatments, or other devices. They also do not apply to school crossings, since such sites were purposely excluded from the site selection process.

The results of this study have some clear implications on the placement of marked crosswalks and the design of safer pedestrian crossings at uncontrolled locations. These include:

1. Pedestrian crashes are relatively rare at uncontrolled pedestrian crossings (1 crash every 43.7 years per site in this study); however, the certainty of injury to the pedestrian and the high likelihood of a severe or fatal injury in a high-speed crash makes it critical to provide a pedestrian-friendly transportation network.

2. Marked crosswalks alone (i.e., without traffic-calming treatments, traffic signals with pedestrian signals when warranted, or other substantial improvement) are not recommended at uncontrolled crossing locations on multi-lane roads (i.e., 4 or more lanes) where traffic volume exceeds approximately 12,000 vehicles per day (with no raised medians) or approximately 15,000 ADT (with

raised medians that serve as refuge areas). This recommendation is based on the analysis of pedestrian crash experience, as well as exposure data and site conditions described earlier. To add a margin of safety and/or to account for future increases in traffic volume, the authors recommend against installing marked crosswalks alone on two-lane roads with ADT's greater than 12,000 or on multi-lane roads with ADT's greater than 9,000 (with no raised median). The authors of this study also recommend against installing marked crosswalks alone on roadways with speed limits higher than 40 mi/h (64.4 km/h). Instead, enhanced crossing treatments (e.g., traffic-calming treatments, traffic and pedestrian signals when warranted, or other substantial improvement) are recommended. Specific recommendations are given later in table 1 regarding installation of marked crosswalks and other crossing measures. It is important for motorists to understand their legal responsibility to yield to pedestrians at marked and unmarked crosswalks, which may vary from State to State. Also, pedestrians should use caution when crossing streets, regardless of who has the legal right-of-way, since it is the pedestrian who suffers the most physical injury in a collision with a motor vehicle.

3. On two-lane roads and lower volume multi-lane roads (ADT's less than 12,000), marked crosswalks were not found to have any positive or negative effect on pedestrian crash rates at the study sites. Marked crosswalks may encourage pedestrians to cross the street at such sites. However, it is recommended that crosswalks alone (without other crossing enhancements) not be installed at locations that may pose unusual safety risks to pedestrians. Pedestrians should not be encouraged to cross the street at sites with limited sight distance, complex or confusing designs, sites with certain vehicle mixes (many heavy trucks), or other dangers, without first providing them with adequate design features and/or traffic control devices.

4. At uncontrolled pedestrian crossing locations, installing marked crosswalks should not be regarded as a magic cure for pedestrian safety problems. However, they also should not be considered as a negative measure that will necessarily increase pedestrian crashes. Marked crosswalks are appropriate at some locations (e.g., at selected low-speed two-lane streets at downtown crossing locations) to help channel pedestrians to preferred crossing locations, but they should also have other roadway improvements (e.g., raised medians, traffic-calming treatments, traffic and pedestrian signals when warranted, or other substantial crossing improvement) when used at other locations. The guidelines presented in table 1 are intended to provide guidance for installing marked crosswalks and other pedestrian crossing facilities.

   Note that speed limit was used in table 1 in addition to ADT, number of lanes, and presence of a median. In developing the table, roads with higher speed limits (higher than 40 mi/h [64.4 km/h]) were considered to be inappropriate for adding marked crosswalks alone. This is because virtually no crosswalk sites where speed limits exceed 40 mi/h (64.4 km/h) were found in the 30 U.S. cities (and thus could not be included in the analysis). Also, high-speed roadways present added problems for pedestrians and thus require more substantial treatments in many cases. That may be why Germany, Finland, and Norway do not allow uncontrolled crosswalks on roads with high speed limits.[6]

5. For three-lane roads, adding marked crosswalks alone (without other substantial treatments) is generally not recommended for ADT's greater than 12,000, although exceptions may be allowed under certain conditions (e.g., lower speed roads).

6. If nothing else is done beyond marking crosswalks at an uncontrolled location, pedestrians will not experience increased safety (under any situations included in the analysis). This finding is in some ways consistent with the companion study by Knoblauch et al.[5] that found that marking a

Table 1. Recommendations for installing marked crosswalks and other needed pedestrian improvements at uncontrolled locations.*

Roadway Type (Number of Travel Lanes and Median Type)	Vehicle ADT ≤ 9,000			Vehicle ADT >9000 to 12,000			Vehicle ADT >12,000 - 15,000			Vehicle ADT > 15,000		
	Speed Limit**											
	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h	≤ 30 mi/h	35 mi/h	40 mi/h
2 Lanes	C	C	P	C	C	P	C	C	N	C	P	N
3 Lanes	C	C	P	C	P	P	P	P	N	P	N	N
Multi-Lane (4 or More Lanes) With Raised Median***	C	C	P	C	P	N	P	P	N	N	N	N
Multi-Lane (4 or More Lanes) Without Raised Median	C	P	N	P	P	N	N	N	N	N	N	N

* These guidelines include intersection and midblock locations with no traffic signals or stop signs on the approach to the crossing. They do not apply to school crossings. A two-way center turn lane is not considered a median. Crosswalks should not be installed at locations that could present an increased safety risk to pedestrians, such as where there is poor sight distance, complex or confusing designs, a substantial volume of heavy trucks, or other dangers, without first providing adequate design features and/or traffic control devices. Adding crosswalks alone **will not** make crossings safer, nor will they necessarily result in more vehicles stopping for pedestrians. Whether or not marked crosswalks are installed, it is important to consider other pedestrian facility enhancements (e.g., raised median, traffic signal, roadway narrowing, enhanced overhead lighting, traffic-calming measures, curb extensions), as needed, to improve the safety of the crossing. **These are general recommendations; good engineering judgment should be used in individual cases for deciding where to install crosswalks.**

** Where the speed limit exceeds 40 mi/h (64.4 km/h) marked crosswalks alone should not be used at unsignalized locations.

C = **Candidate sites for marked crosswalks**. Marked crosswalks must be installed carefully and selectively. Before installing new marked crosswalks, an engineering study is needed to determine whether the location is suitable for a marked crosswalk. For an engineering study, a site review may be sufficient at some locations, while a more in-depth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, etc. may be needed at other sites. It is recommended that a minimum of 20 pedestrian crossings per peak hour (or 15 or more elderly and/or child pedestrians) exist at a location before placing a high priority on the installation of a marked crosswalk alone.

P = **Possible increase in pedestrian crash risk may occur if crosswalks are added without other pedestrian facility enhancements.** These locations should be closely monitored and enhanced with other pedestrian crossing improvements, if necessary, before adding a marked crosswalk.

N = **Marked crosswalks alone are insufficient, since pedestrian crash risk may be increased due to providing marked crosswalks alone. Consider using other treatments, such as traffic-calming treatments, traffic signals with pedestrian signals where warranted, or other substantial crossing improvement to improve crossing safety for pedestrians.**

*** The raised median or crossing island must be at least 4 ft (1.2 m) wide and 6 ft (1.8 m) long to adequately serve as a refuge area for pedestrians in accordance with MUTCD and American Association of State Highway and Transportation Officials (AASHTO) guidelines.

crosswalk will not necessarily increase the number of motorists that will stop or yield to pedestrians. Research from Europe shows the need for pedestrian improvements beyond uncontrolled crosswalks. [10-11]

7. In some situations (e.g., low-speed, two-lane streets in downtown areas), installing a marked crosswalk may help consolidate multiple crossing points. Engineering judgment should be used to install crosswalks at preferred crossing locations (e.g., at a crossing location at a streetlight as opposed to an unlit crossing point nearby). Also, higher priority should be placed on providing crosswalks where pedestrian volume exceeds about 20 per peak hour (or 15 or more elderly pedestrians and/or children per peak hour).

8. Marked crosswalks and other pedestrian facilities (or lack of facilities) should be routinely monitored to determine what improvements are needed.

What Are Possible Measures to Help Pedestrians Cross Streets Safely?

9. Although simply installing marked crosswalks by themselves cannot solve pedestrian crossing problems, the safety needs of pedestrians must not be ignored. More substantial engineering and roadway treatments need to be considered, as well as enforcement and education programs and possibly new legislation to provide safer and easier crossings for pedestrians at problem locations. Transportation and safety engineers have a responsibility to consider all types of road users in roadway planning, design, and maintenance. Pedestrians must be provided with safe facilities for travel. A variety of pedestrian facilities have been found to improve pedestrian safety and/or ability to cross the street under various conditions.[7-22] Examples of some of these pedestrian improvements include:

- Providing raised medians (figure 10) or intersection crossing islands on multi-lane roads, which can significantly reduce the pedestrian crash rate and also facilitate street crossing. Also, raised medians may provide aesthetic improvement and may control access to prevent unsafe turns out of driveways. Refuge islands should be at least 4 ft (1.2m) wide (and preferably 6 to 8 ft [1.8 to 2.4 m] wide) and of adequate length to allow for pedestrians to stand and wait for gaps in traffic before crossing the second half of the street. When built, the landscaping should be designed and maintained to provide good visibility between pedestrians and approaching motorists.

Figure 10. Raised medians and crossing islands can improve pedestrian safety on multi-lane roads.

- Installing traffic signals (with pedestrian signals), where warranted (see figure 11).

Figure 11. On some high-volume or multi-lane roads, traffic and pedestrian signals are needed to better accommodate pedestrian crossings.

- Reducing the effective street crossing distance for pedestrians by narrowing the roads or by providing curb extensions (figure 12) and/or raised pedestrian islands at intersections.

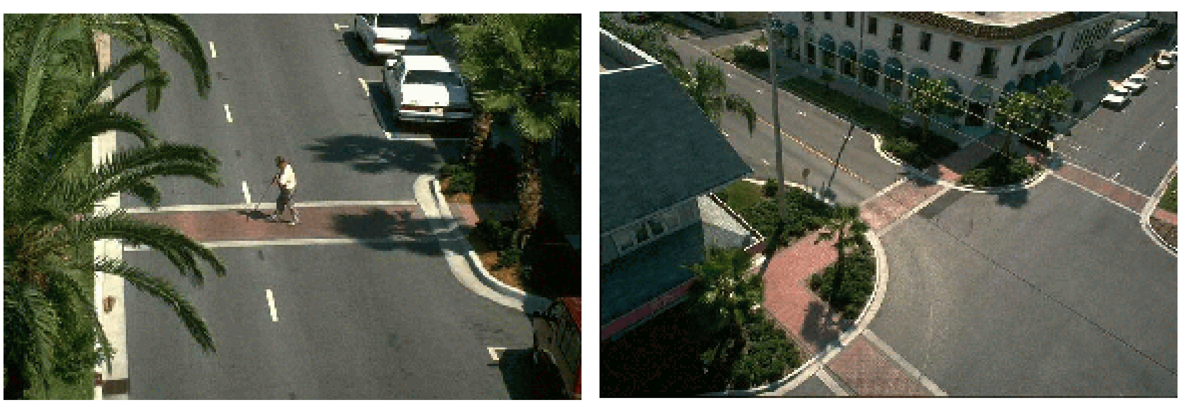


Figure 12. Curb extensions at intersections or midblock locations will shorten the crossing distance for pedestrians.

Another option is to reduce four-lane undivided road sections to two through-lanes with dual left-turn lanes or left-turn bays. Reducing the width of the lanes may result in slower speeds in some situations, which can benefit pedestrians who are attempting to cross the street. This creates enough space to provide median islands. The removal of a travel lane may also allow enough space for sidewalks and/or bike lanes.

- Installing traffic-calming measures may be appropriate on certain streets to slow vehicle speeds and/or reduce cut-through traffic, as described in the report entitled, *Traffic Calming: State of the Practice.*[17] Such measures may include:

    — Raised crossings (raised crosswalks, raised intersections) (see figure 13).

Figure 13. Raised crosswalks can control vehicle speeds on local streets at pedestrian crossings.

    — Street narrowing measures (chicanes, slow points, "skinny street" designs).
    — Intersection designs (traffic mini-circles, diagonal diverters).

  Some of these traffic-calming measures may not be appropriate on major collector or arterial streets.

- Providing adequate nighttime lighting for pedestrians (figure 14). Adequate nighttime lighting should be provided at marked crosswalks and areas near churches, schools, and community centers with nighttime pedestrian activity.

Figure 14. Adequate lighting can improve pedestrian safety at night.

- Designing safer intersections for pedestrians (e.g., crossing islands, tighter turn radii).

- Providing narrower widths and/or access management (e.g., consolidation of driveways).

- Constructing grade-separated crossings or pedestrian-only streets (see figure 15). It should be mentioned that grade-separated crossings are very expensive and should only be considered in extreme situations, such as where pedestrian crossings are essential (e.g., school children need to cross a six-lane arterial street), street crossing at-grade is not feasible for pedestrians, and no other measures are considered to be appropriate. Grade-separated crossings must also conform to Americans With Disabilities Act (ADA) requirements.

Figure 15. Grade-separated crossings are sometimes used when other measures are not feasible to provide safe ped crossings.

- Using various pedestrian warning signs, flashers, and other traffic control devices to supplement marked crosswalks (figure 16). However, the effects of supplemental signs and other devices at marked crosswalks are not well known under various roadway conditions. According to the MUTCD, pedestrian crossing signs should only be used at locations that are unusually hazardous or at locations where pedestrian crossing activity is not readily apparent.[2]

Figure 16. Pedestrian warning signs are sometimes used to supplement crosswalks.

- Building narrower streets in new communities to achieve desired vehicle speeds.

- Increasing the frequency of two-lane or three-lane arterials when designing new street networks so that fewer multi-lane arterials are required.

10. Whenever a marked crosswalk is installed on an uncontrolled multi-lane road (i.e., three or more lanes), consideration of an advance stop line is recommended at a point up to approximately 30 ft (9.1 m) in advance of the crosswalk along with the sign STOP HERE FOR CROSSWALK. The distance for the stop line and sign should be set based on vehicle speeds at each site, with lesser distances for lower speed approaches. This will encourage motorists to stop farther back from the crosswalk, thereby improving sight distance and stopping distance for approaching motorists in the adjacent lanes. Adding such advance stop lines with the STOP HERE FOR CROSSWALK sign has been found by Van Houten[18] to increase the percentage of vehicles that stop farther back from the crosswalk, which could reduce the likelihood of pedestrian multiple-threat collisions on multi-lane roads. Research is needed, however, to better quantify the effects of advance stop lines on driver behavior and pedestrian crashes.

11. It is recommended that parking be eliminated on the approach to uncontrolled crosswalks to improve vision between pedestrians and motorists.

12. Some agencies provide railings in the medians of multi-lane roads that direct pedestrians to the right and increase the likelihood of pedestrians looking for vehicles coming from their right in the second half of the street (figure 17).

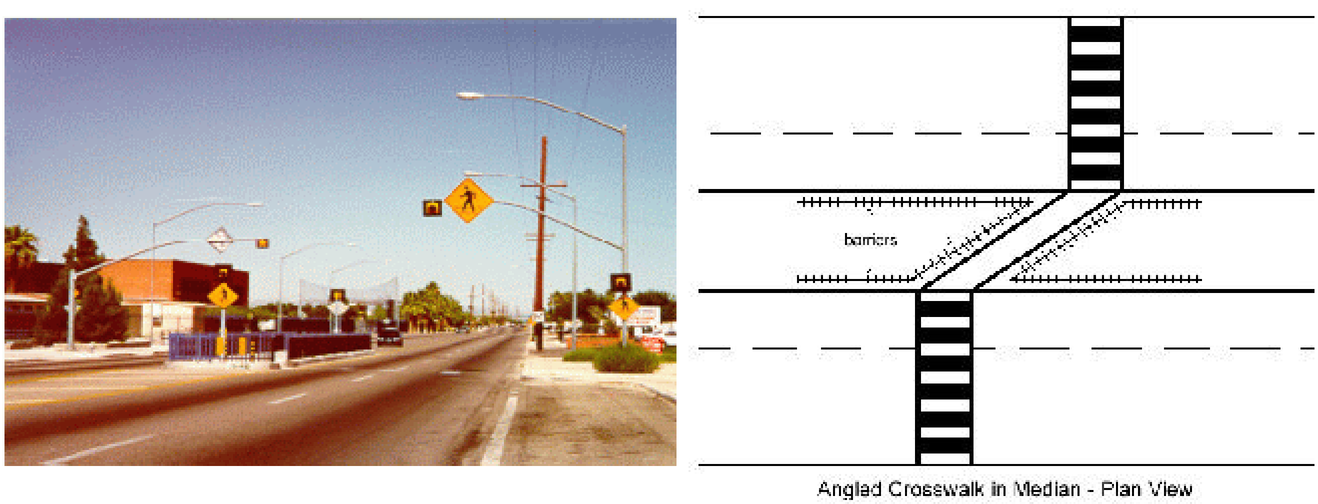


Figure 17. Railings in the median direct pedestrians to the right and may reduce pedestrian crashes on the second half of the street.

13. Proper planning and land use practices should be applied to benefit pedestrians. For example, busy arterial streets should be used as a boundary for school attendance or school busing. Major pedestrian generators should not be separated from each other or from their parking facilities by a busy street.

14. The current MUTCD pedestrian signal warrant should be reviewed to determine whether the warrant should be modified to more easily allow for installing a traffic signal at locations where pedestrians cannot safely cross the street (and where no alternative safe crossings exist nearby). Consideration must always include pedestrians with disabilities and proper accommodations must be provided to meet ADA requirements.

15. There should be continued research, development, and testing/explanation of innovative traffic control and roadway design alternatives that could provide improved access and safety for pedestrians attempting to cross streets. For example, in-pavement warning lights, variations in pedestrian warning and regulatory signs (including signs placed in the centerline to reinforce motorists yielding to pedestrians), roadway narrowing, traffic-calming measures, automated speed-monitoring techniques, etc. deserve further research and development to determine their feasibility under various traffic and roadway conditions.

More details about these and other pedestrian facilities are given in the *Pedestrian Facilities User's Guide: Providing Safety and Mobility*, recently developed for FHWA[19] and in the ITE publication *Design and Safety of Pedestrian Facilities*,[20] and ITE's *The Traffic Safety Toolbox* (Chapter 19, "Designing for Pedestrians").[21]

PROPOSED RECOMMENDATIONS FOR INSTALLING MARKED CROSSWALKS

Marked crosswalks serve two purposes: (1) they tell the pedestrian the best place to cross; and (2) they clarify that a legal crosswalk exists at a particular location.

Marked crosswalks are one tool to get pedestrians safely across the street. When considering marked crosswalks at uncontrolled locations, the question should not simply be: "Should I provide a marked crosswalk or not?" Instead, the question should be: "Is this an appropriate tool for getting pedestrians across the street?" Regardless of whether marked crosswalks are used, there remains the fundamental objective to get pedestrians safely across the street.

In most cases, marked crosswalks are best used in combination with other treatments. (e.g., curb extensions, raised crossing islands, traffic signals, roadway narrowing, enhanced overhead lighting, traffic-calming measures, etc.) Think of marked crosswalks as one of a progression of design treatments. If one treatment does not adequately accomplish the task, then move on to the next one. Failure of one particular treatment is not a license to give up and do nothing. In all cases, the final design must address the goal of getting pedestrians across the road safely.

Marked pedestrian crosswalks **may** be used to delineate preferred pedestrian paths across roadways under the following conditions:

1. At locations with stop signs or traffic signals. Vehicular traffic might block pedestrian traffic when stopping for a stop sign or red light; marking crosswalks may help to reduce this occurrence.

2. At non-signalized street crossing locations in designated school zones. Use of adult crossing guards, school signs and markings, and/or traffic signals with pedestrian signals (when warranted) should be used in conjunction with the marked crosswalk, as needed.

3. At non-signalized locations where engineering judgment dictates that the number of motor vehicle lanes, pedestrian exposure, average daily traffic (ADT), posted speed limit, and geometry of the location would make the use of specially designated crosswalks desirable for traffic/pedestrian safety and mobility. This must consider the conditions listed below and also in table 1.

Marked crosswalks alone are insufficient (i.e., without traffic-calming treatments, traffic signals and pedestrian signals when warranted, or other substantial crossing improvement) and should **not** be used under the following conditions:

1. Where the speed limit exceeds 40 mi/h (64.4 km/h).

2. On a roadway with four or more lanes **without a raised median or crossing island** that has (or will soon have) an ADT of 12,000 or greater.

3. On a roadway with four or more lanes **with a raised median or crossing island** that has (or will soon have) an ADT of 15,000 or greater.

Street crossing locations should be routinely reviewed to consider the following available options:

- Option 1 - No special provisions needed.

- Option 2 - Provide a marked crosswalk alone.

- Option 3 - Install other crossing improvements (with or without a marked crosswalk) to reduce vehicle speeds, shorten crossing distance, or increase the likelihood of motorists stopping and yielding.

The intent of table 1 is to provide initial guidance on whether an uncontrolled location might be a candidate for a marked crosswalk alone and/or whether additional geometric and/or traffic control improvements are needed. As a part of the review process for pedestrian crossings, an engineering study should be used to analyze such other factors, including (but not limited to), as gaps in traffic, approach speed, sight distances, illumination, the needs of special populations, and the distance to the nearest traffic signal.

The spacing of marked crosswalks should also be considered so that they are not placed too close together. Overuse of marked crosswalks may breed driver disrespect for them, and a more conservative use of crosswalks is generally preferred. Thus, it is recommended that in situations where marked crosswalks alone are acceptable (see table 1) a higher priority be placed on their use at locations having a minimum of 20 pedestrian crossings per peak hour (or 15 or more elderly and/or child pedestrians per peak hour). In all cases, good engineering judgment must be applied.

OTHER FACTORS

Distance of Marked Crosswalks From Signalized Intersections: Marked crosswalks should not be installed in close proximity to traffic signals, since pedestrians should be encouraged to cross at the signal in most situations. The minimum distance from a signal for installing a marked crosswalk should be determined by local traffic engineers based on pedestrian crossing demand, type of roadway, traffic volume, and other factors. The objective of adding a marked crosswalk is to channel pedestrians to safer crossing points. It should be understood, however, that pedestrian crossing behavior may be difficult to control merely by the addition of marked crosswalks. The new marked crosswalk should not unduly restrict platooned traffic, and should also be consistent with marked crosswalks at other unsignalized locations in the area.

Other Treatments: In addition to installing marked crosswalks (or in some cases, instead of installing marked crosswalks), there are other treatments that should be considered to provide safer and easier crossings for pedestrians at problem locations. Examples of these pedestrian improvements include:

- Providing raised medians (or raised crossing islands) on multi-lane roads.

- Installing traffic signals and pedestrian signals where warranted, and where serious pedestrian crossing problems exist.

- Reducing the exposure distance for pedestrians by:

    — Providing curb extensions.
    — Providing pedestrian islands.
    — Reducing four-lane undivided road sections to two through lanes with a left-turn bay (or a two-way left- turn lane), sidewalks, and bicycle lanes.

- When marked crosswalks are used on uncontrolled multi-lane roads, consideration should be given to installing advance stop lines as much as 30 ft (9.1 m) prior to the crosswalk (with a STOP HERE FOR CROSSWALK sign) in each direction to reduce the likelihood of a multiple-threat pedestrian collision.

- Bus stops should be located on the far side of uncontrolled marked crosswalks.

- Installing traffic-calming measures to slow vehicle speeds and/or reduce cut-through traffic. Such measures may include:

  — Raised crossings (raised crosswalks, raised intersections).
  — Street-narrowing measures (chicanes, slow points, "skinny street" designs).
  — Intersection designs (traffic mini-circles, diagonal diverters).
  — Others (see ITE Traffic-Calming Guide for further details).[17]

Some of these traffic-calming measures are better suited to local or neighborhood streets than to arterial streets.

- Providing adequate nighttime street lighting for pedestrians in areas with nighttime pedestrian activity where illumination is inadequate.

- Designing safer intersections and driveways for pedestrians (e.g., crossing islands, tighter turn radii), which take into consideration the needs of pedestrians.

In developing the proposed U.S. guidelines for marked crosswalks and other pedestrian measures, consideration was given not only to the research results in this study, but also to crosswalk guidelines and related pedestrian safety research in Sweden, Netherlands, Canada, Australia, England, Germany, Norway, and Hungary (see references 9-11 and 13-16). More details on these foreign guidelines and studies are provided in the full FHWA report.[4] More details on pedestrian facilities are given in the 1999 *Pedestrian Facilities User's Guide: Providing Safety and Mobility* for FHWA,[19] the ITE *Design and Safety of Pedestrian Facilities*,[20] the ITE *Traffic Safety Toolbox*,[21] and the City of Seattle guide *Making Streets That Work*,[22] among others.

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