Pedestrian Signal Safety for Older Persons

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LIST OF ABBREVIATIONS

Access Board	Architectural and Transportation Barriers Compliance Board
ADPV	average delay per vehicle
AVD	average vehicle delay
CORSIM	CORridor SIMulation
DW	DON'T WALK interval
FDW	flashing DON'T WALK interval
FHWA	Federal Highway Administration
G/C	green time to cycle length ratio
ITE	Institute of Transportation Engineers
LOS	level of service
LPI	leading pedestrian interval
MnDOT	Minnesota Department of Transportation
MOE	measure of effectiveness
MUTCD	*Manual on Uniform Traffic Control Devices*
MWS	mean walking speed
NCUTCD	National Committee on Uniform Traffic Control Devices
PATH	Portable Archival Traffic History
PCD	pedestrian countdown
PCI	pedestrian clearance interval
PCT	pedestrian clearance time
TAC	Transportation Association of Canada
TPS	traditional pedestrian signals
TRIS	Transportation Research Information Service
W	WALK interval

LIST OF DEFINITIONS

Access Board
The Access Board is an independent federal agency devoted to accessibility for people with disabilities. Created in 1973 to ensure access to federally funded facilities, the Access Board is now a leading source of information on accessible design. The Access Board develops and maintains design criteria for the built environment, transit vehicles, telecommunications equipment, and electronic and information technology. It also provides technical assistance and training on these requirements and on accessible design and continues to enforce accessibility standards that cover federally funded facilities.

Available Green Time
The available green time is the maximum time that can be allotted to the pedestrian signal interval based on existing signal timings and phasing. The available green represents the green intervals for the parallel streets. Available green times do not add up to the cycle length because of time allotted to exclusive phasing for turn movements, concurrent phasing for approaches on the same street (for example, northbound and southbound approaches), and yellow and red intervals.

Cycle Length
Cycle length is the time required to complete one sequence of signal indications (see *Manual on Uniform Traffic Control Devices for Streets and Highways, 2003 Edition.* 2003. Washington, DC: U.S. Department of Transportation).

Green Time to Cycle Length Ratio
The G/C ratio is the proportion of green time available for all traffic movements (other non-concurrent movements) after the pedestrian phase for a single crossing has been determined based on a given walking speed, cycle length, and crossing distance. Higher G/C ratios permit higher vehicle throughput and, many times, less time for pedestrians to cross a street. Conversely, lower G/C ratios permit lower vehicle throughput and, potentially, more pedestrian crossing time—many times with tradeoffs in vehicular intersection efficiency.

Interval
The interval is the part of a signal cycle during which the signal indications do not change (see *Manual on Uniform Traffic Control Devices for Streets and Highways, 2003 Edition.* 2003. Washington, DC: U.S. Department of Transportation).

Leading Pedestrian Interval
A leading pedestrian interval is equipment or new timing installed at signalized intersections to release pedestrian traffic in advance of turning vehicles for signals with protected left-turn movements or all movements for permitted left-turn movements. The WALK indication or WALKING PERSON symbol is displayed in advance of the green signal indication for vehicles (see Zegeer, C.V. et al. 2001. *Pedestrian Facilities Users Guide—Providing Safety and Mobility.* FHWA-RD-01-102. McLean, Virginia: Federal Highway Administration; Staplin, L., S. Lococo, S. Byington, and D. Harkey. 2001. *Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians.* FHWA-RD-01-051. McLean, Virginia: Federal Highway Administration; and Van Houten, R., R.A. Retting, C.M. Farmer, and J. Van Houten. 2000. Field evaluation of a leading pedestrian interval signal phase at three urban intersections. *Transportation Research Record* 1734).

Level of Service

LOS is a qualitative measure used to describe the operational condition of an intersection. LOS utilizes a rating system ranging from A to F, with A signifying the highest LOS, characterized by insignificant vehicular delay, and F signifying the lowest LOS, characterized by excessive vehicular delay. By definition, an intersection operating at its capacity is operating at LOS E.

National Committee on Uniform Traffic Control Devices

NCUTCD, or the National Committee, is an organization whose purpose is to assist in the development of standards, guides, and warrants for traffic control devices and practices used to regulate, warn, and guide traffic on streets and highways. NCUTCD recommends to the Federal Highway Administration (FHWA) and other appropriate agencies proposed revisions to and interpretations of the *Manual on Uniform Traffic Control Devices* (MUTCD) and other accepted national standards. NCUTCD develops public and professional awareness of the principles of safe traffic control devices and practices and provides a forum for qualified individuals with diverse backgrounds and viewpoints to exchange professional information.

Pedestrian Change Interval

An interval in which the flashing UPRAISED HAND (symbolizing DON'T WALK) signal indication is displayed. When a verbal message is provided at an accessible pedestrian signal, the verbal message is "wait" (see *Manual on Uniform Traffic Control Devices for Streets and Highways, 2003 Edition.* 2003. Washington, DC: U.S. Department of Transportation).

Pedestrian Clearance Time

PCT is the time provided for a pedestrian crossing in a crosswalk, after leaving the curb or shoulder, to travel to the far side of the traveled way or to a median. PCT is calculated by taking the length of the crosswalk and dividing it by the crossing speed.

Transportation Association of Canada

The Transportation Association of Canada is a national association with a mission to promote the provision of safe, secure, efficient, effective, and environmentally and financially sustainable transportation services in support of Canada's social and economic goals.

FOREWORD

ABOUT THE SPONSOR

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If trade or manufacturers' names are mentioned, it is only because they are considered essential to the object of this report, and their mention should not be construed as an endorsement. The AAA Foundation for Traffic Safety does not endorse products or manufacturers.

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EXECUTIVE SUMMARY

This study had two primary objectives: 1) to provide the supporting research to assist traffic engineers in understanding the walking characteristics of older pedestrians and 2) to provide more information on the extent to which various intersection operational conditions might be able to tolerate additional time for the pedestrian interval without sacrificing substantial efficiencies (and, conversely, the identification of intersection operational conditions that would provide significant degradation in the movement of vehicles).

This project addressed both objectives by answering the following questions:

- What are the walking speeds of pedestrians when crossing under signal control?
- How does walking speed differ with respect to age?
- Do pedestrians understand pedestrian countdown (PCD) signals? Do they prefer PCD signals or traditional pedestrian signals (TPS)?
- What are the impacts of countdown signals on pedestrian behavior and walking speed?
- How does the amount of time allocated for pedestrian intervals affect traffic operations such as vehicle delay?

The project objectives were accomplished through the following activities:

- A literature review on topics including the pedestrian walking task, pedestrian signal timing (especially as it relates to the needs of older pedestrians), pedestrian walking speed, and PCD signals.
- A survey of agencies to identify the state of the art and state of the practice in pedestrian signal timing and the use of pedestrian signals.
- An observational study of pedestrian walking speed and crossing behaviors at four intersections in each of six jurisdictions equipped with both TPS and PCD signals.
- A survey of pedestrians at those study sites.
- A traffic operations simulation using CORSIM to determine how the time allocated for pedestrian intervals affects intersection traffic operations.

LITERATURE REVIEW FINDINGS

- Older pedestrians had slower walking speeds than their younger counterparts. The mean walking speed (MWS) for older pedestrians (age 65 and older) varied among the studies from 3.19 feet/second (ft./sec.) to 4.60 ft./sec. The 15th-percentile walking speed varied from 2.20 ft./sec. to 4.00 ft./sec.

- Fitzpatrick, Brewer, and Turner found that the 15th-percentile walking speed was 3.03 ft./sec. and 3. 77 ft./sec., respectively, for older and younger pedestrians. The authors defined older pedestrians as persons older than 60 and younger pedestrians as persons under age 60. This study found a statistical difference in walking speeds between older and younger pedestrians. This study included 2,445 pedestrians at 42 sites in seven states (Fitzpatrick, Brewer, and Turner August 2005).

- Gates, Noyce, Bill, and Van Ee found that pedestrians older than 65 had a 15th-percentile walking speed of 3.02 ft./sec. Fewer than half of the older pedestrians observed in the study would be accommodated by traffic signals with pedestrian clearance intervals (PCIs) timed for walking speeds of 4.00 ft./sec. (Gates et al. 2006).

- Knoblauch found that the 15th-percentile walking speed was 3.19 ft./sec. and 3.08 ft./sec., respectively, when considering all older pedestrians and only those older persons who complied with the pedestrian signal (Knoblauch et al. 1995).

- The City of Berkeley, California conducted a study to evaluate potential impacts of new PCD signals on pedestrian behavior. The study concluded that overall pedestrian speed was 4.60 ft./sec. and 4.80 ft./sec. for traditional and countdown signals, respectively (City of Berkeley Office of Transportation).

WALKING SPEED RESULTS

- Older pedestrians walked slightly faster at intersections equipped with PCD signals at most of the sites in the study. MWS in the six jurisdictions ranged from 3.98 ft./sec. to 4.60 ft./sec. at traditional signals compared to 4.20 ft./sec. to 4.80 ft./sec. at PCD signals.

- Walking speeds for older pedestrians were generally slower than for younger pedestrians by approximately 0.80 ft./sec.

- Pedestrians with mobility impairments and without wheelchairs had appreciably slower walking speeds—their mean was 3.30 ft./sec. when averaged across all six jurisdictions.

- The 15th-percentile speeds for older pedestrians varied from 3.40 ft./sec. to 3.80 ft./sec. at traditional signals and, similarly, from 3.40 ft./sec. to 4.00 ft./sec. at PCD signals.

RESULTS FROM THE TRAFFIC OPERATIONS ANALYSIS

- Table ES-1 shows the descriptive effect on the change in vehicular delay for each level of service (LOS) for walking speeds of 3.50 ft./sec. and 3.00 ft./sec. The results are as follows:
  - Lowering pedestrian walking speeds to 3.50 ft./sec. or even 3.00 ft./sec. at intersections that operate at LOS A, B, or C would result in insignificant to minor increases in overall vehicular delay at the intersections.
  - Using a walking speed of 3.50 ft./sec. at intersections that operate at LOS D or E would cause minor to moderate increases in overall vehicular delay at the intersections.
  - Using a walking speed of 3.00 ft./sec. at intersections that operate at LOS D or E would cause moderate to major increases in overall vehicular delay at the intersections.
- Vehicle delay increased significantly when pedestrian times approached or exceeded the available minimum green times for the concurrent phase. This occurred most often on the major street approaches, which tended to be wider and, thus, had longer crossing distances resulting in a greater increase in the pedestrian clearance interval (PCI). Increased vehicle delays at intersections with reduced walking speeds primarily were due to delays on the major street approaches.
- Intersections with a slightly higher LOS in the base condition showed a more uniform increase in delay for each walking speed.
- Intersections operating closer to vehicle capacity, for example, LOS E in the base or existing condition, exhibited an exponential increase in vehicle delay with a pedestrian walking speed of 3.00 ft./sec.

Table ES-1. Increase in vehicular delay at intersections operating with level of service A to F due to changes in walking speed (WALK interval and flashing DON'T WALK interval).

Walking speed	Level of service					
	A	B	C	D	E	F
3.50 ft./sec.	Insignificant	Insignificant	Insignificant	Minor	Minor to moderate	Major
3.00 ft./sec.	Insignificant	Insignificant	Minor	Moderate	Major	Major

SIGNIFICANCE OF THIS STUDY'S FINDINGS FOR CURRENT PRACTICE

Overall, the results of this study support the proposed National Committee on Uniform Traffic Control Devices (NCUTCD) guidance for reducing overall pedestrian walking speeds for use in pedestrian signal timing from 4.00 ft./sec. to 3.50 ft./sec. In the jurisdictions studied, this clearly would be beneficial for older pedestrians and, in many cases, could be accommodated without causing significant increases in vehicular delay.

1. Based on the results observed in each jurisdiction, a walking speed of 4.00 ft./sec. would accommodate a pedestrian walking at the 15th-percentile walking speed for younger pedestrians in all jurisdictions studied.

2. A walking speed of 4.00 ft./sec. also would accommodate a pedestrian walking at the mean speed observed for older pedestrians in all of the jurisdictions studied but would not accommodate a 15th-percentile older pedestrian in any of the jurisdictions studied.

3. A walking speed of 3.50 ft./sec. still would not accommodate the 15th-percentile older pedestrian in all jurisdictions studied. However, at all intersections in this study, if the signal timing provided a 7-sec. WALK and a change interval based on 3.50 ft./sec., older pedestrians with walking speeds at the 15th-percentile of older pedestrians would be able to cross the intersection provided they left the curb within 3.00 sec. of the start of the WALK interval.

4. Modifying pedestrian signal timing to accommodate a 7-sec. WALK interval and a pedestrian clearance interval based on a walking speed of 3.50 ft./sec. should be feasible with minimal operational impacts.

5. Intersection delay can be expected to increase significantly when the total time for the pedestrian interval approaches or exceeds the available green times for the concurrent vehicular traffic phase. This occurs most often on the major street approaches, which tend to be longer.

6. Walking speeds of 3.00 ft./sec. also may potentially be accommodated by increasing traffic signal cycle lengths. This, however, may have negative impacts on pedestrians; shorter cycle lengths are preferred for pedestrian traffic so that wait time is shorter. Furthermore, extending cycle lengths may have detrimental effects on the surrounding roadway network if signals are coordinated. A coordinated traffic signal typically would have to remain coordinated to maintain operational efficiency. Therefore, the entire signal coordination system would require modification, which may be costly and may affect traffic patterns.

NEXT STEPS

The next revision to the *Manual on Uniform Traffic Control Devices* (MUTCD) is currently slated for 2009. Prior to the revision, the Federal Highway Administration (FHWA) will prepare a Notice of Proposed Amendments, inclusive of changes to pedestrian walking speed provisions. Additionally, FHWA will consider recommendations from the NCUTCD. Proposed NCUTCD recommendations pertaining to pedestrian signal timing are shown in Table 9.

This study supports the proposed NCUTCD guidance for reducing overall pedestrian walking speeds to 3.50 ft./sec. It is important to note that the proposed guidance includes options to increase or decrease the pedestrian walking speed based on specific pedestrian characteristics and available pedestrian signal hardware at intersections.

There is a need for guidance regarding when to use pedestrian countdown (PCD) signals. This current study focused on a few communities that have developed criteria for implementing PCD signals.

The scope of this study did not specifically investigate the impact of signal timing on blind, low-vision, or otherwise disabled pedestrians and their use of pedestrian-accessible signals. Future studies should convene focus groups to develop parameters of future efforts that would consider the start-up time and walking speed differences of these pedestrian subgroups.

INTRODUCTION

Three major trends contribute to the need for better understanding and better design of traffic signals for older pedestrians: 1) the aging population; 2) the desire to make communities more livable and walkable; and 3) the number of pedestrian injuries and fatalities.

Increasingly, citizens are petitioning community leaders and transportation professionals to make communities more walkable. In the United States, the proportion of the population over age 65 is expected to increase from 12.4 percent (approximately 30 million) in 2000 to approximately 20 percent (an estimated 71.5 million) in 2030 (Federal Interagency Forum on Aging-Related Statistics).

In 2004, 4,641 pedestrians were killed in motor vehicle crashes. Of this number, 939 pedestrians (20 percent) were age 65 or older. Of the 939 older pedestrians killed, 80 percent were age 70 or older (Traffic Safety Facts 2004 Data, Pedestrians).

Given the expected population increase in people age 65 and older, this likely will be accompanied by an increase in highway injuries and fatalities for the same age group if the transportation community is not able to lower the risks faced by older road users, including older pedestrians.

Because of these trends, traffic engineers must respond with better designed intersections and traffic signals that are timed to meet the needs of pedestrians and vehicles. At many signalized intersections, pedestrian signals are used to provide pedestrians with a prescribed period of time during which they can cross the road. This is accomplished either through an exclusive pedestrian phase or concurrently with parallel traffic. Pedestrian signal indications consist of illuminated symbols such as a WALKING PERSON (symbolizing WALK and referred to subsequently as “WALK”) and an UPRAISED HAND (symbolizing DON’T WALK and referred to subsequently as “DON’T WALK” or as “flashing DON’T WALK” during the change interval).

The timing of the pedestrian clearance interval (PCI)—when flashing DON’T WALK (FDW) is displayed—is based on pedestrian walking speed and crossing distance. The *Manual on Uniform Traffic Control Devices* (MUTCD) prescribes 4.00 feet/second (ft./sec.) as a walking speed, with the allowance for a slower speed where there are users who are not capable of walking at that speed, such as older pedestrians (Federal Highway Administration 2003).

However, limited research has been done to provide traffic engineers with guidance on what walking speeds are appropriate for an aging population and when to use them. This is a key element for pedestrian safety. Only with sound research and guidance on pedestrian and vehicular issues can a traffic engineer adequately determine the appropriate balance regarding the provision of signal time for all users at an intersection.

In addition, there is considerable evidence that pedestrians do not fully comprehend the nuances of traditional pedestrian signals (TPS). As a result, some communities are experimenting with pedestrian countdown (PCD) signals. These signals provide a numerical display that counts down the change interval, which is displayed concurrently with the FDW symbol. This is depicted in Figure 1. However, little is understood about the impacts of PCD signals on pedestrian behavior and walking speed. This project was designed to address this knowledge gap as well.

Figure 1. Example of a pedestrian countdown signal.

WHY IS PEDESTRIAN WALKING SPEED SO IMPORTANT FROM AN OLDER PERSON'S PERSPECTIVE?

The Web site www.walkinginfo.org features an article entitled "The Design Needs of Senior Pedestrians," by Rebecca Johnson, which states: "Even the smallest design and engineering improvements can make a big difference… and for senior pedestrians… they can mean the difference between walking safely and confidently across the street—or waiting in traffic." (Pedestrian and Bicycle Information Center)

The walking speed set for signal operations is by far one of the most important design and operational parameters that can affect pedestrian-vehicular conflicts, pedestrian safety, and crashes at signalized intersections. All pedestrians and, in particular, those who are older or mobility-impaired, need to be provided with adequate time to cross the street safely and need to know that they have sufficient time to cross.

The current study and many previous studies suggest that there is at least a 0.70-ft./sec. walking speed difference between older and younger persons.

Figure 2 illustrates how important establishing adequate signal timing for pedestrians can be. This figure shows a 70-ft. street crossing from point A to point B. Given that older and younger pedestrians walk at different speeds, where will the older pedestrian be when his/her younger counterpart reaches the far curb?

Assuming that the younger pedestrian walks at 4.00 ft./sec. (the speed prescribed by the current edition of MUTCD) and the older pedestrian walks 0.70 ft./sec. slower, the older pedestrian would have more than 12 feet to walk—or another whole lane to cross—when the younger pedestrian had successfully crossed the street.

Figure 2. Senior Showcase Driver Roadway in Detroit, Michigan. Presentation to the North American Conference on Elderly Mobility, September 12, 2004. Source: Kimberly Lariviere.
Photo overlay: Edward Stollof. Note: Map not to scale

This study had two primary objectives: 1) to provide the supporting research to assist traffic engineers in understanding the walking characteristics of older pedestrians and 2) to provide more information on the extent to which various intersection operational conditions might be able to tolerate additional time for the pedestrian interval without sacrificing substantial efficiencies (and, conversely, the identification of intersection operational conditions that would provide significant degradation in the movement of vehicles).

This project addressed both objectives by answering the following questions:

- What are the walking speeds of pedestrians when crossing under signal control?
- How does walking speed differ with respect to age?
- Do pedestrians understand PCD signals? Do they prefer PCD signals or TPS?
- What are the impacts of countdown signals on pedestrian behavior and walking speed?
- How does the amount of time allocated for pedestrian intervals affect traffic operations such as vehicle delay?

Note: *Older persons were defined in this study as individuals age 65 and older. Younger persons were defined as individuals under age 65. Many studies define older and younger persons differently.*

METHODS

The project objectives were accomplished through the following activities:

- A literature review on topics including the pedestrian walking task, pedestrian signal timing (especially as it relates to the needs of older pedestrians), pedestrian walking speed, and pedestrian countdown (PCD) signals.

- A survey of agencies to identify the state of the art and state of the practice in pedestrian signal timing and the use of pedestrian signals.

- An observational study of pedestrian walking speed and crossing behaviors at four intersections in each of six jurisdictions equipped with both traditional pedestrian signals (TPS) and PCD signals.

- A survey of pedestrians at those study sites.

- A traffic operations simulation to determine how the amount of time allocated for pedestrian intervals affects traffic operations at each intersection.

This chapter discusses how each of these activities was pursued.

LITERATURE REVIEW

To provide background information on safely accommodating older pedestrians at intersections, recently published literature (within the last 20 years) was reviewed on topics including the pedestrian walking task, pedestrian signal timing (especially as it relates to the needs of older pedestrians), pedestrian walking speed, and PCD signals. This literature was identified through searching the Transportation Research Information Service and the Internet. This chapter provides a summary of the key findings from that review.

OVERVIEW OF PEDESTRIAN TASK

The pedestrian task for crossing an intersection can be described as including the following processes: expectation, perception, detection, cognition, selection, action, and reaction. Visual acuity and color perception are the main processing skills required to make safe judgments about when to cross the street at a signalized intersection. Reduced visual abilities can be assumed for nearly all older pedestrians. Reductions in auditory processing, motor functions, and cognition can complicate the process of crossing at intersections for older pedestrians (Gates et al 2006).

In 1995, Harkey explored the problems of older drivers and pedestrians at intersections. The author noted that elderly pedestrians (age 75 and older) were overrepresented in both left-turn and right-turn accidents. The author cited the following potential causes for this overrepresentation: increased exposure resulting from slower walking speeds; lack of understanding that vehicles may turn during their WALK interval; inability to react quickly enough to avoid turning vehicles; reduced vision; and too much reliance on the pedestrian signal alone (Harkey 1995).

PEDESTRIAN WALKING CHARACTERISTICS

Most transportation agencies calculate pedestrian interval durations for traffic signals based on pedestrian walking and crossing characteristics, namely pedestrian walking speeds. The current edition of the *Manual on Uniform Traffic Control Devices* (MUTCD) provides the following guidance:

> *The pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder during the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 1.2 m (4 ft.) per second, to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. Where pedestrians who walk slower than 1.2 m (4 ft.) per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 1.2 m (4 ft.) per second should be considered in determining the pedestrian clearance time.*

However, no further guidance or support is provided regarding what speed should be used or how to define or measure the proportion of slow walkers or wheelchair users, visually impaired or blind persons, or persons with other disabilities.

Empirical Data on Walking Speeds

In addition to consideration of mean walking speed (MWS), the 15th-percentile speed also is important. Fifteen percent of pedestrians walk at or slower than this speed. This is analogous to most 85th-percentile measures commonly used in traffic engineering and highway design—where 85 percent of the observed values fall within the capabilities of all users observed. Kell indicated that the 15th-percentile speed generally is an accepted value to use in timing signals for pedestrians (*Manual of Transportation Engineering Studies* 2000).

In *Older Pedestrian Characteristics for Use in Highway Design*, the authors provided empirical data on walking speeds for older pedestrians. Field studies were conducted to quantify the walking speed, start-up time, and stride length of pedestrians of various ages at 16 crosswalks in four urban areas. Walking speed was measured from when a pedestrian stepped off the curb until the pedestrian stepped up on the opposite curb. All pedestrians other than older pedestrians were considered younger pedestrians.

MWS for younger and older pedestrians was 4.95 feet/second (ft./sec.) and 4.11 ft./sec., respectively (Knoblauch et al. 1995). The 15th-percentile speed was 4.09 ft./sec. and 3.19 ft./sec. for younger and older pedestrians, respectively. These data also were stratified by city, pedestrian characteristics, signal and operational characteristics, geometric characteristics, and ambient conditions.

The report also provided MWS and 15th-percentile walking speeds for only those pedestrians who complied with the signal indication (pedestrians who started their crossing during the WALK indication at a pedestrian signal–equipped intersection and during a green signal for parallel traffic at all other intersections). MWS for compliers was 4.79 ft./sec. for younger pedestrians and 3.94 ft./sec. for older pedestrians. The 15th-percentile speed for compliers was 3.97 ft./sec. for younger pedestrians and 3.08 ft./sec. for older pedestrians.

Bowman and Vecellio measured pedestrian walking speeds at urban and suburban intersections in Atlanta, Georgia; Phoenix, Arizona; and Los Angeles–Pasadena, California. Pedestrians were classified into two age groups: pedestrians aged 18 to 60 and pedestrians older than 60. At signalized intersections, MWS was 4.46 ft./sec. for pedestrians aged 18 to 60 (based on 316 pedestrians) and 3.40 ft./sec. for pedestrians older than 60 (based on 44 pedestrians). The study also compared walking speeds at intersections with two-way left-turn lanes with walking speeds at intersections of undivided arterials. Pedestrians had higher walking speeds at the intersections with two-way left-turn lanes (Bowman and Vecellio 1994).

Coffin and Morrall conducted a study of walking speeds for pedestrians older than 60 at six field locations in Calgary, Canada: two pedestrian-actuated mid-block crosswalks, two crosswalks at signalized intersections, and two crosswalks at unsignalized intersections. Pedestrians were timed from when they stepped off the curb until they stepped onto the sidewalk at the other side. The measured distance for each intersection was the observed most-traveled path of pedestrians using the crosswalk. After pedestrians crossed the road, they were intercepted and asked if they had time to answer questions about the intersection. The interviews were used to determine pedestrians' age. Only those who consented to the interview were included in the study. MWS at the two signalized intersection crosswalks was 4.50 ft./sec. and 4.60 ft./sec. The 15th-percentile speed at the two signalized intersection crosswalks combined was 4.00 ft./sec. MWS at the signalized pedestrian-actuated mid-block crossings was 4.10 and 4.00 ft./sec., with a combined 15th-percentile speed of 3.30 ft./sec. (Coffin and Morrall 1995).

Rouphail summarized the recommendations related to pedestrian characteristics from the companion volume, *Review for Chapter 13, Pedestrians*, of the *Highway Capacity Manual*. This study concluded that "walking speeds need to be adjusted based on the proportion of older pedestrians at an intersection." Rouphail noted that the elderly proportion can materially affect the overall speed distribution of a facility (*Highway Capacity Manual* 2000).

Gates, Noyce, Bill, and Van Ee conducted a literature review as well as an analysis of walking speeds at 11 intersections in Madison and Milwaukee, Wisconsin. They found that pedestrians older than 65 had an MWS of 3.81 ft./sec. and a 15th-percentile speed of 3.02 ft./sec. For pedestrians of all ages taken together, MWS was 4.60 ft./sec. and the 15th-percentile speed was 3.78 ft./sec. They found that the 4.00-ft./sec. walking speed was the 58th-percentile walking speed for people older than 65. Fewer than half of the older pedestrians observed in the study would be accommodated by traffic signals with pedestrian clearance intervals (PCIs) timed for walking speeds of 4.00 ft./sec. (Gates et al. 2006).

Gates, Noyce, Bill, and Van Ee found that the traffic control condition had a significant effect on walking speed. At signalized intersections, pedestrians who began to cross under DON'T WALK (DW) or flashing DON'T WALK (FDW) indications crossed approximately 0.50 to 0.60 ft./sec. faster than those who began to cross under the WALK indication. The authors suggested that this finding indicated that pedestrians understand that the FDW indication implies the impending release of oncoming traffic and that pedestrians can walk at a slightly faster pace if necessary.

The Gates, Noyce, Bill, and Van Ee study found that there was a statistically significant effect on walking speed when looking at two variables concurrently—traffic control condition and age. Older pedestrians walked slowest at stop-controlled crossings; all other ages walked slowest under the WALK indication of a signalized intersection.

The City of Berkeley, California installed PCD signals between December 2002 and March 2004 at various intersections throughout the city in an effort to enhance pedestrian safety at street intersections (crosswalks). Because the PCD signals were considered non-standard traffic control devices, the City of Berkeley was obligated to conduct a study for the California Traffic Control Devices Committee to evaluate potential impacts of the new signals on pedestrian behavior at the crosswalk, levels of compliance, and conflicts between pedestrians and vehicles (City of Berkeley Office of Transportation).

From an overall walking speed standpoint, the PCD timers did not appear to have an obvious impact on the manner in which pedestrians crossed streets (walk versus run). Pedestrian speed showed only a small improvement from 4.60 ft./sec. to 4.80 ft./sec. The study concluded that pedestrians might have quickened their steps as they saw the remaining time winding down.

Fitzpatrick, Brewer, and Turner, in TCRP D-08/NCHRP 3-71, collected walking speed data from approximately 2,445 pedestrians at 42 study sites in seven states. The field studies included nine different types of pedestrian crossing treatments. The study conclusions were as follows:

- Walking speed values for older pedestrians were lower than for younger people. For younger pedestrians and older pedestrians, the 15th-percentile walking speed was 3.77 ft./sec. and 3.03 ft./sec., respectively. For younger pedestrians and older pedestrians, MWS was 4.25 ft./sec. and 4.74 ft./sec., respectively. There was a statistical difference in walking speeds between older (older than 60) and younger (60 and younger) pedestrians.

- Fitzpatrick, Brewer, and Turner introduced an interesting concept of practical versus statistical differences. In sum, many of the differences in walking speed based on a number of variables may have been significant in terms of statistical significance. However, the values were so small that they would have been impractical for use in the field or the timing of a traffic signal; hence the term “practical differences.”

- Using population projections and 15th-percentile walking speeds for each population group older than 15, the proportionally weighted 15th-percentile walking speed for the year 2045 was 3.56 ft./sec. (for all pedestrians) (Fitzpatrick, Brewer, and Turner August 2005).

Recommended Walking Speeds

Based on the empirical studies reviewed, MWS for older pedestrians varied from 3.40 ft./sec. to 4.60 ft./sec. and the 15th-percentile speed for older pedestrians varied from 3.08 ft./sec. to 4.03 ft./sec.

In the *Pedestrian Facilities Users Guide—Providing Safety and Mobility*, Zegeer et al. recommended a maximum walking speed of 3.50 ft./sec. for the PCI and a walking speed less than 3.50 ft./sec. in areas with a heavy concentration of seniors or children (Zegeer et al. 2001).

In *Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians*, Staplin, Lococo, Byington, and Harkey recommended using an assumed walking speed of 2.80 ft./sec. for pedestrian signal timing to accommodate the shorter stride and slower gait of older pedestrians. This walking speed is lower than the lowest observed 15th-percentile speeds in the reviewed studies (Staplin et al. 2001).

ITE’s 2001 *Traffic Control Devices Handbook* suggested that, where walking speeds slower than a normal rate of 4.00 ft./sec. are known to occur frequently and where resources do not exist to undertake studies to establish the15th-percentile speed, a rate of 3.50 ft./sec. may be applied (*Traffic Control Devices Handbook* 2001).

LaPlante and Kaeser reviewed the history of how walking speeds were determined by MUTCD from 1948 to 2000 and summarized research on pedestrian walking speeds from 1950 to 2004 and the potential impact of various walking speeds on signal timing and capacity. Based on these three inputs, LaPlante and Kaeser recommended that a maximum walking speed of 3.50 ft./sec. be used to determine the PCI from curb to curb and a maximum walking speed of 3.00 ft./sec. be used to determine the entire WALK plus PCI (considering signal phasing of the total crossing from the top of the ramp to the far curb) (LaPlante and Kaeser 2004).

LaPlante and Kaeser presented these recommendations to the National Committee on Uniform Traffic Control Devices (NCUTCD) Signals Technical Committee in January 2004. At its meeting in 2006, NCUTCD voted to recommend these changes for the next edition of MUTCD.

NCUTCD made a proposal to the Federal Highway Administration (FHWA) MUTCD team regarding pedestrian walking speed. If adopted, the changes will occur in the 2009 edition of MUTCD. The recommended changes are shown in Table 1 and are included as an expanded version in Appendix J.

The Architectural and Transportation Barriers Compliance Board (Access Board) set forth a Notice of Availability of Draft Guidelines for accessibility within the Public Rights-of-Way on November 23, 2005. Section R305.3, entitled “Pedestrian Signal Phase Timing,” indicates that “all pedestrian signal phase timing shall be calculated using a pedestrian walking speed of 3.5 ft./sec. maximum. The crossing distance used in calculating pedestrian phase signal timing shall include the entire length of the crosswalk.”

Table 1: NCUTCD recommendations for MUTCD Section 4.E.10.

GUIDANCE ∞ Pedestrian clearance time is to start **at the end** of the WALK signal indication rather than **during** the WALK signal indication. ∞ Walking speed would be reduced from 4.00 ft./sec. to 3.50 ft./sec.
OPTION ∞ An option would be available to use 4.00 ft./sec. to evaluate the sufficiency of the pedestrian clearance time **if** there is equipment at the intersection such as extended pushbutton press or passive pedestrian detection for slower pedestrians to request a longer clearance time.
GUIDANCE ∞ Additional guidance is provided that indicates that a walking speed for pedestrian clearance time of less than 3.50 ft./sec. should be used if pedestrians who use wheelchairs routinely use the crosswalk or pedestrians routinely walk less than 3.50 ft./sec.
GUIDANCE ∞ This new provision provides guidance that would request that traffic engineers use a walking speed of 3.00 ft./sec. to calculate the WALK interval plus the PCI under the following conditions: o Start the calculation when the person is detected by a pedestrian detector or, if no detector is present, from a location 6 ft. back from the face of the curb or from the edge of the pavement at the beginning of the WALK signal indication; and o End the calculation of WALK time when the pedestrian has reached the far side of the traveled way being crossed. ∞ If the total crossing time calculated using the 3.00 ft./sec. guidance is longer than the sum of the PCI (as calculated using 3.50 ft./sec.) and the WALK interval, the WALK interval should be increased. ∞ For most applications on streets that are less than 100 ft. wide, WALK time plus pedestrian clearance time (as calculated using 3.50 ft./sec.) will meet or exceed the recommended total crossing time, especially when pedestrian detectors are located near the ramp and curb.

Pedestrian Start-Up Time

Pedestrian start-up time also should be considered in timing pedestrian intervals at a signal. The FHWA publication *Older Pedestrian Characteristics for Use in Highway Design* provides empirical data on pedestrian start-up times for younger and older (65 or older) pedestrians. Start-up time was defined as the period from when the WALK signal becomes illuminated until the pedestrian first steps off the curb to begin crossing. The mean pedestrian start-up time was 1.93 sec. for younger pedestrians and 2.48 sec. for older pedestrians. The 85th-percentile start-up time was 3.06 sec. for younger pedestrians and 3.76 sec. for older pedestrians (Staplin et al. 2001).

Fugger et al. observed pedestrians at signal-controlled intersections to determine their perception-reaction time to the crosswalk signal. Observations were recorded at six signal-controlled intersections in Los Angeles, California. Perception-reaction time was determined from the time of the illumination of the WALK signal to the initial movement off the curb. Older pedestrians (older than 55) had longer perception-reaction times than younger pedestrians. The report did not provide quantitative information on this difference (Fugger et al. 2000).

PEDESTRIAN COUNTDOWN SIGNALS

PCD signals provide information to the pedestrian regarding the amount of time remaining to safely cross the street. A countdown used in conjunction with conventional pedestrian signal indications during the FDW interval was approved for use in the 2003 edition of MUTCD. Section 4.E.07 provides the following standard:

> *If used, countdown pedestrian signals shall consist of Portland orange numbers that are at least 150 mm (6 in) in height on a black opaque background. The countdown pedestrian signal shall be located immediately adjacent to the associated UPRAISED HAND (symbolizing DW) pedestrian signal head indication.*
>
> *If used, the display of the number of remaining seconds shall begin only at the beginning of the PCI. After the countdown displays zero, the display shall remain dark until the beginning of the next countdown.*
>
> *If used, the countdown pedestrian signal shall display the number of seconds remaining until the termination of the PCI. Countdown displays shall not be used during the walk interval nor during the yellow change interval of a concurrent vehicular phase." (*Manual on Uniform Traffic Control Devices for Streets and Highways, 2003 Edition*)*

Although MUTCD specifies that the countdown should start at the beginning of the FDW, some installations of the signals also display the countdown during the WALK.

A recent survey of 194 jurisdictions in North America by the Traffic Operation and Management Standing Committee of the Transportation Association of Canada (TAC) found that more than 2,300 PCD signals were installed at more than 71 jurisdictions in 2003. An additional 360 were planned for installation in Canada and the United States in 2004. This trend likely will continue (An Informational Report on Pedestrian Countdown Signals 2004).

Pedestrian Understanding and Preference

Many researchers have surveyed pedestrians about how they like PCD signals and/or their understanding of the signal indication. Mahach, Nedzesky, Atwater, and Saunders evaluated six alternative pedestrian crossing signals for comprehension by 24 younger subjects (aged 18–25) and 24 older subjects (65 and older). One of the evaluated signals was a PCD signal. When compared to a standard pedestrian signal, the results suggested that the PCD signal was more easily understood. When asked to identify their favorite pedestrian signal, the majority of subjects selected the PCD signal. It should be noted that the PCD signal displayed the countdown indication during the WALK interval as well as during the FDW, which is not compliant with the 2003 edition of MUTCD (Mahach et al. 2002).

Allsbrook found a similar preference for PCD signals during on-street interviews at an installation in Hampton, Virginia. In December 1996, PCD signals were installed for pedestrians crossing the minor leg of one intersection. Supplemental informational signs were installed that explained the indications of the countdown signals. Pedestrians were interviewed about both TPS and PCD signals so that comparisons between the two types could be made. Based on the first 24 months of the survey, Allsbrook found that although only 48 percent of pedestrians noticed the countdown signal heads initially, 88 percent felt that the new signals were clearer than conventional signals (Allsbrook 1999).

Chester and Hammond found through a written survey that the vast majority of pedestrians understood the meaning of PCD signals. They surveyed 50 pedestrians at one intersection equipped with PCD signals in Orlando, Florida in April 1998. The survey included questions comparing the PCD signals to TPS. They found that the majority of the pedestrians who participated in the survey understood the meaning of the PCD signals. This was true for both English-speaking and non-English-speaking pedestrians (Chester and Hammond 1998).

Eccles, Tao, and Mangum conducted a survey of pedestrians at five intersections equipped with PCD signals in Montgomery County, Maryland in 2003. Surveys were administered on the street to pedestrians who had just crossed at the intersections equipped with PCD signals. In total, 107 pedestrians were surveyed regarding their awareness and understanding of the PCD signals. Pedestrians were asked if they noticed whether or not the pedestrian signal at the intersection was different from pedestrian signals in the surrounding area. If a pedestrian responded “yes,” he or she was asked to explain how the signal was different. Pedestrians whose response mentioned the countdown or “numbers” were considered aware of the PCD signal. Significant findings from this study included the following:

- The majority (68 percent) were aware of the PCD signal. Pedestrians were asked to explain the meaning of the numbers on the PCD signal. The majority (63 percent) understood the meaning of the countdown indication and correctly responded that the countdown indicated the seconds remaining to complete the crossing or to reach the median (if one existed). This was the correct response.

- An additional 32 percent responded that the countdown indicated the seconds remaining until the light turned red. Although this was not correct, it was a more conservative interpretation of time remaining to cross. Accepting this type of misunderstanding as a “safe answer,” 95 percent of the pedestrians understood the meaning of the countdown (Eccles, Tao and Mangum 2004).

Singer and Lerner conducted both a laboratory study and an observational study to determine the comprehension and preference for three types of pedestrian signals:

- a PCD signal with both the countdown and the flashing hand during the FDW interval;
- a PCD signal with the countdown but without the flashing hand during the FDW interval; and
- a traditional signal with only the flashing hand during the FDW interval.

In the laboratory study, participants were shown pictures of five different crossing scenarios for each of the three types of signals and were asked to provide the correct pedestrian behavior for each of the scenarios. Singer and Lerner found that:

- The PCD signal without the flashing hand caused the least amount of confusion, followed by the countdown signal with the flashing hand.
- The traditional signal with only the flashing hand caused the most confusion among study participants.
- When asked about their preference, participants were divided between the two types of PCD signals but preferred them to the traditional signal because they offered more information (Singer and Lerner 2005).

The TAC Traffic Operation and Management Standing Committee conducted a detailed literature review to determine the state of the practice of PCD signals. The various reviewed studies reported that between 26 percent and 80 percent of all pedestrians did not understand the meaning of the conventional FDW display. Conversely, these studies reported that 50 percent to 97 percent of pedestrians understood the meaning of PCD signals and 78 percent to 94 percent of pedestrians found PCD signals easier to understand than conventional signals. The overwhelming majority (80 percent to 92 percent) preferred PCD signals. The reported percentages came from various studies reviewed as part of TAC's effort. The studies likely were conducted in different regions of North America. As such, understanding of the signal indications likely varied by location *(An Informational Report on Pedestrian Countdown Signals* 2004).

The Minnesota Department of Transportation (MnDOT) conducted market research of PCD signals at five intersections in the Minneapolis and St. Paul, Minnesota area. MnDOT also surveyed pedestrians about their understanding of PCD signals. Definitions were developed to identify if a pedestrian was successfully serviced by the TPS and PCD signals.

For TPS, successful service was defined as: 1) a person who started crossing and completed crossing when the walking person/WALK was showing, or 2) a person who started crossing when the walking person/WALK was showing and completed crossing when the flashing hand/FDW was showing.

For PCD signals, successful service was defined as: 1) a person who started crossing and completed crossing when the walking person was showing, or 2) a person who started crossing when the walking person was showing and completed crossing when the flashing hand with numeric countdown was showing (Farraher 1999).

As shown in Table 2, 12 percent of pedestrians overall and 19 percent of pedestrians within the senior age group were successfully serviced by PCD signals. The teenage group showed the largest increase in successful service (38 percent) with the PCD signals in place.

Table 2. Percentage of pedestrians, by type, successfully completing pedestrian crossings under the traditional and countdown signal scenarios.

Signal type	Total	Seniors	Other adults	Teens
TPS	67	57	72	53
PCD signals	75	68	78	73
Difference (numeric/percentage)	8 (11.9)	11 (19.2)	6 (8.3)	20 (37.7)

Effect on Pedestrian Behavior

Although there have been multiple studies on pedestrian understanding or preference for countdown signals, few published studies have reported on the effect on pedestrians. Leonard and Juckes found that PCD signals discouraged pedestrians from crossing at the end of the observed interval and encouraged pedestrians to accelerate their pace toward the end of the interval (Leonard and Juckes 1999).

Huang and Zegeer used a treatment and control study design to evaluate the effect of PCD signals at two intersections in Lake Buena Vista, Florida. One crosswalk in each intersection was equipped with a PCD signal. These intersections were matched with one or two nearby comparison intersections. Three measures of effectiveness were used:

- the number of pedestrians who complied with the WALK indication;
- the number of pedestrians who ran out of time when crossing the street; and
- the number of pedestrians who started running when the FDW signal appeared.

Huang and Zegeer found that compliance with the WALK indication was significantly lower at the crosswalks with PCD signals than at the comparison crosswalks, but they found no increase in the number of pedestrians still in the street when the steady DW signal was displayed. They also found a significant reduction in the percentage of pedestrians who started running during the FDW interval at the PCD signals. They interpreted this to mean that pedestrians were paying attention to the countdown timer display and were not confused as to the meaning of the PCD signal.

Notwithstanding the reduction in the percentage of pedestrians running during the FDW, the authors recommended that PCD signals should not be used at standard intersections in Florida because of the reduction in signal compliance with PCD signals. They suggested that PCD signals may be more promising at intersections frequented by an older adult population because of the value of the added information on the time available for crossing (Huang and Zegeer 2000).

Eccles, Tao, and Mangum observed pedestrian compliance with the pedestrian signal before and after PCD signals were installed at five intersections in Montgomery County, Maryland. They observed when pedestrians started their crossings and the number of phases with pedestrians remaining in the intersection at the release of conflicting traffic. Although two of the 20 crosswalks experienced a statistically significant decrease in the number of pedestrians who entered on WALK, six crosswalks experienced a significant increase. None of the intersections had a significant increase in the number of phases with pedestrians remaining in the intersection at the release of conflicting traffic. The authors concluded that the countdown displays did not negatively affect overall pedestrian crossing behavior (Eccles, Tao, and Mangum 2004).

Singer and Lerner conducted a before-and-after matched control site observational study to compare pedestrian behavior at countdown signals equipped with the countdown but not with the flashing hand during the FDW interval and at countdown signals equipped with both the countdown and the flashing hand during the FDW interval. The study showed that pedestrians crossed later during the FDW interval and were more likely to finish crossing later during the steady DW interval at the intersection with the countdown signal and without the flashing hand (Singer and Lerner 2005).

The TAC literature review also examined a number of studies that evaluated the effect of PCD signals on pedestrian behavior. Based on its review, it concluded that the effects of PCD signals on pedestrian crossing behaviors reported in the various studies were inconsistent.

Effect on Pedestrian Safety

Allsbrook conducted an evaluation of PCD signals at one intersection in Hampton, Virginia. In December 1996, PCD signals were installed only for crossing the minor legs of the intersection. In November 1998, PCD signals were installed for crossing the major legs of the intersection. Allsbrook evaluated three years of crash data at the intersection to determine if the PCD signals had any effect on crashes. The initial analysis indicated that the countdown devices did not contribute to an increase in crashes at this intersection. However, it should be noted that this analysis was based on only one intersection and a very short time period (Allsbrook 1999).

Eccles, Tao, and Mangum observed conflicts as a surrogate measure for pedestrian crashes as part of the previously mentioned study in Montgomery County, Maryland. The observational study of pedestrian-vehicle conflicts found a significant decrease in the proportion of pedestrians involved in conflicts with motor vehicles after the installation of PCD signals at four of the intersections where conflicts were observed (Eccles, Tao, and Mangum 2004).

The TAC literature review examined five studies that evaluated the effect of PCD signals on pedestrian-related crashes or conflicts. None of the studies reviewed found an increase in crashes or conflicts as a result of the installation of PCD signals.

PEDESTRIAN SIGNAL OPERATION

Providing a Pedestrian Interval

Huang and Zegeer recommended that fixed-time signals should be used when high pedestrian traffic exists during the day and actuated signals should be used when pedestrian crossings are intermittent. Shorter cycle lengths and longer walk intervals provide better service to pedestrians (Huang and Zegeer 2000).

Tian, Kacir, Vandehey, and Long compared two signal timing strategies at an intersection in Vancouver, Washington. The first strategy developed timings for the intersection based on vehicle minimums. The timings were based on vehicle volumes at the intersection and optimized the cycle and splits to accommodate the major movements. This required pedestrian actuation for pedestrians to receive the WALK interval and for the side street green to be long enough to accommodate pedestrians. This caused the signal controller to go out of coordination when pedestrians activated the signal to cross. The second timing strategy developed timings based on pedestrian minimums with sufficient phase splits to accommodate a pedestrian crossing at every phase. This timing plan would always remain in coordination.

If the pedestrian minimum strategy was employed, the authors recommended that traffic engineers use a lead/lag phasing scheme for the side street compared to a normal dual left. Additionally, they recommended use of the maximum recall feature of signal controllers in conjunction with the timing plans to achieve better queue management (Tian et al. 1999).

Calculating Signal Timings

MUTCD provides guidance that the WALK interval should be at least 7 sec. in length so that pedestrians will have adequate opportunity to leave the curb or shoulder before the PCI begins. The PCI should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder during the WALK indication to travel at a walking speed of 4.00 ft./sec. to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. MUTCD provides additional guidance that a walking speed of less than 4.00 ft./sec. should be considered in determining the PCI where pedestrians walk slower than 4.00 ft./sec. or pedestrians who use wheelchairs routinely use the crosswalk.

Kochevar and Lalani considered methods for calculating the total pedestrian phase time. They considered the minimum needs of side street green times, the optimization of main street progression, and the provision of safe pedestrian clearances for seven methods for calculating pedestrian phase times. Based on their review, they developed the following recommendations:

- A walking speed of 4.00 ft./sec. should be used except at intersections where a lower speed should be used, such as near housing for the elderly. The exact speed should be based on an engineering study, including field observations.
- The initial WALK interval should be 4 sec. unless, on average, groups of more than 10 pedestrians per cycle use a particular crosswalk for a significant number of cycles. In such cases, the WALK interval should be increased to 7 sec.
- The vehicle change interval should be included as part of the time provided for pedestrian clearance and should be displayed to pedestrians as a steady DW.
- The walking distance should be defined as between the center of the corner radius to the center of the farthest lane, including parking lanes.
- The following formula should be used to compute the total pedestrian phase:

$$Total\ \ pedestrian\ \ phase\ time = W + \left(\frac{D_4}{V_p} - Y - R \right)$$

where:

W = duration of WALK indication
D_4 = distance between the center of the corner radius to the center of the farthest lane
V_p = walking speed
Y = yellow interval duration
R = all-red interval duration

It should be noted that the recommendations of Kochevar and Lalani have not been adopted by MUTCD (Kochevar and Lalani 1985).

Virkler conducted field studies of high-volume two-way pedestrian crossings in Brisbane, Australia to determine appropriate pedestrian signal timing parameters. Based on observations of platoons of pedestrians crossing at four locations, Virkler recommended the following equation for calculating the WALK interval:

$$WALK\ duration = 3.2\ s + (0.57\ s/ped/m) \times \left(\frac{N_1}{W}\right)$$

where:

W = crosswalk width, in meters
N = primary platoon size

When more than 20 people are expected in a platoon, Virkler recommended the following equation to determine the total pedestrian phase (WALK plus FDW):

$$WALK + FDW = 3.2s + \frac{L}{1.2\ m/s} + (0.27\ s/ped) \times N_1$$

where:

N = primary platoon size
L = length to be crossed, in meters

This recommendation also has not been adopted by MUTCD (Virkler 1998).

Leading Pedestrian Intervals

Zegeer et al. suggested the use of a leading pedestrian interval (LPI). At intersections equipped with LPIs, pedestrians are given the WALK indication before motorists on the parallel approach receive the green indication. Pedestrians are more visible to motorists because they already are in the intersection before motorists start their maneuvers (Zegeer et al. 2001).

In *Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians*, Staplin, Lococo, Byington, and Harkey also recommend using an LPI at intersections with high pedestrian volumes, high turning-vehicle volumes, and no-turn-on-red control for parallel traffic. The following formula is provided for calculating the LPI duration:

$$LPI = \frac{(ML + PL)}{2.8}$$

where:

LPI = seconds between the onset of the WALK signal for pedestrians and the green indicator for vehicles, minimum 3-sec. duration
ML = width of moving lane, in ft.
PL = width of parking lane (if any), in ft. (Staplin et al. 2001)

Empirical evidence suggests that LPIs increase pedestrian safety. Van Houten, Retting, Farmer, and Van Houten evaluated the effect of a 3-sec. LPI on pedestrian safety at three urban intersections in St. Petersburg, Florida. Pedestrian behavior and conflicts were the measures of effectiveness. For both left-turning and right-turning vehicles, there were fewer conflicts during the LPI condition than during the baseline period. Van Houten, Retting, Farmer, and Van Houten concluded that the use of the LPI made it somewhat easier for pedestrians to cross the street by allowing them to occupy the crosswalk before turning vehicles were permitted to enter the intersection (Van Houten et al. 2000).

INTERSECTION OPERATIONS

At signalized intersections, various traffic movements compete for time within the cycle length provided. Pedestrian crossings at intersections represent one such traffic movement and are served by a pedestrian phase. The 2003 edition of MUTCD states:

> *Except as noted in the Option, the walk interval should be at least 7 seconds in length so that pedestrians will have adequate opportunity to leave the curb or shoulder before the pedestrian clearance time begins.*

The 2003 edition of MUTCD also states that the PCI should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder during the WALK interval to travel at a walking speed of 4.00 ft./sec. to at least the far side of the traveled way. Lowering the walking speed will result in a longer PCI and will potentially reduce the time available for other movements at a signalized intersection.

A recent study, “The Continuing Evolution of Pedestrian Walking Speed Assumptions,” showed how varying the walking speed on an individual approach to an intersection affected the available intersection green time (LaPlante and Kaeser 2004). The effects were demonstrated using cycle lengths ranging from 60 sec. to 120 sec. and street widths ranging from 40 ft. to 120 ft. The relationship between these variables was expressed by the remaining signal green time to cycle length ratio (G/C) available for all traffic movements after the pedestrian phase for a single crossing had been determined based on a given walking speed, cycle length, and crossing distance.

The G/C ratio is the proportion of green time available for other non-concurrent movements. Higher G/C ratios permit higher vehicle throughput and, many times, less time for pedestrians to cross a street. Conversely, lower G/C ratios permit lower vehicle throughput and, potentially, more pedestrian crossing time—often with tradeoffs in vehicular intersection efficiency.

Intersections with short cycle lengths (60 sec.) and wide street widths (120 ft.) resulted in low G/C ratios, from 0.20 to 0.37 for the different walking speeds examined. Conversely, intersections with long cycle lengths (120 sec.) and short crossing distances for pedestrians (40 ft.) resulted in higher G/C ratios, from 0.82 to 0.85. It was noted that most traffic engineering applications would involve G/C ratios between these ranges, where a balance must be struck between pedestrian phase needs and vehicle phase needs (LaPlante and Kaeser 2004).

Gates, Noyce, Bill, and Van Ee expanded the work of LaPlante and Kaeser and conducted studies that considered the impact of slower walking speeds on intersection efficiency. They concluded that:

- For intersection approaches where vehicular demand governs the amount of green time for through movements, a decrease in walking speeds is not likely to affect the amount of green time necessary to provide pedestrian clearance.
- Narrow intersections are less affected by walking speeds or cycle length.
- Longer cycle lengths do a better job of "absorbing" the impact of slower walking speeds on intersection efficiency.
- The use of slower walking speeds for timing PCIs should not have an overly negative impact on signalized intersection efficiency, as long as the cycle length is greater than or equal to 90 sec., the crossing distance is not excessively wide, and the intersection is not at capacity.
- Slower walking speeds may have a negative effect on vehicular traffic flows under the following conditions:
    - At intersection approaches where vehicular demand is low and pedestrian demand is high, a longer pedestrian clearance time likely will increase the green interval and the overall phase time for that approach. The longer phase will require either a reduction in other phase times, resulting in longer delays, or an increase in the cycle length, having potentially negative impacts on corridor progression.
    - Shorter cycle lengths
    - Wider crossings (Bowman and Vecellio 1994)

SUMMARY

The literature review provided information on published studies on PCD signals, pedestrian walking characteristics, and pedestrian signal operation.

Several studies have been conducted on PCD signals (Mahach et al. 2002; Allsbrook 1999; Chester and Hammond 1998; Eccles, Tao, and Mangum 2004; and Singer and Lerner 2005). Overall, pedestrians appeared to understand and prefer PCD signals to TPS. Studies of the effect of PCD signals on pedestrian behavior were inconclusive (Eccles, Tao, and Mangum 2004; Singer and Lerner 2005; Farraher 1999; and Leonard and Juckes 1999). Leonard and Juckes and MnDOT found a generally positive effect on pedestrian behavior (Farraher 1999; and Leonard and Juckes 1999).

Singer and Lerner and Huang and Zegeer found some negative effect on pedestrian behavior (Singer and Lerner 2005; and Huang and Zegeer 2000). Eccles, Tao, and Mangum concluded that the countdown did not negatively affect overall pedestrian crossing behavior (Eccles, Tao, and Mangum 2004).

Walking speed is important for calculating pedestrian intervals at intersections. The reviewed studies clearly agreed that older pedestrians had slower walking speeds than their younger counterparts. However, the empirical data on the walking speeds of older pedestrians varied greatly between the studies. The reported MWS for older pedestrians varied among the studies from 3.19 ft./sec. to 4.60 ft./sec. The 15th-percentile speed varied from 2.20 ft./sec. to 4.00 ft./sec.

Table 3 summarizes walking speed results from empirical studies within the literature by researchers for re-establishing walking speeds based on age, disability, traffic control condition, and pedestrian signal type.

Table 4 summarizes specific recommendations for walking speeds from various researchers. Several of the key recommendations concerning pedestrian walking speeds are described below:

- Coffin and Morrall suggested using design walking speeds of 3.30 ft./sec. for elderly pedestrians at signalized pedestrian-actuated mid-block crosswalks and 4.00 ft./sec. for elderly pedestrians at signalized intersections. At signalized intersections near seniors or nursing homes, they suggested using a walking speed of 3.30 ft./sec. (Coffin and Morrall 1995).

- Rouphail et al. recommended a pedestrian crosswalk walking speed value of 3.90 ft./sec. for most conditions, except in areas with large numbers of older pedestrians. The number of older pedestrians is considered “large” when the proportion of elderly pedestrians begins to materially affect the overall speed distribution at the facility. A crosswalk walking speed value of 3.30 ft./sec. should be used where the crosswalk incurs a usage of 20 percent or greater by elderly pedestrians. It was found that the 15th-percentile speed for the overall population will drop to 3.77 ft./sec. when the proportion of elderly pedestrians increases to 20 percent. Rouphail et al. recommended the use of the lower 3.30 ft./sec. value when the percentage of elderly using the facility in question exceeds 20 percent (*Highway Capacity Manual* 2000).

- Gates, Noyce, Bill, and Van Ee recommended using a walking speed of 3.80 ft./sec. for locations with normal demographics and walking speeds of 3.60 ft./sec., 3.50 ft./sec., 3.40 ft./sec., and 3.30 ft./sec. at intersections where the proportion of older pedestrians exceeds 20, 30, 40, and 50 percent of pedestrians, respectively. At intersections where nearly all of the pedestrians can be classified as “older pedestrians,” the authors recommended using a walking speed of 2.90 ft./sec (Gates et al. 2006).

- Fitzpatrick, Brewer, and Turner, in TCRP D-08/NCHRP 3-71, recommended the following: 3.50 ft./sec. for the general population and 3.00 ft./sec. for the older or less able population (Fitzpatrick, Brewer, and Turner August 2005).

Very few reported studies have evaluated walking speeds at intersections equipped with PCD signals. Additionally, studies about the effect of PCD signals on pedestrian behavior have reported inconsistent findings. This study addresses these knowledge gaps.

Table 3. Summary of empirical data on walking speeds.

Researcher	Condition	Older pedestrians		Younger pedestrians		All pedestrians	
		Walking speed (ft./sec.)					
		Mean	**15th-percentile**	**Mean**	**15th-percentile**	**Mean**	**15th-percentile**
Knoblauch et al. (study includes 2,081 young and 2,379 old pedestrians)	Age-only	**4.11**	**3.19**	**4.95**	**4.09**		
	Older pedestrians who entered on WALK	**3.94**	**3.08**				
	Younger pedestrians who entered on WALK			**4.79**	**3.97**		
	Road width (28–42 ft.)	**3.73**	**2.97**	**4.73**	**3.90**		
	Road width (43–51 ft.)	**4.01**	**3.16**	**4.77**	**4.01**		
	Road width (52–104 ft.)	**4.18**	**3.31**	**4.88**	**4.06**		
Fitzpatrick, Brewer, and Turner (TCRP D-08/ NCHRP 3-71)	Study included 42 study sites in 7 states; 2,441 pedestrians	**4.25**	**3.03**		**3.77**	**4.74**	**3.70**
	Median refuge present/not present					**4.87**	**4.80**
Akcelik & Associates (2001, Australia)	Pedestrian mid-block signalized crossings on four-lane undivided roads					**4.70**	**4.00**
Bowman and Vecellio	Age	**3.40**		**4.46**			
Coffin and Morrall	Two signalized intersections	**4.50/ 4.60**	**4.00**				
	Signalized, actuated mid-block crossings	**4.10/ 4.00**	**3.30**				

Table 3. Summary of empirical data on walking speeds.
(continued)

Researcher	Condition	Older pedestrians		Younger pedestrians		All pedestrians	
		Walking speed (ft./sec.)					
		Mean	15th-percentile	Mean	15th-percentile	Mean	15th-percentile
Gates,	Age	**3.81**	**3.02**			**4.6**	**3.78**
Noyce, Bill, and Van Ee	Traffic control condition: signalized intersection —WALK phase	**3.87**	**3.24**	**4.52**	**3.91**		
	Traffic control condition: signalized intersection —DON'T WALK phase	**4.30**	**3.45**	**4.96**	**4.21**		
	Traffic control condition: STOP-controlled intersection	**3.66**	**2.75**	**4.63**	**3.99**		
Rouphail et al. (1998 *Highway Capacity Manual*)	Facility where there are greater than 20 percent older pedestrians						**3.77**
1982 *Traffic Engineering Handbook*			**3.30**				
City of Los Angeles, California unpublished study (DOT)	Age		**3.82**				
Guerrier and Jolbois (1998)	Age	**3.19**	**2.20**	**4.42**	**3.31**		**3.09**
City of Berkeley, California pedestrian signal countdown signal study	TPS					**4.60**	
	PCD signal					**4.80**	
Range		**3.19–4.60**	**2.20–4.00**	**4.42–4.96**	**3.31–4.21**	**4.60−4.87**	**3.09–4.80**

Table 4. Summary of researcher recommendations on pedestrian walking speeds.

Researcher	**Condition**	**Older pedestrians**	**All pedestrians**
		Walking speed (ft./sec.) recommendations	
Knoblauch et al. (study includes 2,081 young and 2,379 old pedestrians)	Age-only	3.0	
Fitzpatrick, Brewer, and Turner (TCRP D-08/ NCHRP 3-71)	Study included 42 study sites in 7 states; 2,441 pedestrians		3.50
Coffin and Morrall	Two signalized intersections	4.0	
	Signalized intersections near seniors or nursing homes	3.3	
	Signalized, actuated mid-block crossings	3.3	
Rouphail et al. (1998 *Highway Capacity Manual*)	Facility where there are greater than 20 percent older pedestrians	3.3	3.9
Gates, Noyce, Bill, and Van Ee	Age	3.6 (20 percent > age 65) 3.5 (30 percent > age 65) 3.4 (40 percent > age 65) 3.3 (50 percent > age 65) 2.9 (100 percent > age 65)	3.8
2001 *Traffic Control Devices Handbook*	Where walking speeds slower than a normal rate of 4.0 ft./sec. are known to occur frequently and resources do not exist to undertake studies to establish a 15th-percentile speed	**3.5**	**3.9**
LaPlante and Kaeser	Minimum (curb-to-curb) for determining the pedestrian clearance interval; for use in accessibility guidelines	3.0	
	Use across the total crossing distance (top of ramp to far curb) for the entire WALK plus pedestrian clearance signal phasing	3.5	
Zegeer et al. (*Pedestrian Facilities User Guide*)	Population type; age	3.5	
Staplin, Lococo, Byington, and Harkey (*Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians*)	Recommended due to older pedestrians' shorter stride, slower gait, and exaggerated start-up time	2.8	
Range		2.8–4.0	3.50–3.9

AGENCY SURVEY

The project team conducted a Web-based survey of governmental organizations to identify the state of the art and the state of the practice in pedestrian signal timing and the use of pedestrian signals. The project team also requested information regarding PCD signals, including comprehension, number of countdown signals, advantages, and challenges. A copy of the survey instrument is included in Appendix A.

The e-mail survey was conducted between June 17 and June 29, 2004. There were 1,140 invitees. Invitees comprised members of the Institute of Transportation Engineers (ITE) employed in a public agency either at the local (city, county, or township) or state level. There were 599 visits to the electronic survey (53 percent of invitees viewed the survey), with an overall response rate of 16 percent (n = 182 responses).

As would be expected, not all responses contained answers to every question. Question 1 requested that the respondents indicate the level of privacy desired in exchange for completing the survey. A total of 43 respondents requested complete anonymity in terms of any publication or summary information that might contain information related to their jurisdiction.

Jurisdiction Selection

The criteria for selecting jurisdictions where the observational studies would be conducted included having: both traditional and PCD signals, a large proportion of seniors in the population, agencies that were willing to cooperate, and jurisdictions from various parts of the country. Using information from the agency survey as a starting point, followed by contacts with candidate agencies, the following jurisdictions were selected for the study:

- Broward County, Florida
- Minneapolis, Minnesota
- Montgomery County, Maryland
- White Plains, New York
- Salt Lake City, Utah
- Orange County, California

Detailed data and results from individual jurisdictions are presented in Appendices C–H of this Technical Report.

These agencies were contacted and agreed to participate in the study. The project team also ensured that the PCD signals installed in the jurisdiction were compliant with the 2003 edition of MUTCD. In other words, the countdown was only displayed during the FDW at these intersections.

SITE SELECTION/EFFECT OF DIFFERENT WALKING SPEEDS ON PEDESTRIAN CLEARANCE TIMES

Study Intersection Selection Process

In each jurisdiction, the project team worked with the local engineering staff and local AAA representatives(s) to select four intersections to be used in the study—two intersections equipped with PCD signals and two intersections equipped with TPS. The local engineering staff was asked to provide a list of approximately 20 intersections in the jurisdiction that had significant pedestrian activity. Other criteria that were considered included:

- Pedestrian volumes, particularly older pedestrian volumes
- Lack of any construction or other temporary impediments (such as street closures) that may affect pedestrian behavior
- Ability to sufficiently collect data
- Surrounding land use
- Comparability in walking environment at intersections
- Intersections that may have been operating "at or close to capacity." This was considered to explore the effect on capacity of increasing the pedestrian interval (by using a slower walking speed)
- Pedestrian signal timing parameters

Based on the above criteria, one of the four intersections also was selected to be a case study intersection. In the case studies, the WALK time and pedestrian clearance interval were compared to the available green time for walking speeds of 4.00, 3.50 and 3.00 feet/second to assess whether or not the intersection could accommodate each respective speed without modifying other signal operational parameters.

Pedestrian Behavior Data Collection

Pedestrian behavior data were collected using a Portable Archival Traffic History (PATH) video system. Each video system consists of a recording package and a camera enclosure. The recording package includes a time-lapse VCR and a power source. It is housed in weatherproof aluminum housing, as shown in Figure 3.

The camera systems are less conspicuous than observers in the field. Depending on the type of recording and the view needed, one or more cameras were mounted above the recording enclosure. Field deployment of a camera is shown in Figure 4. The project team installed the PATH system at each study intersection, with the exception of intersections in Orange County, California. Due to concerns for liability, the PATH systems were not used in Orange County. Instead, the pedestrian data were collected in the field by trained observers.

The PATH system was set to record peak pedestrian and vehicle activity, usually from 7:00 a.m. to 7:00 p.m. for one minor leg and one major leg at each intersection for one day. At a few intersections, more data were recorded due to concerns about obtaining an adequate sample size.

The taped recordings were taken back to the office and reduced. From the tapes, trained observers recorded pedestrian start-up times, pedestrian walking speeds, and pedestrian signal compliance. The observations were stratified for younger pedestrians and older pedestrians. The cameras were positioned to provide a close-up view of each pedestrian as he or she crossed the intersection. The observers were trained to look at physical attributes such as hair color and skin to determine age. This age classification was based on the visual inspection of the observer and should be considered an approximation.

Figure 3. Portable Archival Traffic History (PATH) video system.

Figure 4. Field deployment of the PATH camera video system.

Walking Speeds

The project team measured the crossing distance at each crosswalk from the edge of the curb in the middle of the marked crosswalk. This distance was considered the crossing distance at each intersection. The trained observers viewed the videos and used a stopwatch to determine the crossing time for each pedestrian. This was the time for the pedestrian to leave the curb on one side and reach the curb on the other side. This time was divided into the crossing distance to obtain walking speed in ft./sec. Pedestrians who left the influence area of the crosswalk (within 2 to 3 ft. of the edge of the crosswalk) during their crossing were excluded from the analysis. Joggers also were excluded from the analysis. However, pedestrians who started running to complete their crossing were not excluded.

Additionally, measurements of pedestrians with discernable vision or mobility impairments were identified. Examples included pedestrians who walked with a cane or were assisted by service animals. These measurements were not grouped by age.

Start-Up Time

Pedestrians who approached the intersection during the steady DW interval and waited for the WALK interval were observed to determine their start-up lost time. This is the time from when the WALK indication is displayed on the pedestrian signal until the pedestrian leaves the curb and starts his or her crossing. This start-up time is related to the pedestrian’s reaction to the signal timing. However, there could be other factors, such as turning vehicles still in the intersection, that may cause a pedestrian to delay his or her start across the intersection. No distinction was made between those who waited for turning vehicles and those who simply did not react to the signal as quickly.

Pedestrian start-up times were measured from the videotapes of pedestrian activity at one intersection in each jurisdiction. Pedestrian start-up was measured as the time from when the WALK interval was illuminated until the pedestrian stepped from the curb to the roadway.

Signal Compliance

The project team recorded pedestrian compliance to the pedestrian signal indication. Trained observers reviewed the tapes of pedestrian behavior for each intersection and recorded the number of pedestrians entering the intersection during the WALK, FDW, and steady DW indication during two hours of peak vehicle activity. Observations were recorded during the hours of peak vehicle activity because vehicle volumes at intersections likely affect pedestrian compliance to the signal. This is related to the opportunity to cross. That is, at an intersection with low vehicle volume, pedestrians are more likely to violate the pedestrian signal because there are more available crossing gaps.

PEDESTRIAN SURVEYS

A pedestrian survey was developed to gauge pedestrian preference for signal type and to determine if pedestrians understood the meaning of the PCD signals. The survey is included as Appendix B. Pedestrians were intercepted after they completed their crossing at countdown-equipped intersections and asked if they would like to participate in a brief survey on pedestrian safety. Pedestrians were asked if they noticed anything different about crossing at this intersection than at similar intersections. A follow-up question confirmed that the difference noted was the countdown signal. All surveyed pedestrians were asked to explain the meaning of the countdown indication and if they had a preference in pedestrian signals.

INTERSECTION OPERATIONS

The CORSIM traffic simulation software package was used for analyzing intersection operations. CORSIM simulates traffic operations based on a user-specified street network that details roadway geometry, lane use, traffic control devices, traffic volumes, turn movements, etc.

One case study intersection was selected in each of the jurisdictions for the pedestrian behavioral portion of the study. Simulation models were developed for each case study location to reflect existing or observed conditions. Simulated output measures of effectiveness—in particular, average delay per vehicle entering the intersection—were obtained from CORSIM and used to make quantitative and qualitative assessments of the traffic impacts of changing pedestrian walking speeds for each case study intersection. Each case study intersection was different in terms of traffic signal cycle lengths, traffic volume (demand), and geometric characteristics. These operational and geometric characteristics are included in the appendix for each case study.

Cycle length is an important characteristic of each intersection because it establishes the time available for all traffic movements (both vehicle and pedestrian). The 2003 edition of MUTCD defines cycle length as the time required to complete one sequence of signal indications. Typically, longer cycle lengths are used to accommodate higher vehicular traffic volumes so that the available green time is greater. Shorter cycle lengths are preferred for pedestrian traffic so that the wait time is shorter. At each intersection, cycle lengths were held constant. The range of cycle lengths modeled varied between 90 sec. and 150 sec. for the case study intersections.

For the case study intersection in California, traffic signal timing data and traffic volume data were not available. Only geometric data were obtained from the field visit; all other data were generated to simulate congested traffic conditions. For all other case study intersections, delay, queue length, start-up lost time, and volume data were collected during the field visits and used to calibrate and validate the existing condition simulation models.

RESULTS

AGENCY SURVEY FINDINGS

Detailed results of the agency survey are presented in Appendix A. Almost one-half of the respondents (86 of the 175 respondents, or 49 percent) already had pedestrian countdown (PCD) signals in place at the time of the survey (conducted during June 2004). Approximately 40 of the respondents (23 percent) planned to install PCD signals during the next five years. Approximately one in three respondents (28 percent) indicated that they had no plans to install PCD signals.

PEDESTRIAN COUNTDOWN SIGNAL START/END TIMES (AGENCY SURVEY QUESTIONS 17/18)

As shown in Figure 5, 62 percent of the organizations surveyed started the countdown at the beginning of the flashing DON'T WALK (FDW) and completed the countdown at the end of the FDW. Another 3 percent indicated that they started the countdown timer at the beginning of the FDW and ended during the steady DON'T WALK (DW). Taken together, these two responses show that about two of three respondents followed the guidance of the *Manual on Uniform Traffic Control Devices* (MUTCD); one-third were not operating their PCD signals in accordance with MUTCD at the time of the survey.

DO COUNTDOWN SIGNALS PROVIDE A HIGHER LEVEL OF SERVICE TO PEDESTRIANS?

Below are a few responses that illustrate what respondents view as a higher level of service for pedestrians:

- the ability to make a more informed choice that can help them adapt their behavior to ambient conditions;
- allowing pedestrians to cross during FDW (pedestrian can enter the crosswalk) at a [uniform] walking speed and still complete the crossing prior to the beginning of conflicting green;
- reduced delay for the pedestrian;
- a reduced number of pedestrians in the crosswalk at the onset of amber; and
- improved pedestrian compliance with WALK and FDW indications.

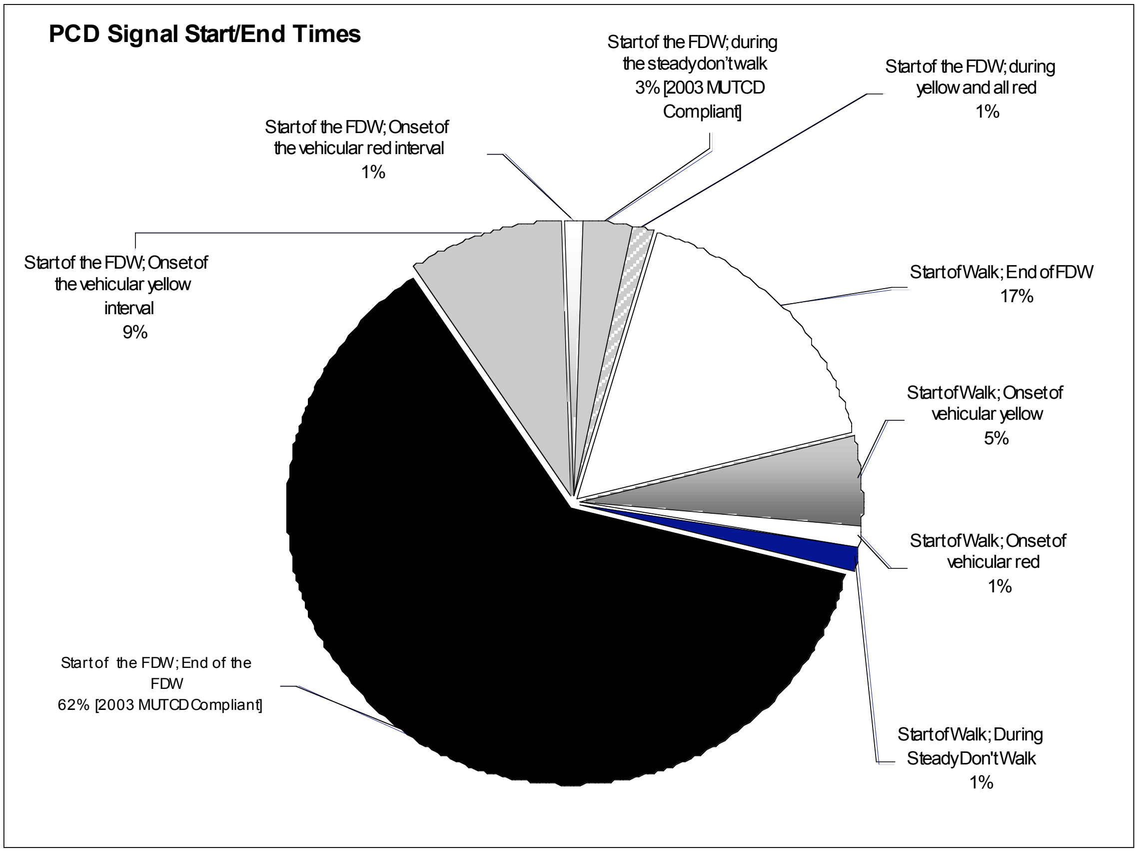

Figure 5. Pedestrian countdown signal start/end times.

LOCATION CRITERIA FOR CONSIDERING INSTALLATION OF PEDESTRIAN COUNTDOWN SIGNALS (AGENCY SURVEY QUESTION 16)

Most jurisdictions reported selectively installing PCD signals. Survey respondents were asked to identify areas where PCD signals should be used. As shown in Figure 6, respondents reported using these signals primarily in school zones, in downtown or urban areas, along pedestrian access routes or near pedestrian activity centers, in areas with a significant number of senior citizens, and in areas adjacent to transit stops or subway stations.

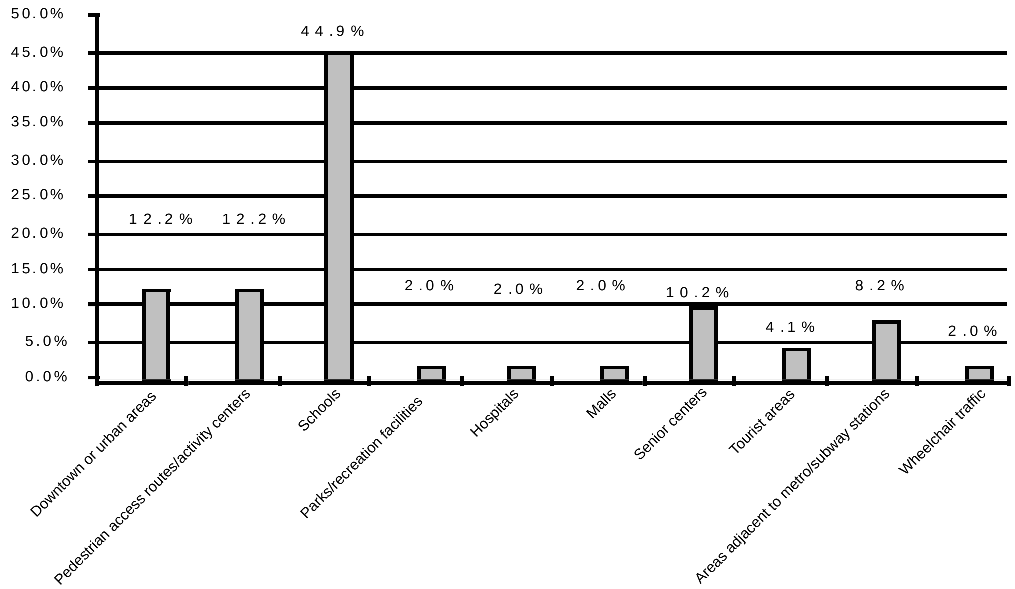

Figure 6. Location criteria for considering installation of pedestrian countdown signals.

PEDESTRIAN CHARACTERISTICS CONSIDERED FOR USE OF PEDESTRIAN COUNTDOWN SIGNALS

Respondents indicated that various pedestrian characteristics would serve as criteria for potential consideration of the use of PCD signals. Figure 7 shows the percentage of respondents who listed a particular pedestrian characteristic in making a decision to use the PCD signal device. As shown, “high pedestrian volumes” received the greatest number of responses (more than 57 percent). Just more than 20 percent of respondents indicated that PCD signals would be beneficial for senior or very young pedestrians. Other pedestrian characteristics listed in lower numbers included pedestrian crash history, ethnic diversity, inexperienced users, high pedestrian pushbutton usage, and high bicycle volumes.

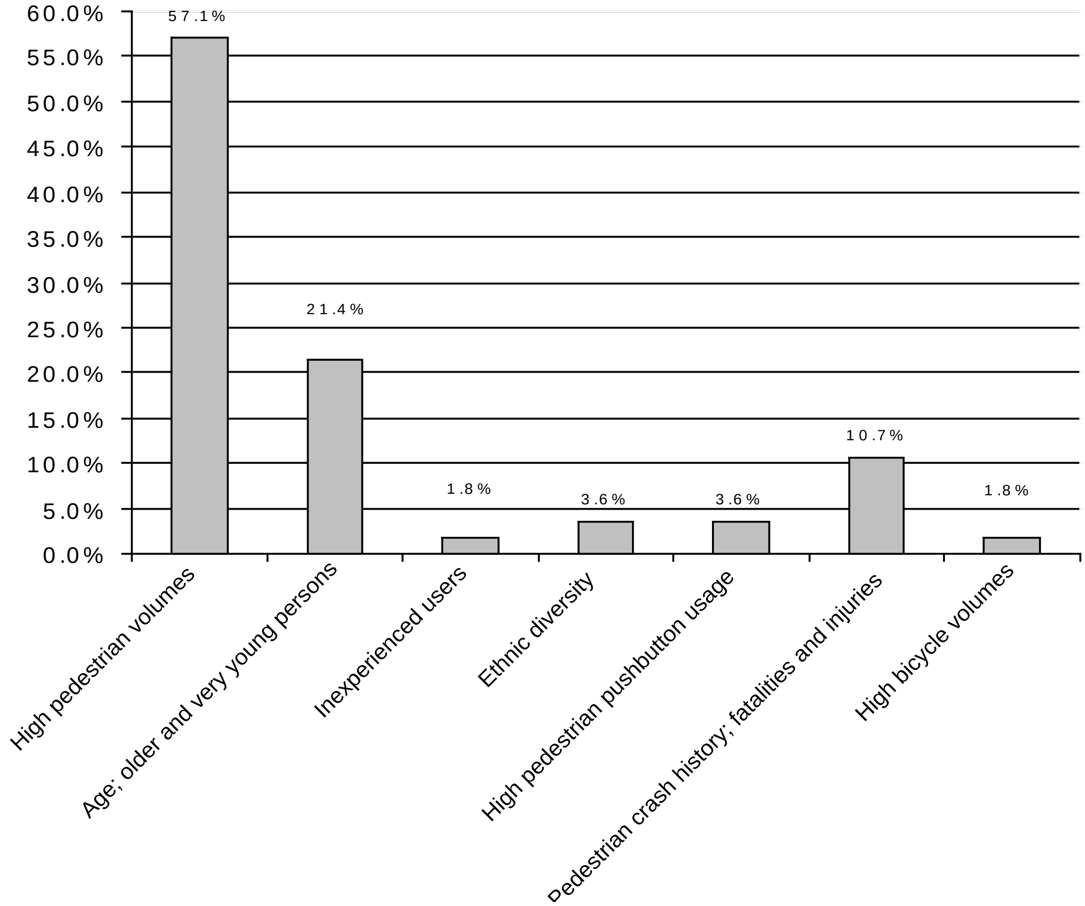

Figure 7. Pedestrian characteristics considered for use of pedestrian countdown signals.

POSITIVE IMPACTS OF PEDESTRIAN COUNTDOWN SIGNALS

Respondents were asked if there were any positive impacts of PCD signals. The stated positive impacts included:

- more time remaining to cross for faster than average pedestrians;
- understandability;
- a more informed choice as to whether to cross the street; thus, better decision-making in response to the pedestrian change indication;
- pedestrians can gauge their own crossing time by their abilities; pedestrians are able to "speed up" to clear the intersection;
- reduced pedestrian delay; and
- more pedestrians finishing the crossing during the clearance interval.

NEGATIVE IMPACTS OF PEDESTRIAN COUNTDOWN SIGNALS

The leading responses for negative impacts included an increase in pedestrians entering during the change interval and pedestrians running to cross the intersection.

CRITERIA AND POLICIES FOR USING PEDESTRIAN COUNTDOWN SIGNALS

Policies as to when PCD signals will be considered in a jurisdiction were reviewed. A summary of those policies and access to source documents are provided below.

Monroe County, New York

The Monroe County, New York Department of Transportation developed traffic operational criteria to assist in the decision to use a PCD signal or a traditional pedestrian signal (TPS). The county considered the influence of conflicting vehicles that could delay a pedestrian briefly during the FDW interval. Locations with heavier right-turning and left-turning vehicle volumes have a higher potential to delay a pedestrian's crossing. The "time remaining" information would be helpful in this situation to reassure a pedestrian that there is still adequate crossing time available for the completion of the crossing. The criteria include the following (full text of the draft policy is included in Appendix J):

- PCD signals are recommended where right-turning and left-turning volumes that conflict with the crosswalk are greater than 400 vehicles per hour.
- There is increased usefulness of the PCD signal as the crosswalk distance increases, especially in cases of extreme length. The county developed a threshold of at least a 60-foot (ft.) crossing distance to implement a PCD signal (Pond 2006).

City Of Oakland, California

Policies. Action 1.2.7. Consider using crossing enhancement technologies like PCD signals at the highest pedestrian volume locations (City of Oakland, California Pedestrian Master Plan).

City of Sacramento, California Pedestrian Safety Guidelines

Countdown signals are useful:

- At locations with crossing distances greater than 60 ft. and pedestrian clearance intervals (PCIs) greater than 15 seconds (sec.).
- At locations with high pedestrian volume.
- At wide streets with long clearance intervals, the countdown signal effectively communicates the amount of time left to cross the street. At wide streets with medians, there should be adequate crossing time for the pedestrian to traverse the entire distance and countdown signals should be used as a default.
- At actuated pedestrian signals, an additional, accessible pedestrian pushbutton should be located in the median. The countdown signal and median pushbutton should be used together wherever possible (City of Sacramento, California Pedestrian Safety Guidelines).

City of Monterey, California

Guidelines were outlined for the future implementation of pedestrian signal countdown devices. The following situations would justify the use of this device:

- Any crosswalk requiring a clearance interval of more than 15 sec.

The following circumstances may justify the use of pedestrian signal countdowns even if the interval is less than 15 sec.:

- o high pedestrian volume;
- o high levels of vehicular traffic presenting a hazardous pedestrian crossing;
- o a high percentage of pedestrians with walking disabilities and/or a high percentage of senior citizens, for example, near health centers, hospitals, and retirement communities; and
- o school zones. (City of Monterey, California Pedestrian Countdown Signal Guidelines)

State of Utah

Example Guidelines. Given that the feedback on countdown pedestrian indicators has been positive, continue to install them at signalized intersections.

- If it is necessary to prioritize, give top priority to recurrent and fatal pedestrian-vehicle crash sites. The sites are a subset of all signalized intersections in Utah; selected sites tended to have either high severity scores (fatalities or serious injuries) or more than seven pedestrian-vehicle crashes.
- Give second priority to signalized intersections along recurrent pedestrian-vehicle crash corridors.

- Give third priority to signalized intersections that feature regular pedestrian activity.

- Consider a policy that incorporates countdown pedestrian indicators and pedestrian indicators into all new traffic signals (Cottrell and Sichun).

PEDESTRIAN BEHAVIOR FINDINGS

Mean Walking Speed

Detailed results for each jurisdiction are presented in Appendices C through H, including approach level results. The results reported in the appendices include the mean, median, and 15th-percentile speeds. This section presents the results of the mean walking speed (MWS) and 15th-percentile walking speed in each jurisdiction.

Table 5 presents the walking speeds of younger pedestrians for each jurisdiction. Table 6 presents the walking speeds of older pedestrians for each jurisdiction. The tables present the combined MWS at both the traditional and the PCD-equipped intersections in each jurisdiction, the sample size collected, the difference in MWS (in ft./sec.) between traditional and PCD signals, and the results of the significance testing of the difference in MWS between intersections with TPS and intersections with PCD signals within each jurisdiction.

The results indicate:

- For younger pedestrians, MWS ranged from 4.80 ft./sec. to 5.30 ft./sec. at traditional signals and from 5.00 ft./sec. to 5.30 ft./sec. at countdown signals. Younger people walked faster or about the same at countdown signals. The slightly faster walking speeds observed at the countdown signal intersection may indicate that the countdown indication encouraged pedestrians to walk faster. Note that when a countdown signal is designed to conform with the current version of MUTCD, pedestrians who complete their crossing maneuvers during the WALK indication will not see the countdown display, so their behavior should not be affected by the fact that the signal in question is a countdown signal. However, in this study, crossing distances at most intersections were long enough that pedestrians would have seen the countdown display while crossing.

- For younger pedestrians in three of the jurisdictions, MWS at countdown signals was faster than at traditional signals. In the remaining study jurisdictions, MWS was faster in one jurisdiction at TPS as compared to countdown signals, and MWS was equal at traditional and PCD signals in two jurisdictions. This finding is significant and was based on 95-percent confidence testing.

- For older pedestrians, MWS ranged from 3.98 ft./sec. to 4.60 ft./sec. at traditional signals and from 4.20 ft./sec. to 4.80 ft./sec. at countdown signals. (Older people walked faster at countdown signals.)

- While there were three locations where MWS was slower for the older group, the three locations with faster mean speeds for the older group had statistically significant differences. This table reports statistical differences but does not provide practical differences. Note that although the difference in walking speeds of 0.10 ft./sec. in Minneapolis/St. Paul, Minnesota was statistically significant at 95-percent confidence, this difference may or may not be of practical significance. For a 100-ft. crossing, this difference in walking speed would result in less than 0.5 sec. of walking time.

- The study results indicate that both younger and older persons walked faster or approximately the same at countdown signals as compared to TPS.

Table 5. Combined results of mean walking speeds for younger pedestrians.

Table 5. Combined results of mean walking speeds for younger pedestrians.

Jurisdiction	Traditional (T)		Countdown (C)		Difference (T–C)	Is the difference significant at 95-percent confidence?
	Sample	MWS (ft./sec.)	Sample	MWS (ft./sec.)		
Broward County, Florida	193	5.30	248	5.10	0.20	No
Minneapolis/St. Paul, Minnesota	293	4.90	434	5.00	-0.10	Yes
Montgomery County, Maryland	354	5.30	340	5.30	0.00	No
Orange County, California	454	4.80	248	5.30	-0.50	Yes
Salt Lake City, Utah	183	4.90	371	5.30	-0.40	Yes
White Plains, New York	472	5.00	562	5.00	0.00	No

Table 6. Combined results of mean walking speeds for older pedestrians.

Jurisdiction	Traditional (T)		Countdown (C)		Difference (T–C)	Is the difference significant at 95-percent confidence?
	Sample	Mean (ft./sec.)	Sample	Mean (ft./sec.)		
Broward County, Florida	125	4.60	136	4.20	0.40	Yes
Minneapolis/St. Paul, Minnesota	33	4.00	68	4.30	-0.30	No
Montgomery County, Maryland	121	4.50	143	4.20	0.30	Yes
Orange County, California	136	4.20	164	4.80	-0.60	Yes
Salt Lake City, Utah	133	4.20	108	4.30	-0.10	No
White Plains, New York	110	4.30	160	4.50	-0.20	No

15th-Percentile Walking Speed

The 15th-percentile walking speed represents the slower pedestrians at the intersection. Table 7 presents the 15th-percentile speed for each jurisdiction stratified by signal type and pedestrian age. The 15th-percentile speeds for younger pedestrians varied from 4.10 ft./sec. to 4.60 ft./sec. at traditional signals and similarly from 4.10 ft./sec. to 4.70 ft./sec. at PCD signals. The 15th-percentile speeds for older pedestrians varied from 3.40 ft./sec. to 3.80 ft./sec. at traditional signals and similarly from 3.40 ft./sec. to 4.00 ft./sec. at PCD signals.

Based on the combined approaches in each jurisdiction, a clearance interval that is based upon a walking speed of 4.00 ft./sec. would accommodate the 15th-percentile younger pedestrian. A walking speed of 4.00 ft./sec. would not accommodate the 15th-percentile older pedestrian. A walking speed of 3.50 ft./sec. also would not be sufficient for the 15th-percentile pedestrian in all jurisdictions. A minimum of 3.40 ft./sec. would be needed to accommodate the 15th-percentile walking speed under traditional and PCD signals in all jurisdictions.

Table 7. Combined results of 15th-percentile walking speeds.

Jurisdiction	15th-percentile walking speed for younger pedestrians (ft./sec.)		15th-percentile walking speed for older pedestrians (ft./sec.)	
	Traditional	**Countdown**	**Traditional**	**Countdown**
Broward County, Florida	4.40	4.30	3.80	3.40
Minneapolis/St. Paul, Minnesota	4.20	4.40	3.40	3.70
Montgomery County, Maryland	4.60	4.60	3.60	3.50
Orange County, California	4.10	4.70	3.60	4.00
Salt Lake City, Utah	4.30	4.70	3.40	3.50
White Plains, New York	4.20	4.10	3.50	3.60
Range	4.10–4.60	4.10–4.70	3.40–3.80	3.40–4.00

Pedestrians with Impairments. Pedestrians with discernable mobility or visual impairments were recorded separately, regardless of their age. At the six jurisdictions combined, 154 pedestrians with impairments were observed for walking speed during the study periods. Table 8 lists walking speeds categorized by impairments. These data were not stratified by age, jurisdiction, or signal type because of the small sample size.

MWS was lowest for pedestrians with mobility impairments such as walking with a limp or cane. MWS averaged across the six jurisdictions was 3.30 ft./sec. for pedestrians with mobility impairments.

Table 8. Mean walking speeds for pedestrians with impairments, stratified by impairment.

Observed impairment	Pedestrians	MWS (ft./sec.)
Mobility impaired (walked with a cane, crutch, limp, or push cart)	93	3.3
Motorized wheelchair	28	5.1
Non-motorized wheelchair	9	4.5
Visually impaired	21	4.3
Other impairments	3	4.2

Compliance with the Pedestrian Signal

Pedestrian compliance with the pedestrian signal indication varied widely by intersection leg and was likely a result of the different volume levels and available crossing gaps at intersections. That is, compliance is likely to be lower at a low-volume minor street approach (major pedestrian movement crossing the minor street vehicle approach) than at a high-volume major street approach because there are fewer cars and, therefore, more gaps. This makes it difficult to attribute differences in signal compliance to the different pedestrian signal indications.

Tables 9 and 10 show the percentage of younger pedestrians and pedestrians age 65 and older entering on WALK, FDW, and DW at the study intersections in each jurisdiction. The traditional crossings and the PCD crossings were combined in each jurisdiction. The sample size for each jurisdiction was greater than 30 observations, with the exception of Minneapolis/St. Paul, Minnesota (for the population group age 65 and older).

Table 9. Pedestrian signal compliance for younger pedestrians by jurisdiction for traditional and pedestrian countdown signals.

Jurisdiction	Pedestrians entering intersection under different signal indications (percent)					
	Traditional			Countdown		
	W	FDW	DW	W	FDW	DW
Broward County, Florida	55	4	42	61	9	30
Minneapolis/St. Paul, Minnesota	72	13	15	62	12	26
Montgomery County, Maryland	44	13	43	67	11	22
Orange County, California	71	9	20	46	13	41
Salt Lake City, Utah	82	13	5	73	18	9
White Plains, New York	63	16	21	53	11	36

Table 10: Pedestrian signal compliance for older pedestrians by jurisdiction for traditional and pedestrican countdown signals.

Jurisdiction	Pedestrians entering intersection under different signal indications (percent)					
	Traditional			Countdown		
	W	FDW	DW	W	FDW	DW
Broward County, Florida	51	4	44	59	10	31
Minneapolis/St. Paul, Minnesota (N_{trad} = 12, N_{pcs} = 30)	100	0	0	67	10	23
Montgomery County, Maryland	71	4	26	74	10	17
Orange County, California	79	7	14	73	6	21
Salt Lake City, Utah	81	9	10	86	7	6
White Plains, New York	72	11	16	62	10	28

- In four and three of the six jurisdictions, respectively, there was greater compliance with the WALK indication for younger pedestrians compared to older pedestrians at traditional signals.

- For older pedestrians, the percentage entering on WALK was greater than 51 percent at all intersections and generally was greater than 70 percent.

- In three and three of the six jurisdictions, there was greater compliance with the FDW indication for younger pedestrians compared to older pedestrians at traditional signals.

- In four and three of the six jurisdictions, there was greater compliance with the DW indication for younger pedestrians compared to older pedestrians for countdown signals.

- For younger pedestrians in four of the six jurisdictions, the countdown intersections had a higher percentage of pedestrians entering on DW. This may be because these intersections were more likely to be pedestrian actuated. Most notably, the two PCD signals in Orange County, California were pedestrian actuated but the two traditional signals were not. The project team observed a higher level of noncompliance at intersections that were pedestrian actuated. The higher noncompliance at these pedestrian-actuated signals often was because pedestrians did not locate and push the pedestrian signal actuation button and, therefore, did not receive a WALK indication. Instead, they waited until they found a gap in traffic or until the parallel movement had the green indication.

- Older pedestrians generally had a higher rate of compliance than their younger counterparts at the same intersection.

Pedestrians Left in the Intersection

At the end of each FDW interval, the number of pedestrians remaining in the intersection was noted. Only pedestrians who entered during the WALK or FDW interval were included. Table 11 shows the number of younger pedestrians left in the intersection for each jurisdiction. The total number of pedestrians left in the intersection during the observation period is noted as a percentage of the number of pedestrians crossing at the intersection during the same period. The results are combined for traditional and countdown signals within each jurisdiction. The percentage of pedestrians remaining in the intersection was greater at traditional intersections than at countdown intersections in two of the jurisdictions; the percentage was greater at countdown intersections for three of the jurisdictions; and the percentage was the same (0 percent) at one of the jurisdictions.

Table 11. Younger pedestrians remaining in the intersection at the onset of the DON'T WALK interval.

Jurisdiction	Traditional		Countdown	
	Total pedestrians	Pedestrians left in intersection	Total pedestrians	Pedestrians left in intersection
Broward County, Florida	130	0 (0 percent)	275	1 (0 percent)
Minneapolis/St. Paul, Minnesota	223	28 (13 percent)	311	6 (2 percent)
Montgomery County, Maryland	1582	14 (1 percent)	1063	52 (5 percent)
Orange County, California	235	3 (1 percent)	208	13 (6 percent)
Salt Lake City, Utah	154	3 (2 percent)	541	21 (4 percent)
White Plains, New York	1459	143 (10 percent)	1682	132 (8 percent)

Table 12 shows the number of older pedestrians left in the intersection for each jurisdiction. With the exception of White Plains, New York, the number of older pedestrians remaining in intersections was of negligible difference for both traditional and countdown signal intersections. In White Plains, the percentage of pedestrians remaining in the intersection was approximately 10 percent for both types of intersections. There is no apparent explanation for why the percentages were so high in White Plains, other than the fact that the pedestrian population was different.

Note that in most cases, the number of pedestrians left in the intersection, as presented in Tables 11 and 12, was lower than the number of pedestrians who may have entered on FDW, as presented in Tables 9 and 10. This difference is because many pedestrians who entered on FDW were able to clear the intersection before the onset of the DW because they walked faster than the walking speed used to set the signal timing—generally faster than 4.00 ft./sec.

Table 12. Older pedestrians remaining in the intersection at the onset of the DON'T WALK interval.

Jurisdiction	Traditional		Countdown	
	Total pedestrians	Pedestrians left in intersection	Total pedestrians	Pedestrians left in intersection
Broward County, Florida	70	0 (0 percent)	150	1 (1 percent)
Minneapolis/St. Paul, Minnesota	12	1 (8 percent)	30	0 (0 percent)
Montgomery County, Maryland	78	1 (1 percent)	72	1 (1 percent)
Orange County, California	129	1 (1 percent)	110	2 (2 percent)
Salt Lake City, Utah	124	2 (2 percent)	94	2 (2 percent)
White Plains, New York	87	8 (9 percent)	164	17 (10 percent)

Start-Up Time

Pedestrian start-up time is related to the pedestrian's reaction to the signal timing, but it is not purely a measure of this. Start-up time varies greatly at different intersections due to other factors not related to the pedestrian's reactions, such as turning vehicles still in the intersection that may cause a pedestrian to delay his or her start into the intersection. Therefore, start-up time can be compared across age groups at a single intersection, but it cannot be compared across intersections.

Table 13 presents the start-up times recorded at one intersection in each of the six jurisdictions. The difference in start-up times was compared for younger and older pedestrians. Older pedestrians had a slower start-up time by 0.20 to 0.80 sec. The mean start-up times varied from 1.10 to 2.90 sec. The 2003 edition of MUTCD recommends 7 sec. of WALK prior to the FDW interval. This is ample time for a pedestrian with an average start-up time, in any of the jurisdictions and in either age group, to start crossing.

Table 13. Pedestrian start-up times for older and younger pedestrians.

Jurisdiction	Under 65 years of age		65 years of age and older		Difference (older–younger) (sec.)
	Sample	Mean (sec.)	Sample	Mean (sec.)	
Broward County, Florida	41	2.40	23	2.90	-0.50
Minneapolis/St. Paul, Minnesota	100	2.10	19	2.90	-0.80
Montgomery County, Maryland	267	2.20	58	2.40	-0.20
Orange County, California	31	1.20	30	1.60	-0.40
Salt Lake City, Utah	71	1.70	30	2.30	-0.60
White Plains, New York	153	1.10	30	1.80	-0.70

PEDESTRIAN SURVEY FINDINGS

Approximately 300 pedestrians were surveyed at countdown signals in five of the jurisdictions. The project team did not survey pedestrians in Salt Lake City, Utah: The survey instrument was intended for use in an area where PCD signals were fairly novel and differed from pedestrian signals at surrounding intersections. In Salt Lake City, PCD signals are ubiquitous and have been in place for a number of years.

Pedestrians were asked if they noticed anything different about crossing at the intersection than at similar intersections in the surrounding area. A follow-up question confirmed that the difference noted was the countdown signal. Key findings of the pedestrian survey included the following:

- In all jurisdictions, the majority of surveyed pedestrians noticed the PCD signals.
- All surveyed pedestrians were asked to explain the meaning of the countdown indication. In each of the five jurisdictions, more than 90 percent of pedestrians provided a satisfactory understanding of the countdown signals.
- Of those pedestrians who had a preference regarding the use of TPS or countdown signals, the majority preferred PCD signals and indicated that they were helpful in crossing the street safely.
- In the Minneapolis/St. Paul, Minnesota surveys, only 25 percent of those who had a preference preferred the PCD signal. However, approximately 75 percent of all pedestrians surveyed in Minneapolis/St. Paul indicated that the PCD signal was helpful in crossing the street safely. These findings are in disagreement. When asked to provide additional information, many of those surveyed who preferred the traditional signal noted that the PCD signal did not provide enough time to cross. Therefore, the preference for traditional over countdown may have been a reflection of concern for the amount of time available at the countdown intersection and not the signal display.

INTERSECTION OPERATIONS ANALYSIS

The intersections used for the behavioral analysis were used as case studies for this operations analysis. The CORSIM traffic simulation program was used to evaluate the effect of different walking speeds for determining pedestrian clearance times and to evaluate intersection level of service (LOS).

EFFECT OF DIFFERENT WALKING SPEEDS ON PEDESTRIAN CLEARANCE TIMES

Each case study intersection appendix to this report contains a table that displays the required pedestrian signal times for different walking speeds and the time available for that movement at each of the intersections studied. The pedestrian clearance time (PCT) is the time provided for a pedestrian crossing in a crosswalk, after leaving the curb or shoulder, to travel to the far side of the traveled way or to a median. PCT is calculated by taking the length of the crosswalk and dividing it by the crossing speed.

The total time allotted for pedestrians to completely traverse a crosswalk is the sum of the PCT and the WALK time. A 7-sec. WALK time was used as recommended in the 2003 edition of MUTCD for five of the six case study intersections. For the case study intersection in Minneapolis, Minnesota, a 12-sec. WALK time was required by agency policy for use in calculating total pedestrian walk time.

The case study intersections in Salt Lake City, Utah and Montgomery County, Maryland had existing PCTs based on a walking speed greater than 4.00 ft./sec. or a WALK time less than 7 sec.

The available green time is the maximum time that can be allotted to the pedestrian signal interval based on existing signal timings and phasing. The available green represents the green intervals for the parallel streets. The available green times do not add up to the cycle length because of time allotted to exclusive phasing for turn movements, concurrent phasing for approaches on the same street (such as northbound and southbound approaches), and yellow and red intervals.

Table 14 provides an example for understanding similar data provided for each case study intersection included in the appendices. The "☒" symbol in the table indicates where the total pedestrian signal time exceeds the available green time.

As shown in Table 14, the southbound approach (north crosswalk) had an available green time of 34 sec. A walking speed of 4.00 ft./sec. yielded a pedestrian interval of 32 sec.; a walking speed of 3.50 ft./sec. yielded a pedestrian interval of 34 sec. Because this is less than or equal to the available green time, the pedestrian interval for this approach could be serviced adequately during the time available without taking time from other phases.

Table 14. Pedestrian WALK and clearance time durations for case study intersection in Minneapolis, Minnesota.

Approach/ crosswalk	Length (ft.)	Clearance time (sec.)			Clearance time with 12-sec. WALK (sec.) [Total pedestrian time]			Available green (sec.)
		3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	
Northbound/ south	75	25	21	19	37☒	33	31	34
Southbound/ north	78	26	22	20	38☒	34	32	34
Eastbound/ west	3	18	15	13	30☒	27	25	28
Westbound/ east	50	17	14	13	29☒	26	25	28

A walking speed of 3.00 ft./sec. resulted in a required time for the pedestrian interval that was greater than the available green time (38 sec. versus 34 sec.). In this case, the available green could be increased to meet the time required for the pedestrian interval; however, this action could potentially take time away from other movements served by other phases. Consequently, this may increase vehicular delay depending upon traffic volumes. The LOS analysis shows that increases in the available green time would result in greater delay for the major street approaches.

For this case study intersection, the pedestrian interval exceeded the available green time only for the 3.00 ft./sec. scenario in four of the four crosswalks/approaches. If the City of Minneapolis used the 2003 MUTCD recommendation of 7-sec. (minimum) WALK time instead of the policy-based 12-sec.

time, the available green time would be adequate at the 3.00 ft./sec. scenario. The city's use of a greater minimum WALK time interval in this case implied a proactive policy to provide greater LOS to pedestrians.

Key findings related to pedestrian WALK clearance time durations for the case study intersections include the following:

- The White Plains, New York case study intersection did not have pedestrian intervals that exceeded the available green time for any crosswalk and/or WALK time scenarios.
- The pedestrian intervals exceeded the available green times for the 3.00 ft./sec. scenario in the case study intersection in Broward County, Florida, in one of three crosswalks and in four of four crosswalks in the Minneapolis, Minnesota; Montgomery County, Maryland; and Salt Lake City, Utah, case study intersections, respectively.
- The pedestrian intervals exceeded the available green times for both the 3.50 ft./sec. and the 4.00 ft./sec. scenarios in the case study intersections in three of four crosswalks in Montgomery County, Maryland and in four of four crosswalks in Salt Lake City, Utah.

INTERSECTION OPERATION ANALYSIS

CORSIM traffic simulations were developed for each intersection, with walking speeds of 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec. used to determine the PCI. The impacts of these different walking speeds on traffic operations were studied by determining the resulting LOS for each walking speed under different vehicular traffic conditions.

LOS is a qualitative measure used to describe the operational condition of an intersection. LOS utilizes a rating system ranging from A to F, with A signifying the highest LOS, characterized by insignificant vehicular delay, and F signifying the lowest LOS, characterized by excessive vehicular delay. By definition, an intersection operating at its capacity is operating at LOS E. The relationship between vehicular delay and LOS at signalized intersections is shown in Table 15.

Table 15. Level of service at signalized intersections (*Highway Capacity Manual* 2000).

LOS	Control delay (sec./vehicle)
A	≤10.0
B	10.1–20.0
C	20.1–35.0
D	35.1–55.0
E	55.1–80.0
F	≥80.0

Five different traffic volume conditions were analyzed, ranging from 10 percent lower than the existing (observed) peak-hour condition to 25 percent higher than the existing (observed) peak-hour condition. This range was selected for evaluation to resemble possible variations in traffic volumes that may exist during off-peak hours, seasonal variations, and future traffic growth.

Changing the walking speeds and, thus, the pedestrian signal times for a pair of parallel crosswalks often results in a change in the available green time for the parallel vehicular movement. This change will be most significant on long crosswalks across the major approaches to the intersection. The variations in walking speeds can be evaluated to determine their impact on vehicular delays on the major and minor approaches to an intersection.

For the purpose of this analysis, the major street was defined as the street with the highest traffic volume. The minor street was defined as having the lowest traffic volume. In five of the six cases studied, the major streets also had the larger roadway cross section and, thus, had larger crossing distances. In the White Plains, New York case study intersection, both the major and the minor street cross sections were similar. Discussions of analysis of the major and minor street approaches are included in the technical appendix for each case study intersection.

Given that the study by LaPlante and Kaeser described the impacts of varying walking speeds on intersection operations with different cycle lengths, for the purposes of this study, cycle lengths were held constant at the existing values throughout the analysis, and the effects of varying walking speeds on vehicular delay under different traffic conditions were studied. (LaPlante and Kaeser 2004).

Traffic operations analyses were completed for one case study intersection in each of the following jurisdictions:

- Broward County, Florida
- Minneapolis/St. Paul, Minnesota
- Montgomery County, Maryland
- White Plains, New York
- Salt Lake City, Utah
- Orange County, California

Broward County, Florida

Figure 8 and Table 16 show the total intersection LOS and average delay per vehicle (ADPV) for the Broward County, Florida case study intersection under various peak-hour traffic volume and pedestrian walking speed scenarios. Table C-12 in Appendix C shows the intersection operational and geometric characteristics for the Broward County case study intersection.

For the overall intersection, there was no change in LOS (LOS C remained the same) and a minor increase of 2 to 3 sec. in terms of ADPV when comparing existing volume conditions to a modeled increase of 15 percent above existing volumes. From a practical standpoint, this would not be noticeable to the average driver. Because the LOS was relatively good (LOS C) in the base condition, the trends in LOS and ADPV showed a uniform and relatively small incremental delay for each of the walking speeds simulated.

A discussion of LOS and average vehicle delay (AVD) for the major and minor approaches is included in Appendix C to this report. Table C-13 and Figures C-3, C-4, and C-5 in Appendix C show intersection delay for major and minor street approaches at walking speeds of 3.00, 3.50, and 4.00 ft./sec. at the Broward County case study intersection.

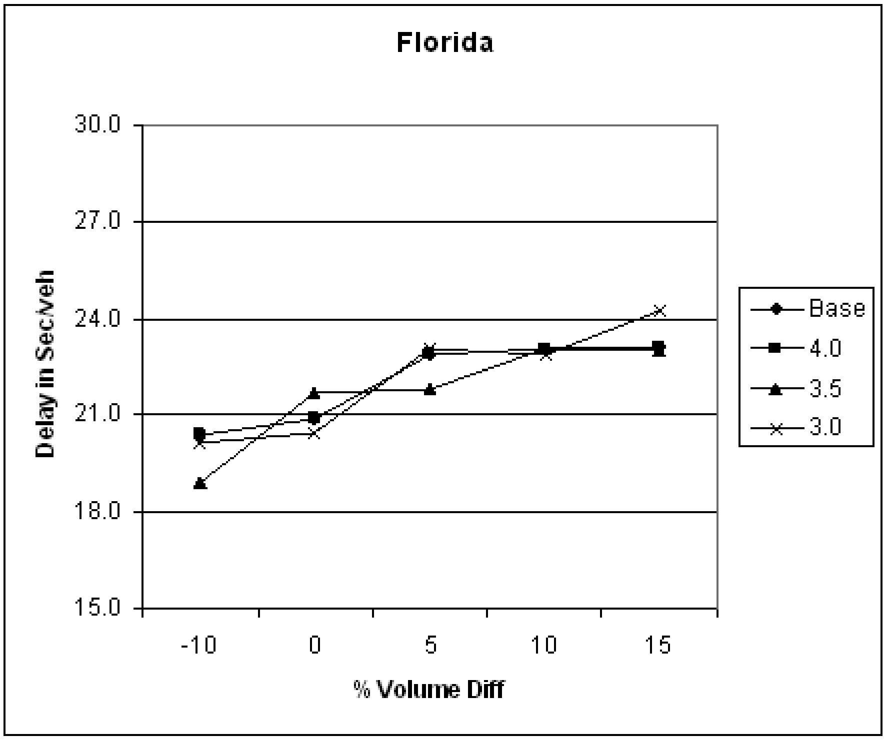

Figure 8. Delay vs. volumes at Broward County, Florida case study intersection for walking speeds of 3.00, 3.50, 4.00 ft./sec. and base conditions.

Table 16. Broward County, Florida: Total intersection level of service and average delay per vehicle under various volume and pedestrian walking speed scenarios.

Walking speed scenario	LOS (and average delay, in sec.)				
	-10-percent volume	Existing volume	+5-percent volume	+10-percent volume	+15-percent volume
3.00 ft./sec.	C (20)	C (21)	C (23)	C (23)	C (24)
3.50 ft./sec.	B (19)	C (21)	C (21)	C (23)	C (23)
4.00 ft./sec.	C (20)	C (21)	C (23)	C (23)	C (23)

Minneapolis/St.Paul, Minnesota

Figure 9 and Table 17 show the total intersection LOS and ADPV for the Minneapolis/St. Paul, Minnesota case study intersection under various peak-hour traffic volume and pedestrian walking speed scenarios. Table D-10 in Appendix D shows the intersection operational and geometric characteristics for the Minneapolis/St. Paul case study intersection.

When existing volume conditions were compared to a modeled increase of 10 percent above existing volume conditions, there was a decrease of one LOS designation (from LOS C to D) with a corresponding increase in ADPV of 14 sec. under the 3.00 ft./sec. walking speed scenario. An incremental increase of another 5 percent of peak-hour volume to the 3.00 ft./sec. walking speed lowered the LOS from D to E and added 7 sec. to the ADPV. Thus, from existing volume conditions to a modeled increase of 15 percent over existing volumes, there was a reduction of two LOS designations (from LOS C to E) and a corresponding increase of approximately 21 sec. for the ADPV.

Under the 3.50 ft./sec. and 4.00 ft./sec. walking speed scenarios, under existing volumes to an increase of 15 percent above existing volumes, there was no change in LOS (LOS C remained the same); however, there was a corresponding increase in ADPV of approximately 5 sec. and 4 sec. under the 3.50 ft./sec. and 4.00 ft./sec. walking speed scenarios, respectively.

In summary, the 3.00 ft./sec. pedestrian walking speed, compared to the 3.50 ft./sec. and 4.00 ft./sec. pedestrian walking speeds, had a greater negative impact on vehicular traffic operations at the case study intersection.

A discussion of LOS and AVD for the major and minor approaches is included in Appendix D to this report. Table D-11 and Figures D-5, D-6, and D-7 in Appendix D show intersection delay for major and minor street approaches at walking speeds of 3.00, 3.50, and 4.00 ft./sec. at the Minneapolis/St. Paul case study intersection.

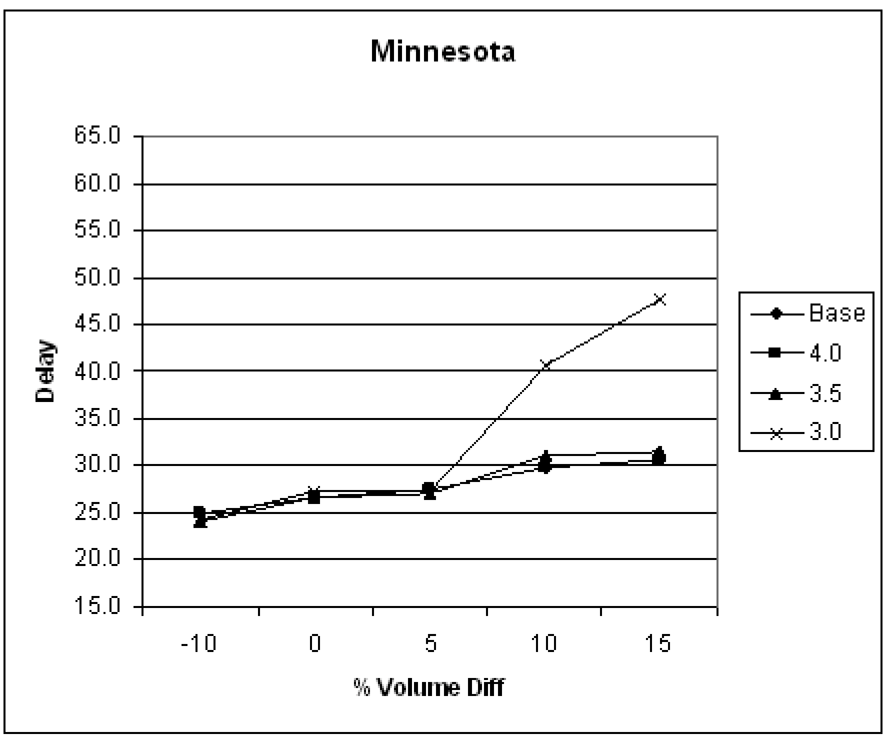

Figure 9. Delay vs. volumes at Minneapolis/St. Paul, Minnesota case study intersection for walking speeds of 3.00, 3.50, 4.00 ft./sec. and base conditions.

Table 17. Minneapolis/St. Paul, Minnesota: Total intersection level of service and average delay per vehicle under various volume and pedestrian walking speed scenarios.

Walking speed scenario	LOS (and average delay, in sec.)				
	-10-percent volume	Existing volume	+5-percent volume	+10-percent volume	+15-percent volume
3.00 ft./sec.	C (24)	C (27)	C (27)	D (41)	E (48)
3.50 ft./sec.	C (24)	C (27)	C (27)	C (31)	C (32)
4.00 ft./sec.	C (25)	C (27)	C (28)	C (30)	C (31)

Montgomery County, Maryland

Figure 10 and Table 18 show the total intersection LOS and ADPV for the Montgomery County, Maryland case study intersection under various peak-hour traffic volume and pedestrian walking speed scenarios. Table E-11 in Appendix E shows the intersection operational and geometric characteristics for the Montgomery County case study intersection.

The modeled peak-hour volumes at the Montgomery County case study intersection ranged from a decrease of 10 percent to an increase of 10 percent of existing peak-hour volumes. The existing LOS at this case study intersection for the 3.00 ft./sec pedestrian walking speed scenario was at capacity (LOS E) with a corresponding average delay of 60 sec. per vehicle.

When existing volume conditions were compared to a modeled increase of 5 percent above existing volume conditions, the LOS designation (LOS E) did not change; however, there was a corresponding increase in ADPV of approximately 9 sec. under the 3.00 ft./sec. walking speed scenario. An incremental increase of another 5 percent of peak-hour volume (to 10 percent above existing volumes) at the 3.00 ft./sec. walking speed lowered LOS from E to F and added 49 sec. to ADPV. Thus, from existing volume conditions to a modeled increase of 10 percent over existing volumes, there was a reduction of two LOS designations (from LOS D to F) and a corresponding increase of 58 sec. for ADPV.

Under the 3.50 ft./sec. and 4.00 ft./sec. walking speed scenarios, under existing volumes to an increase of 10 percent over existing volumes, there was no change in LOS (LOS D); however, there was a corresponding increase in ADPV of 6 sec. and 4 sec. under the 3.50 ft./sec. and 4.00 ft./sec. walking speeds, respectively.

Thus, under the conditions analyzed, the 3.00 ft./sec. pedestrian walking speed, compared to the 3.50 ft./sec. and 4.00 ft./sec. pedestrian walking speeds, may have negatively impacted vehicular traffic operations at the case study intersection to a much greater extent.

A discussion of LOS and AVD for the major and minor approaches is included in Appendix E to this report. Table E-12 and Figures E-5, E-6, and E-7 in Appendix E show intersection delay for major and minor street approaches at walking speeds of 3.00, 3.50, and 4.00 ft./sec. at the Montgomery County case study intersection.

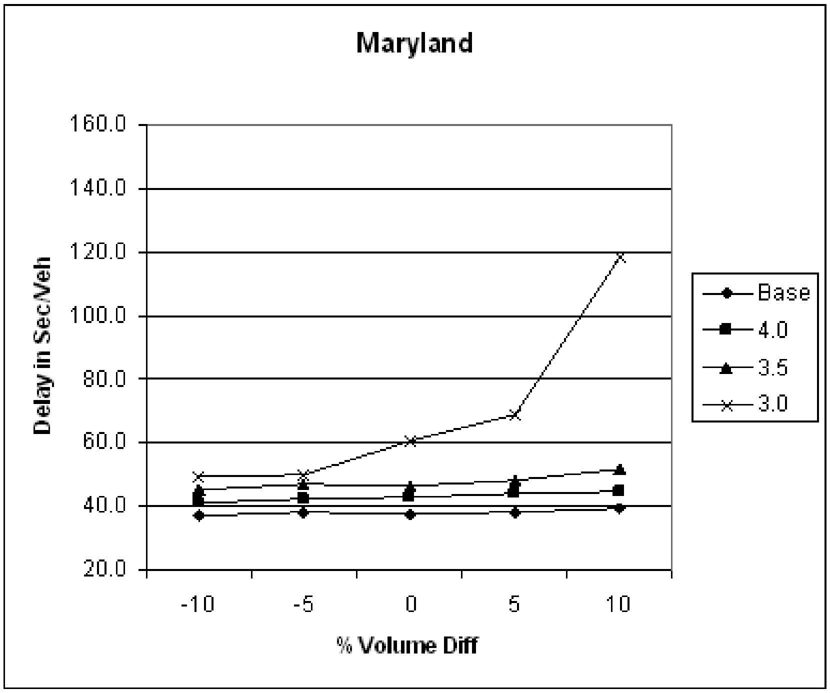

Figure 10. Delay vs. volumes at Montgomery County, Maryland case study intersection for walking speeds of 3.00, 3.50, 4.00 ft./sec. and base conditions.

Table 18. Montgomery County, Maryland: Total intersection level of service and average delay per vehicle under various volume and pedestrian walking speed scenarios.

Walking speed scenario	LOS (and average delay, in sec.)				
	-10-percent volume	-5-percent volume	Existing volume	+5-percent volume	+10-percent volume
3.00 ft./sec.	D (49)	D (50)	E (60)	E (69)	F (118)
3.50 ft./sec.	D (46)	D (47)	D (47)	D (49)	D (52)
4.00 ft./sec.	D (41)	D (43)	D (43)	D (44)	D (45)

White Plains, New York

Figure 11 and Table 19 show the total intersection LOS and ADPV for the White Plains, New York case study intersection under various peak-hour traffic volume and pedestrian walking speed scenarios. Table F-11 in Appendix F shows the intersection operational and geometric characteristics for the White Plains case study intersection.

The traffic volumes modeled at the White Plains case study intersection ranged from existing conditions to an increase of 25 percent of existing conditions. Traffic volumes at this intersection were substantially lower than capacity, and even increasing the traffic volumes on each approach by 25 percent did not cause any impact on the overall AVD or along major and minor street approaches. LOS and vehicular delay for each walking speed scenario essentially did not differ from existing conditions.

This intersection had adequate signal time available for all pedestrian phases with lower walking speeds and each of the concurrent traffic movements. Therefore, vehicular delay was not affected when the green times were adjusted based on the lower walking speeds

LOS and AVD for the major and minor approaches are included in Table F-12 in Appendix F to this report.

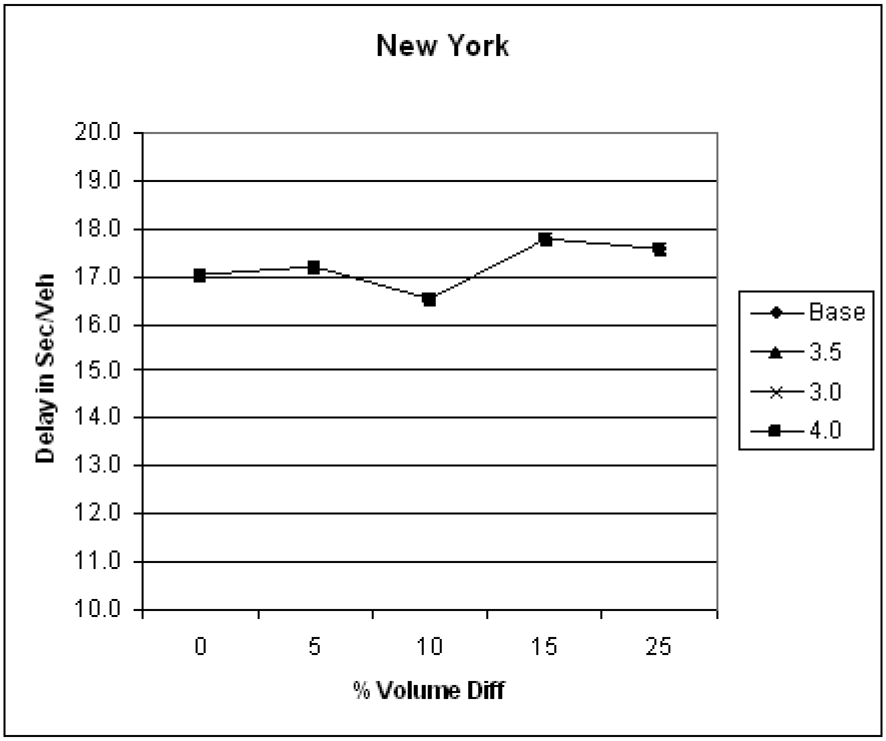

Figure 11. Delay vs. volumes at White Plains, New York case study intersection for walking speeds of 3.00, 3.50, 4.00 ft./sec. and base conditions.

Table 19. White Plains, New York: Total intersection level of service and average delay per vehicle under various volume and pedestrian walking speed scenarios.

Walking speed scenario	LOS (and average delay, in sec.)				
	Existing volume	+5-percent volume	+10-percent volume	+15-percent volume	+2-percent volume
3.00 ft./sec.	B (17)	B (17)	B (17)	B (18)	B (18)
3.50 ft./sec.	B (17)	B (17)	B (17)	B (18)	B (18)
4.00 ft./sec.	B (17)	B (17)	B (17)	B (18)	B (18)

Salt Lake City, Utah

Figure 12 and Table 20 show the total intersection LOS and ADPV for the Salt Lake City, Utah case study intersection under various peak-hour traffic volume and pedestrian walking speed scenarios. Table G-11 in Appendix G shows the intersection operational and geometric characteristics for the Salt Lake City case study intersection.

There was no change in overall LOS (LOS C remained the same) when comparing the modeled decrease in volumes of -10 percent of existing volumes to a modeled increase of 15 percent above existing volumes. There was a maximum increase of 4 sec. in ADPV under any of the volume or walking speed scenarios when comparing existing volume conditions to a modeled increase of 15 percent above existing volumes. The graph included in Figure 12 shows there was a uniform increase in ADPV as peak-hour volumes increased.

A discussion of LOS and AVD for the major and minor approaches is included in Appendix G to this report. Table G-12 and Figures G-4, G-5, and G-6 in Appendix G show intersection delay for major and minor street approaches at walking speeds of 3.00, 3.50, and 4.00 ft./sec. at the Salt Lake City case study intersection.

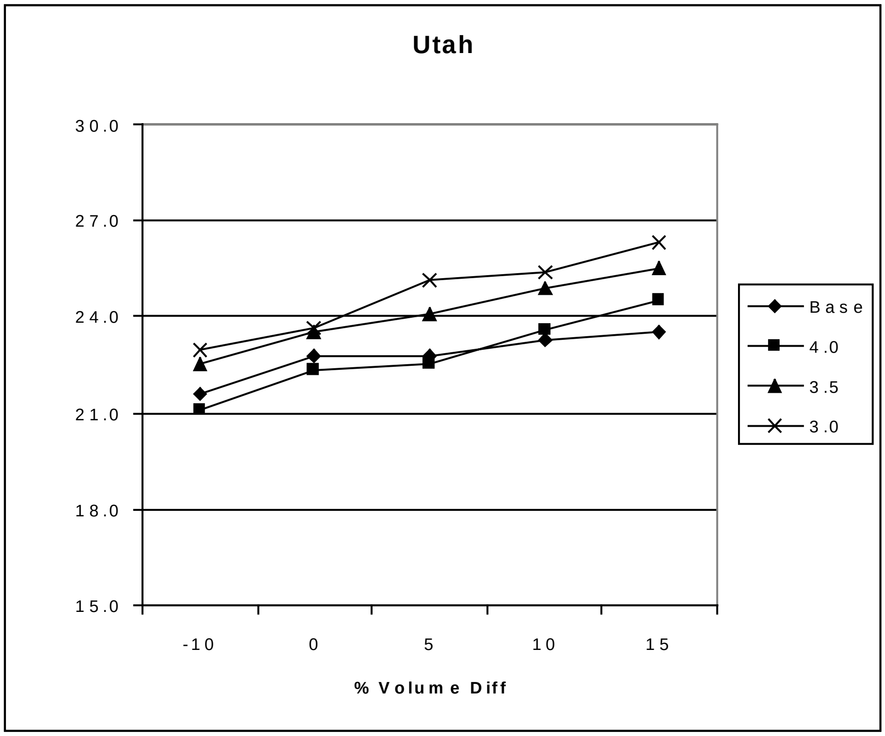

Figure 12. Delay vs. volumes at Salt Lake City, Utah case study intersection for walking speeds of 3.00, 3.50, 4.00 ft./sec. and base conditions.

Table 20. Salt Lake City, Utah: Total intersection level of service and average delay per vehicle under various volume and pedestrian walking speed scenarios.

Walking speed scenario	LOS (and average delay,in sec.)				
	-10-percent volume	Existing volume	+5-percent volume	+10-percent volume	+15-percent volume
3.00 ft./sec.	C (23)	C (24)	C (25)	C (22)	C (26)
3.50 ft./sec.	C (23)	C (24)	C (24)	C (25)	C (26)
4.00 ft./sec.	C (21)	C (22)	C (23)	C (24)	C (25)

Orange County, California

Figure 13 and Table 21 show the total intersection LOS and ADPV for the Orange County, California case study intersection under various peak-hour traffic volume and pedestrian walking speed scenarios. Table H-11 in Appendix H shows the intersection operational and geometric characteristics for the Orange County case study intersection.

Because volume data were not available from the jurisdiction, existing volumes were estimated based on the operational and geometric characteristics of the intersection. Total intersection volume was estimated at 6,500 peak-hour vehicles, with 2,000 vehicles and 1,250 vehicles on the major and minor street approaches, respectively. This approach produced more of a saturated/lower LOS condition at a "base" scenario level similar to the base condition LOS at the Montgomery County, Maryland case study intersection.

Table 21 shows there was a uniform increase in ADPV for the volume scenario that was 5 percent above existing volumes. Here, there was a greater vehicular delay at pedestrian walking speeds of 4.00 ft./sec., 3.50 ft./sec., and 3.00 ft./sec. (in that order). The ADPV was 72 sec., 68 sec., and 55 sec., respectively. This trend remained the same for volume scenarios to 10 and 15 percent above existing volumes.

The total intersection LOS decreased from LOS D to LOS F under the 3.00 ft./sec. walking speed scenario when existing volume conditions were compared to a modeled increase of 10 percent above existing volume conditions. Concomitantly, there was a corresponding increase in ADPV of 75 sec. An incremental increase of another 5 percent of peak-hour volume (to 15 percent above existing volumes) at the 3.00 ft./sec. pedestrian walking speed added 47 sec. to the ADPV. Thus, from existing volume conditions to a modeled increase of 15 percent over existing volumes, there was a reduction of two LOS designations (from LOS D to F) and a corresponding increase in 122 sec. for ADPV.

Under the 3.50 ft./sec. pedestrian walking speed scenario, the delay for the 3.50 ft./sec. scenario increased at a greater rate than the 3.00 ft./sec. scenario until traffic volumes were increased between 5 and 10 percent. This occurred because the 3.00 ft./sec. scenario provided more green time for the minor street due to the increase in the PCI for the parallel pedestrian movement. Under the 3.50 ft./sec. pedestrian walking speed scenario and under a scenario that increased existing volumes by 15 percent, the total intersection LOS decreased from LOS D to F and there was a corresponding increase of 108 sec. in ADPV.

At the 4.00 ft./sec. pedestrian walking speed scenario, a large increase in ADPV occurred at the existing level to 5 percent above existing volume conditions (17 sec.), following smaller increases exhibited in the modeled 5 to 10 percent above existing conditions volume level (4 sec.) and at the modeled 10 to 15 percent above existing conditions volume level (6 sec.). The total increase in average intersection delay per vehicle from the existing volume condition level to the 15 percent above existing volume condition level was 28 sec. and there was a reduction of one LOS designation from LOS E to F. Note that the difference in ADPV between the 15 percent above existing volume condition and the existing volume condition at the 3.00 ft./sec. and 3.50 ft./sec. pedestrian walking speed scenarios was 94 sec. and 80 sec., respectively.

A discussion of LOS and AVD for the major and minor approaches is included in Appendix H to this report. Table H-12 and Figures H-3, H-4, and H-5 in Appendix H show intersection delay for major and minor street approaches at walking speeds of 3.00, 3.50, and 4.00 ft./sec. at the Orange County case study intersection.

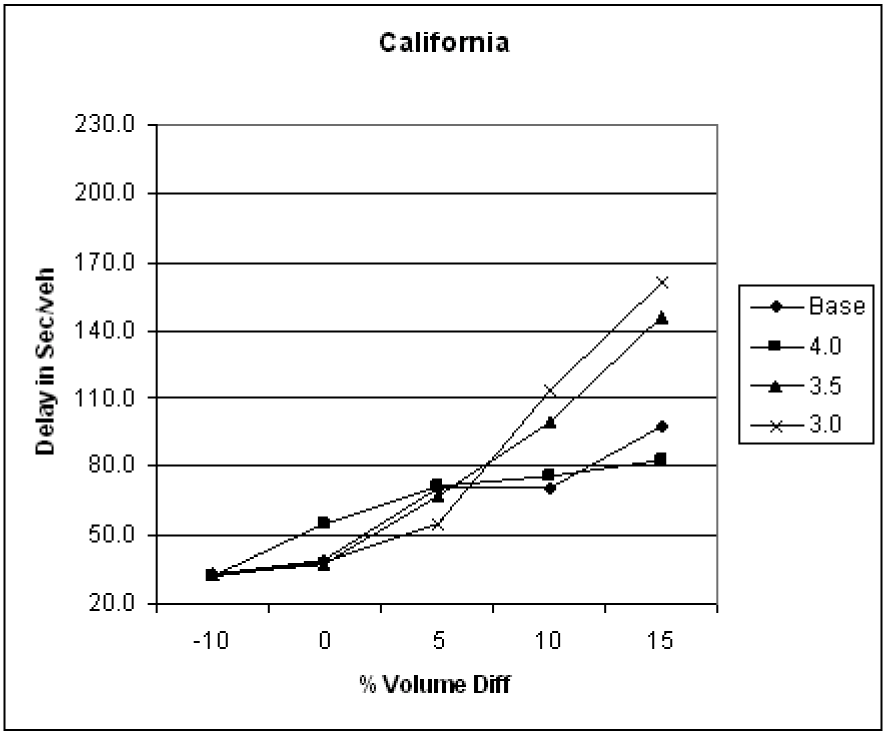

Figure 13. Delay vs. volumes at Orange County, California case study intersection for walking speeds of 3.00, 3.50, 4.00 ft./sec. and base conditions.

Table 21. Orange County, California: Total intersection level of service and average delay per vehicle under various volume and pedestrian walking speed scenarios.

Walking speed scenario	LOS (and average delay, in sec.)				
	-10-percent volume	Existing volume	+5-percent volume	+10-percent volume	+15-percent volume
3.00 ft./sec.	C (32)	D (39)	E (55)	F (114)	F (161)
3.50 ft./sec.	C (33)	D (38)	E (68)	F (99)	F (146)
4.00 ft./sec.	C (32)	E (55)	E (72)	E (76)	F (83)

DISCUSSION

SUMMARY OF STUDY FINDINGS

Observational Study of Pedestrians

Walking Speeds

- Older pedestrians walked slightly faster at intersections equipped with pedestrian countdown (PCD) signals at most of the sites in the study. Mean walking speed (MWS) in the six jurisdictions ranged from 3.98 feet/second (ft./sec.) to 4.60 ft./sec. at traditional signals compared to 4.20 to 4.80 ft./sec. at PCD signals.

- Younger pedestrians also walked slightly faster at intersections equipped with PCD signals, although comparisons at individual jurisdictions varied. MWS ranged from 4.85 ft./sec. to 5.30 ft./sec. at traditional signals compared to 5.00 to 5.30 ft./sec. at PCD signals.

- Walking speeds for older pedestrians were generally slower than for younger pedestrians by about 0.80 ft./sec., although this varied by jurisdiction and type of intersection. Differences in MWS between the two age groups were statistically significant at the 95-percent confidence level for both traditional and PCD signals.

- Pedestrians with mobility impairments and without wheelchairs had appreciably slower walking speeds—their mean was 3.30 ft./sec. when averaged across all six jurisdictions.

- The 15th-percentile speeds for younger pedestrians varied from 4.10 to 4.60 ft./sec. at traditional signals and from 4.10 to 4.70 ft./sec. at PCD signals.

- The 15th-percentile speeds for older pedestrians varied from 3.40 to 3.80 ft./sec. at traditional pedestrian signals (TPS) and similarly from 3.40 to 4.00 ft./sec. at PCD signals.

Start-Up Times

- Older pedestrians had slower start-up times, but this varied by intersection and leg of intersection. The mean start-up times varied from 1.60 sec. to 2.90 sec. for older pedestrians.

Signal Compliance

- The differences in pedestrian signal compliance at the two signal types were difficult to interpret and may have been a result of other factors at the intersection, such as pedestrian actuation, street width, and availability of gaps. Older pedestrians generally had a higher rate of compliance than their younger counterparts at the same intersections.

- As with signal compliance, the differences in the percentage of young pedestrians left in the intersection at the onset of the DON'T WALK (DW) interval for the two signal types varied by jurisdiction. The percentage of older pedestrians left in the intersection was negligible for both signal types.

Pedestrian Understanding and Preference for Countdown Signals

- The overwhelming majority of pedestrians who responded to the survey noticed, understood, and preferred the PCD signals, except in Minneapolis/St. Paul, Minnesota, where pedestrians preferred the traditional signal. However, in Minneapolis/St. Paul, there was some evidence that this difference reflected a perception that the available crossing time was less at the PCD signal based on comments of the interviewed pedestrians.

Intersection Operations Impact Analysis

The purpose of this analysis was to determine the effects on traffic flow by changing the walking speed of pedestrians from 4.00 ft./sec. to a slower value and, thereby, increasing the pedestrian interval time. The following criteria were developed to relate intersection level of service (LOS) and delay impacts with differential walking speeds:

- Insignificant
    - no change in LOS; and
    - an increase in vehicular delay greater than 0.0 sec. and less than or equal to 2.0 sec.
- Minor
    - no more than one change in LOS designation (for example, from B to C); and
    - an increase in vehicular delay greater than 2.0 sec. and less than or equal to 8.0 sec.
- Moderate
    - no more than two change in LOS designation (for example, from B to D); and
    - an increase in vehicular delay greater than 8.0 sec. and less than or equal to 15.0 sec.
- Major
    - intersection may have a degradation of three or more LOS designations (for example, from B to E); and
    - an increase in vehicular delay greater than 15.0 sec.

Table 22 shows the descriptive effect on the change in vehicular delay for each LOS for walking speeds of 3.50 and 3.00 ft./sec. In general, lowering pedestrian walking speeds to 3.50 ft./sec. or even 3.00 ft./sec. at intersections that operate at LOS A, B, or C would result in insignificant to minor increases in overall vehicular delay at the intersections. However, using a walking speed of 3.50 ft./sec. at intersections that operate at LOS D or E would cause minor to moderate increases to the overall vehicular delay at the intersections. Using a walking speed of 3.00 ft./sec. at intersections that operate at LOS D or E would cause moderate to major increases in vehicular delay at the intersections.

Table 22. Increase in vehicular delay at intersections operating with level of service A to F due to changes in walking speed (WALK interval and flashing DON'T WALK interval).

Walking speed	LOS					
	A	B	C	D	E	F
3.50 ft./sec.	Insignificant	Insignificant	Insignificant	Minor	Minor to Moderate	Major
3.00 ft./sec.	Insignificant	Insignificant	Minor	Moderate	Major	Major

Furthermore, it was found that delay increased significantly when pedestrian times approached or exceeded the available minimum green times for the concurrent phase. This occurred most often on the major street approaches, which tended to be wider and, thus, had longer crossing distances resulting in a greater increase in the pedestrian clearance interval (PCI).

This phenomenon was examined more closely by comparing the effects that varying walking speeds had on the major and minor approaches to an intersection. According to the data, increased vehicle delays at intersections with reduced walking speeds primarily were due to delays on the major street approaches.

Intersections with a slightly higher LOS in the base condition (such as in Florida and Utah) showed a more uniform increase in delay for each walking speed.

Case study intersections operating closer to vehicle capacity (with a lower LOS) in the base or existing condition, such as in Minnesota, Maryland, and California, were found to show exponential increases in average vehicle delay for the 3.00 ft./sec. scenario. The California case study also exhibited exponential increases in delay for the 3.50 ft./sec. scenario. The data indicate that the increased delay for all these case studies was due to increases in delay on the major street approaches.

Agency Experience Survey

Respondents' Use of Pedestrian Countdown Signals and Traditional Pedestrian Signals

- Almost one-half of the respondents already had PCD signals in place. Approximately one-quarter of all respondents planned to install PCD signals during the next five years. Approximately one-third of all respondents indicated that they had no plans to install PCD signals.

- Most agencies that were using PCD signals reported positive benefits, including favorable public reaction, increased pedestrian understanding and decision-making in response to the pedestrian change indication, and increased pedestrian compliance to the signal.

Pedestrian Countdown Signal Start/End Times

- More than six of 10 respondents (62 percent) started the countdown (the show of the remaining seconds) at the beginning of the flashing DON'T WALK (FDW) and completed the countdown at the end of the FDW. Another 3 percent indicated that they started the countdown timer at the beginning of the FDW and ended during the steady DW. Taken together, approximately two of three respondents followed the *Manual on Uniform Traffic Control Devices* (MUTCD) guidance; one-third of the respondents were not operating their PCD signals in accordance with MUTCD.

Criteria Used to Identify Where Pedestrian Countdown Signals Should Be Installed

Most jurisdictions reported selectively installing PCD signals. Criteria used by a number of the respondent organizations to consider the installation of PCD signals included:

- Specific areas including:
  - school zones;
  - downtowns or urban areas;
  - pedestrian access routes or proximity to pedestrian activity centers; and
  - proximity to transit stops or subway stations.
- Specific characteristics of pedestrians including:
  - number of senior citizens;
  - number of very young pedestrians;
  - high pedestrian and/or bicycle volumes;
  - inexperienced users;
  - ethnic diversity; and
  - high pedestrian pushbutton usage.
- Specific characteristics of intersection or roadway operations including:
  - pedestrian crash history;
  - use where right-turning and left-turning volumes that conflict with the crosswalk are greater than 400 vehicles per hour;
  - use where there are long crosswalk distances (for example, Monroe County, New York, developed a threshold of at least a 60-ft. crossing distance to implement a PCD signal); and
  - any crosswalk requiring a clearance interval of more than 15 sec.
    - The following circumstances may justify the use of a PCD signal even if the interval is less than 15 sec.: 1) high pedestrian volume; 2) high levels of vehicular

traffic presenting a hazardous pedestrian crossing; 3) a high percentage of pedestrians with walking disabilities and/or a high percentage of senior citizens, for example near health centers, hospitals, and retirement communities; and (4) school zones.

- Pedestrian crashes (state of Utah):
    - o Give top priority to high severity scores (fatalities or serious injuries) or more than seven pedestrian-vehicle crashes.
    - o Give second priority to signalized intersections along recurrent pedestrian-vehicle crash corridors.
    - o Give third priority to signalized intersections that feature regular pedestrian activity.
- Consider a policy that incorporates countdown pedestrian indicators and pedestrian indicators into all new traffic signals.

SIGNIFICANCE OF THIS STUDY'S FINDINGS FOR CURRENT PRACTICE

Overall, the results of this study support the proposed National Committee on Uniform Traffic Control Devices (NCUTCD) guidance for reducing overall pedestrian walking speeds for use in pedestrian signal timing from 4.00 ft./sec. to 3.50 ft./sec. In the jurisdictions studied, this clearly would be beneficial for older pedestrians and, in many cases, could be accommodated without causing significant increases in vehicular delay.

1. Based on the results observed in each jurisdiction, a walking speed of 4.00 ft./sec. would accommodate a pedestrian walking at the 15th-percentile walking speed for younger pedestrians in all jurisdictions studied.

2. A walking speed of 4.00 ft./sec. also would accommodate a pedestrian walking at the mean speed observed for older pedestrians in all of the jurisdictions studied but would not accommodate a 15th-percentile older pedestrian in any of the jurisdictions studied.

3. A walking speed of 3.50 ft./sec. still would not accommodate the 15th-percentile older pedestrian in all jurisdictions studied. However, at all intersections in this study, if the signal timing provided a 7-sec. WALK and a change interval based on 3.50 ft./sec., older pedestrians with walking speeds at the 15th-percentile of older pedestrians would be able to cross the intersection provided they left the curb within 3.00 sec. of the start of the WALK interval.

4. Modifying pedestrian signal timing to accommodate a 7-sec. WALK interval and a pedestrian clearance interval based on a walking speed of 3.50 ft./sec. should be feasible with minimal operational impacts.

5. Intersection delay can be expected to increase significantly when the total time for the pedestrian interval approaches or exceeds the available green times for the concurrent vehicular traffic phase. This occurs most often on the major street approaches, which tend to be longer.

6. Walking speeds of 3.00 ft./sec. also may potentially be accommodated by increasing traffic signal cycle lengths. This, however, may have negative impacts on pedestrians; shorter cycle

lengths are preferred for pedestrian traffic so that wait time is shorter. Furthermore, extending cycle lengths may have detrimental effects on the surrounding roadway network if signals are coordinated. A coordinated traffic signal typically would have to remain coordinated to maintain operational efficiency. Therefore, the entire signal coordination system would require modification, which may be costly and may affect traffic patterns.

COMPARISON TO PAST STUDIES

The literature review identified a number of studies that reported pedestrian walking speeds. The average reported walking speeds for older pedestrians varied from 3.19 ft./sec. to 4.60 ft./sec. MWS for older pedestrians in this study ranged from 3.98 ft./sec. to 4.60 ft./sec. at traditional signals. This is comparable to walking speeds reported in the literature, although the lower end of the range in the literature was slower. MWS in this study ranged from 4.20 to 4.80 ft./sec. at PCD signals. This range is slightly higher than reported in the literature. However, the studies reported in the literature were, for the most part, conducted at TPS, and this study provides some evidence that pedestrians walk faster at PCD signals. The one study conducted at a PCD signal (City of Berkeley, California) found that all pedestrians (regardless of age) walked 4.80 ft./sec. at PCD signals versus 4.60 ft./sec. at traditional signals.

The literature review also identified studies that reported 15th-percentile pedestrian walking speeds. The reported 15th-percentile speeds varied from 2.20 ft./sec. to 4.00 ft./sec. for older pedestrians, 3.31 ft./sec. to 4.21 ft./sec. for younger pedestrians, and 3.09 to 4.80 for all pedestrians.

Table 23 provides a detailed comparison of the literature review data for walking speeds as compared to the data developed in this study. The shaded areas are for the pedestrian types and statistics that provided cases where walking speeds were greater at PCD signals.

Similarities and differences between the literature review and this study's walking speed data are shown below. In sum, there was a 0.52 ft./sec. (greater) average difference in walking speed for this study's data.

- At the low end of the range for MWS:
    - For older pedestrians, this study showed 25 percent (0.79 ft./sec.) greater walking speeds at traditional signals (compared to the literature review's "all signals") and 32 percent (1.01 ft./sec.) greater walking speeds at PCD signals (compared to the literature review's "all signals").
    - For younger pedestrians, this study showed 10 percent (0.43 ft./sec.) greater walking speeds at traditional signals (compared to the literature review's "all signals") and 13 percent (0.58 ft./sec.) greater walking speeds at PCD signals (compared to the literature review's "all signals").
- At the high end of the range for MWS:
    - For older pedestrians, this study showed the same walking speed at traditional signals (compared to the literature review's "all signals") and 4 percent (0.20 ft./sec.) greater walking speeds at PCD signals (compared to the literature review's "all signals").

    - For younger pedestrians, this study showed 7 percent (0.37 ft./sec.) greater walking speeds at traditional signals (compared to the literature review's "all signals") and 7 percent (0.34 ft./sec.) greater walking speeds at PCD signals (compared to the literature review's "all signals").

- At the low end of the range for 15th-percentile speed:

    - For older pedestrians, this study showed 55 percent (1.2 ft./sec.) greater walking speeds at traditional signals (compared to the literature review's "all signals") and 55 percent (1.2 ft./sec.) greater walking speeds at PCD signals (compared to the literature review's "all signals").

    - For younger pedestrians, this study showed 24 percent (0.79 ft./sec.) greater walking speeds at traditional signals (compared to the literature review's "all signals") and 24 percent (0.79 ft./sec.) greater walking speeds at PCD signals (compared to the literature review's "all signals").

- At the high end of the range for 15th-percentile speed:

    - For older pedestrians, this study showed a reduction of 5 percent (-0.20 ft./sec.) in walking speeds at traditional signals (compared to the literature review's "all signals") and the same (no difference) walking speeds at PCD signals (compared to the literature review's "all signals").

    - For younger pedestrians, this study showed 9 percent (0.39 ft./sec.) greater walking speeds at traditional signals (compared to the literature review's "all signals") and 12 percent (0.49 ft./sec.) greater walking speeds at PCD signals (compared to the literature review's "all signals").

NEXT STEPS

The next revision to MUTCD is currently slated for 2009. Prior to the revision, the Federal Highway Administration (FHWA) will prepare a Notice of Proposed Amendments, inclusive of changes to pedestrian walking speed provisions. Additionally, FHWA will consider recommendations from the NCUTCD. Proposed NCUTCD recommendations pertaining to pedestrian signal timing are shown in Table 9.

This study supports the proposed NCUTCD guidance for reducing overall pedestrian walking speeds to 3.50 ft./sec. It is important to note that the proposed guidance includes options to increase or decrease the pedestrian walking speed based on specific pedestrian characteristics and available pedestrian signal hardware at intersections.

There is a need for guidance regarding when to use pedestrian countdown (PCD) signals. This current study focused on a few communities that have developed criteria for implementing PCD signals.

The scope of this study did not specifically investigate the impact of signal timing on blind, low-vision, or otherwise disabled pedestrians and their use of pedestrian-accessible signals. Future studies should convene focus groups to develop parameters of future efforts that would consider the start-up time and walking speed differences of these pedestrian subgroups.

Table 23. Comparison of the literature review data and this study's data on walking speeds.

	Literature review	This study		Literature review	This study		Literature review	This study		Literature review	This study	
	MWS						15^{th} -percentile					
	Low end of range			High end of range			Low end of range			High end of range		
Pedestrian stratification	All signals	Traditional signals	PCD signals	All signals	Traditional signals	PCD signals	All signals	Traditional signals	PCD signals	All signals	Traditional signals	PCD signals
Older pedestrians	3.19	3.98	4.20	4.60	4.60	4.80	2.20	3.40	3.40	4.00	3.80	4.00
Younger pedestrians	4.42	4.85	5.00	4.96	5.33	5.30	3.31	4.10	4.10	4.21	4.60	4.70
All pedestrians	4.60	N/A	N/A	4.87	N/A	N/A	3.09	N/A	N/A	4.80	N/A	N/A

STUDY LIMITATIONS

Several limitations should be considered when interpreting the results, as discussed below.

Comparability of Intersections

This study employed a cross-sectional design instead of a potentially more robust before-and-after design. Four intersections were selected in each jurisdiction: two with PCD signals and two with TPS. The pedestrian behavior observations were taken at approximately the same time and compared between the two types of intersections. The assumption in this cross-sectional design was that differences in pedestrian behavior observed at the two intersections could be attributed to the difference in pedestrian signals. Although similar, the intersections were different in some respects that could affect pedestrian behavior, confounding the relationship between pedestrian signals and behavior. For instance, surrounding land use, traffic volumes, pedestrian volumes, crossing distance, intersection amenities, and conflict points were potential confounders.

The comparison also assumed that the same pedestrian populations were present at both sets of intersections. The project team attempted to select study intersections in close proximity to one another to minimize this concern. However, this was not always possible. For example, in Orange County, California, the two sets of intersections were in two neighboring jurisdictions. The pedestrian populations may have been different and may have exhibited different behaviors, such as signal compliance.

Weather

Pedestrians are likely to change their behavior during cold or otherwise unpleasant weather. The project team attempted to collect the pedestrian behavior data during periods of dry, clear, warm weather. However, the initial data collection in Salt Lake City, Utah occurred during a very rainy week for the city. Observations during rainy conditions were not used in the analysis; however, the prevailing weather may have modified pedestrians' behavior during that week. This was a concern particularly for older pedestrians, who one might expect to be more likely to stay home during adverse weather, despite periods when it was not raining. Because there were not enough data from Salt Lake City, the project team revisited the city during a dryer period to supplement the data with additional observations.

Survey Response Rate

The pedestrian survey response rates were much lower than expected during the on-street intercept survey, particularly for older pedestrians. Because the survey was voluntary with no incentives, the responses may have been skewed toward those pedestrians who were concerned enough with intersection safety to respond to the survey and possibly were less "fearful" of strangers.

Visual Determination of Age

The pedestrian behavior results were examined separately for pedestrians under 65 and pedestrians 65 and older. The determination of pedestrian age was made based on visual inspection only. Trained observers were used to collect the data. The observers were trained to be consistent in looking at physical attributes such as hair color, posture, and skin features to determine age. The cameras were positioned to provide a close-up view of each pedestrian as he/she crossed the intersection. Only one observer was assigned to each intersection and he/she tried to be consistent in determining age. A project engineer oversaw quality control and was available to provide guidance in the determination of the age of individual pedestrians. Nevertheless, there certainly was some incorrect coding of age groups, which, hopefully, balanced out in the end but may have diluted (or inflated) age effects of interest in the study.

Self Selection

The walking speed measurements were based on samples of pedestrians crossing at the study intersections. This study did not examine walking speeds of pedestrians who would have liked to cross at the study intersections but were not able. It is possible that some pedestrians with slower walking speeds sought alternate routes or alternate transportation modes because they were not able to cross at the study intersections given the available time.

Persons with Disabilities

This study included measurements of start-up time and walking speed for persons with vision, cognitive, or mobility impairments that the research team could discern by visual inspection. Due to the small number of pedestrians with discernible disabilities observed in this study and/or possible misclassification of individuals, this report's recommendations may not be appropriate for accommodating persons with disabilities.

Applicability to Other Intersections

This study is based on samples of pedestrians from 23 intersections in six jurisdictions around the United States. This report presents information on the characteristics of younger and older pedestrians at those intersections. It is unlikely that the samples were representative of all pedestrian populations at all intersections in the United States. Many aspects of a single intersection or jurisdiction may affect the walking characteristics of pedestrians, including traffic volumes, approach grades, temperature, and surrounding land use. The project team attempted to identify jurisdictions that were geographically dispersed and diverse.

FUTURE DIRECTIONS

1. There is a need for guidance regarding when to use PCD signals. This current study focused on a few communities that have developed criteria for implementing PCD signals.

2. More detailed traffic operational analysis using both micro-simulations and field data should be undertaken prior to actually making a recommendation for changes to MUTCD.

3. The scope of this study did not specifically investigate the impact of signal timing on blind and low-vision pedestrians and their use of pedestrian-accessible signals. Future studies should convene focus groups to develop parameters of future efforts that would consider the start-up time and walking speed differences of these pedestrian subgroups.

4. Research recommendations addressing gaps in the profession include the following:

   A. Investigate the impact of longer pedestrian clearance times on traffic flow for a highly traveled urban corridor with coordinated signals.

B. Investigate the ability of individual pedestrians of various age groups and disability status to vary their crossing speeds based on the signal indication and/or threat of conflicting vehicles.

C. Investigate the effect of age in greater detail because “all pedestrians over age 65” is not necessarily a homogenous group in terms of walking speeds and mobility levels (*Manual of Transportation Engineering Studies* 2000).

APPENDIX A

WEB-PEDESTRIAN COUNTDOWN SIGNAL SURVEY: INSTRUMENT AND FINDINGS

LIST OF TABLES

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PURPOSE OF SURVEY

The purpose of this survey is to identify the state of the art and state of the practice in pedestrian signal timing and the use of pedestrian signals. This Web-based survey will have as its objective the development of a body of knowledge on walking speeds as they relate to special user populations, including older persons. We also are requesting information regarding pedestrian countdown (PCD) signals, including comprehension, number of countdown signals in a jurisdiction, advantages, and challenges.

INSTRUCTIONS

Complete the survey questions as accurately as time permits. If your jurisdiction does not use PCD signals, there are only three questions for you to answer in this survey. If your jurisdiction does have PCD signals, there are a total of 21 survey questions. Do not worry if you cannot answer every question; any information you can provide will be useful and is appreciated.

QUESTIONS

Confidentiality (Q1)

We understand the need for confidentiality regarding any data and responses you provide. In most instances, the data and responses will be aggregated and/or summarized. There may be occasions where we would like to showcase jurisdictions using state-of-the-art equipment and/or methods and lessons learned. Please check the appropriate box below to indicate the level of privacy you prefer based on the responses you provide in this survey.

I desire complete anonymity. Please do not refer to my organization specifically in this project.
_____ Yes _____ No

I will allow references to the practices, techniques, and equipment used by my organization.
_____ Yes _____ No

If you answered “yes” to the above question, a representative from the Institute of Transportation Engineers will contact you prior to any use of specific data.

Contact Information (Q2)

Name: ________________________________ Title: ________________________________
Telephone:______________________________ Fax: ________________________________
E-mail: ____
Agency: ____
Years working at agency: ____

Question 3

How many signalized intersections does your jurisdiction maintain? _____ (Q3)

Question 4

How many signalized intersections have pedestrian signals? _____ (Q4)

Questions 5a and 5b

At intersections with pedestrian signals, how do you calculate the duration of the pedestrian signal intervals?

WALK interval:____ (Q5a)

Pedestrian clearance time: ____ (Q5b)

Question 6

If walking speed is used in the calculation, what walking speed do you use?

a) _____ feet/second (ft./sec.) is always used (Q6a)

b) _____ variable, depending on the following considerations:

____

Question 7

Do you include the yellow and all-red intervals for the parallel vehicular phase in satisfying the calculated pedestrian clearance time? (For example, with a calculated pedestrian clearance time of 20 sec., 15 sec. would be during the vehicular green, 4 sec. during the yellow interval, and 1 sec. during the all-red interval.)

a) No—calculated time is always contained within just the green.

b) Yes—yellow and all-red time are always used to partially satisfy the calculated time.

c) Sometimes, depending on:

____

Question 8

Section 4.E.0.7 in the 2003 edition of the *Manual on Uniform Traffic Control Devices* (MUTCD) allows for the use of PCD signals. Does your organization use or plan to use PCD signals in the future? (Please check all that apply.) (Q8)

a) Already have countdown signals installed _____

b) No plans to use countdown signals _____

c) Plan to use in the short term (next 12 months) _____

d) Plan to use during the next one to two years _____

e) Plan to use during the next two to five years _____

IF YOUR JURISDICTION DOES NOT OPERATE OR MAINTAIN PCD SIGNALS, STOP HERE.

Question 9

How many signalized intersections are equipped with one or more PCD signals in your jurisdiction? _____ (Q9)

Question 10

How many approaches are equipped with PCD signals in your jurisdiction? _____ (Q10)

Question 11

Total approaches: _____

Of this number:

How many "major street" approaches use PCD signals? ____ (Q11a)

How many "minor/side street" approaches use PCD signals? _____ (Q11b)

Question 12

In what month and year was your first PCD signal installed? (Q12)

_____ Month _____ Year

Question 13

What warrants or criteria do you use to identify where PCD signals should be installed? (Q13)

___

Question 14

Have you developed any policies or procedures for the use of PCD signals in your jurisdiction? (Note: If yes, please attach or send us a copy of any documentation. Contact information is provided at the end of this survey.) (Q14) _____ Yes _____ No

Question 15

Based on your experience, at what type of intersections do you recommend that PCD signals be used? (Q15)

___

Question 16

Are there any types of locations where you would recommend that countdown signals should not be used? (Q16)

____

Question 17

For your PCD signals, when does the countdown begin? (Q17)

a) At the start of the WALK _____

b) At the start of the flashing DON'T WALK _____

c) Other ____

Question 18

When does the countdown end? (Q18)

a) At the end of the flashing DON'T WALK _____

b) During the steady DON'T WALK _____

c) At the onset of the vehicular yellow interval _____

d) At the onset of the vehicular red interval _____

e) Other____

Question 19

Do PCD signals encourage pedestrians to begin crossing during the flashing hand clearance interval (Q19a) resulting in a higher level of service for pedestrians (whether the crossings were initiated legally or not)? (Q19b) _____ Yes _____ No

Question 20

If the answer to Question 19a is "yes" and we are also seeing the same or fewer pedestrians in crosswalks when traffic signal phases change, are changes needed to Section 4E.02 of MUTCD to reflect the actions of reasonable pedestrians? (Q20) _____ Yes _____ No

Question 21

Has the countdown signal ever provided an erroneous indication of the crossing time remaining? (Q21) _____ Yes _____ No

If your answer is "yes" please go to Question 22.

Question 22

If you answered “yes” to Question 21, was this the result of: (Q22)

a) A preemption of the intersection _____

b) Manual control of the intersection _____

c) Other circumstances (please describe) ____

Question 23

If you conducted any evaluations of PCD signals, please briefly describe the evaluation(s) below and attach any supporting documentation (such as reports). (Q23)

____

Question 24

What positive effects, if any, have been observed with PCD signals? (Include effects on pedestrian compliance, safety, walking speed, etc.) (Q24)

____

Question 25

What negative effects, if any, have been observed with PCD signals? (Q25)

____

Question 26

With the use of PCD signals, have you observed any evidence of differential pedestrian experience based on age and/or physical abilities (such as school-age children, teenagers, the elderly, or wheelchair users)? (Q26)

____

Question 27

Have you observed any differences in motorist behavior at intersections equipped with PCD signals? (Q27)

____

Question 28

Can we follow up with you by telephone if we have additional questions? (Q28)
_____ Yes _____ No

RESULTS OF PEDESTRIAN SIGNAL SURVEY

Purpose of Survey

The purpose of the survey of governmental organizations was to identify the state of the art and state of the practice in pedestrian signal timing and the use of pedestrian signals. This Web-based survey had as its objective the development of a body of knowledge on walking speeds as they relate to special user populations, including older persons. The project team also requested information regarding PCD signals, including comprehension, number of countdown signals, advantages, and challenges.

Survey Methodology

The e-mail survey was conducted between June 17 and June 29, 2004. There were 1,140 invitees. Invitees comprised members of the Institute of Transportation Engineers (ITE) employed in a public agency either at the local (city, county, or township) or state level. There were 599 visits to the electronic survey (53 percent of invitees viewed the survey), with an overall response rate of 16 percent (n = 182 responses).

As would be expected, not all responses contained answers to every question. ITE understood the need for privacy for some organizations and the hesitancy of some respondents to provide data. Question 1 requested that the respondents indicate the level of privacy desired in exchange for completing the survey. A total of 43 respondents requested complete anonymity in terms of any publication or summary information that might contain information related to their jurisdiction.

SURVEY DEMOGRAPHICS

Table A-1 shows the distribution of respondents by agency/organization type. As shown, more than half (54.2 percent) of the respondents were employed by U.S. city governmental agencies. Approximately 14 percent of the respondents worked for county or combined city/county governmental organizations. Combined, almost seven of 10 respondents (115 of the 168 respondents) worked for local governmental organizations. Almost 20 percent of the respondents (n = 31) were employed at state departments of transportation. Non-U.S. respondents included Canadian cities and provinces (17, or 10.2 percent) and international cities and provinces (5, or 3.0 percent).

Figure A-1 shows the 41 states where survey respondents were employed. The numbers included in Figure A-1 (1/1) represent the number of jurisdictions or organizations that responded from a particular state and the number of jurisdictions or organizations that have PCD signals in place.

Table A-1. Distribution of respondents by agency/organization type.

Agency/organization type	Number	Percentage of total
U.S. cities	91	54.2
U.S. city/county governments	4	2.4
U.S. counties	20	11.9
State departments of transportation	31	18.5
Canadian cities	9	5.4
Canadian provinces	8	4.8
International cities/provinces	5	3.0
Total	168	100.0

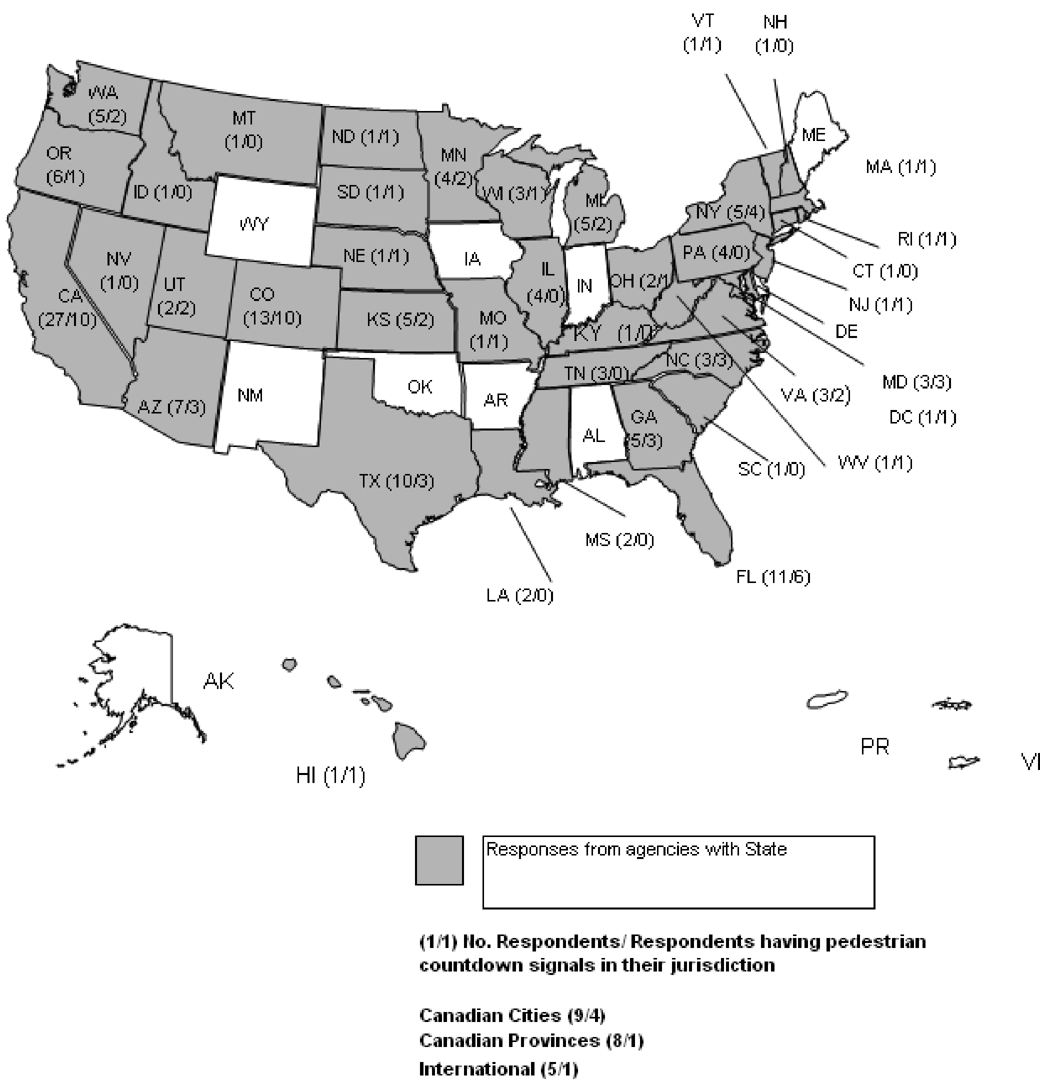


Figure A-1. Location of pedestrian signal survey respondents.

Table A-2 lists the number of intersection approaches (approaches have been stratified by major street and minor street) where PCD timers were used for each respondent organization. Organizations included in this table did not request anonymity and provided the required information for survey questions 9 through 12. Numbers of PCD signals were ranked for each respondent organization. The five highest ranked respondent organizations for number of PCD timers included Salt Lake City, Utah; Charlotte, North Carolina; Fountain Valley, California; Denton, Texas; and Phoenix, Arizona.

Respondents were asked the extent to which PCD signals were used on major streets or minor (side) streets. A total of 52 respondents completed this set of questions. The average for PCD signals on major streets and minor (side streets) was 54.9 percent and 43.2 percent, respectively.

Table A-2. Respondent organizations for number of PCD signal timers and their use on major and minor street approaches.

Employer type	Agency	Q10: approaches with PCD timers	Rank, number of PCD timers	Q11a: major street	Percentage of total on major street	Q11b: minor street	Percentage of total on minor street approach
City	Salt Lake City Corporation, Utah	578	1	517	89.4	61	10.6
City	Charlotte Department of Transportation, North Carolina	280	2	140	50.0	140	50.0
City	City of Fountain Valley, California	170	3	85	50.0	85	50.0
City	City of Denton, Texas	158	4	66	41.8	92	58.2
City	City of Phoenix, Arizona	122	5	40	32.8	82	67.2
State department of transportation	Florida Department of Transportation	120	6	60	50.0	60	50.0
City	City of Alexandria, Virginia	120	6	60	50.0	60	50.0
City	City of San Antonio, Texas	100	8	50	50.0	50	50.0
City	City of Pueblo, Colorado	96	9	80	83.3	16	16.7
City	City of Grand Junction, Colorado	84	10	32	38.1	52	61.9
City, Canada	City of Montreal, Canada	50	11	5	10.0	45	90.0
City	City of Boulder, Colorado	41	12	5	12.2	36	87.8
City	City of Greeley, Colorado	40	13	20	50.0	20	50.0
City, Canada	Corporation of Delta, British Columbia, Canada	40	13	20	50.0	20	50.0
State department of transportation	Maryland State Highway Administration	34	15	16	47.1	18	52.9
City	City of White Plains, New York	30	16	14	46.7	16	53.3
City	City of Kelowna, British Columbia, Canada	30	16	16	53.3	14	46.7
City	City of Ventura,	28	18	14	50.0	14	50.0

Table A-2. Respondent organizations for number of PCD signal timers and their use on major and minor street approaches.
(continued)

Employer type	Agency	Q10: approaches with PCD timers	Rank, number of PCD timers	Q11a: major street	Percentage of total on major street	Q11b: minor street	Percentage of total on minor street approach
	California						
City	City of San Jose, California	27	19	19	70.4	8	29.6
City	City of Bismarck, North Dakota	22	20	10	45.5	12	54.5
City	City of Lakewood, Colorado	20	21	20	100.0	0	0.0
County	Broward County, Florida	18	22	10	55.6	8	44.4
City	City of Beaverton, Oregon	15	23	12	80.0	3	20.0
State department of transportation	Minnesota Department of Transportation	12	24	12	100.0	0	0.0
City, international	Madrid City Hall–Urbanism–Housing–Infrastructres	12	24	12	100.0	0	0.0
Region, Canada	Region of Peel, Canada	12	24	0	0.0	12	100.0
City	City of Rancho Cucamonga, California	12	24	6	50.0	6	50.0
State department of transportation, international	VicRoads	10	28	10	100.0	0	0.0
County	Palm Beach County, Florida	8	29	4	50.0	4	50.0
State department of transportation	West Virginia Division of Highways	8	29	2	25.0	6	75.0
County	Road Commission for Oakland County, Michigan	8	29	6	75.0	2	25.0
City	City of Mesquite, Texas	8	29	4	50.0	4	50.0
City	City of Palm Desert, California	8	29	8	100.0	0	0.0
City, Canada	City of St. George, Canada	8	29	4	50.0	4	50.0
City	City of Fayetteville, North Carolina	7	35	4	57.1	3	42.9
City	City of San Diego, California	6	36	3	50.0	3	50.0
County	Monterey County Public Works, Monterey County,	5	37	4	80.0	1	20.0

Table A-2. Respondent organizations for number of PCD signal timers and their use on major and minor street approaches.
(continued)

Employer type	Agency	Q10: approaches with PCD timers	Rank, number of PCD timers	Q11a: major street	Percentage of total on major street	Q11b: minor street	Percentage of total on minor street approach
	California						
City	City of Dallas, Texas	4	38	0	0.0	4	100.0
City	City of Overland Park, Kansas	4	38	0	0.0	4	100.0
City	City of Kissimmee, Florida	4	38	2	50.0	2	50.0
City	City of Ithaca, New York	4	38	2	50.0	2	50.0
City	Department of Transportation Services, Honolulu, Hawaii	4	38	2	50.0	2	50.0
City	City of Lincoln, Nebraska	3	43	2	66.7	1	33.3
County	Monmouth County, New Jersey	3	43	1	33.3	2	66.7
City	Hampton, Virginia	3	43	2	66.7	1	33.3
County	Nassau County, New York	2	46	1	50.0	1	50.0
State department of transportation	Washington State Department of Transportation NW Region	2	46	1	50.0	1	50.0
State department of transportation	Rhode Island Department of Transportation	2	46	0	0.0	2	100.0
City, Canada	City of Windsor, Ontario, Canada	2	46	2	100.0	0	0.0
City	City of Yuma, Arizona	1	50	1	100.0	0	0.0
State department of transportation	Vermont Agency of Transportation	1	50	1	100.0	0	0.0
City	Lake Havasu City, Arizona	1	50	1	100.0	0	0.0
Average					54.9		43.2

Figure A-2 shows the distribution of respondents' plans to install PCD signals. As shown, 86 of the 175 respondents (49 percent) already had PCD signals in place. Another 40 of the respondents (23 percent) planned to install PCD signals during the next five years. Approximately one in three respondents (28 percent) indicated that they had no plans to install PCD signals.

CRITERIA USED TO IDENTIFY WHERE PCD SIGNALS SHOULD BE INSTALLED

Most jurisdictions will selectively install PCD signals as opposed to retrofitting all existing pedestrian signals with countdown timers. Figure A-3 shows the general categories of factors that traffic engineers used to decide where to install PCD signals. Respondents were permitted to provide multiple answers to this question. In total, 152 responses were provided. As shown, the largest categories of responses were location criteria (n = 49, or 32 percent) and pedestrian characteristics (n = 56, or 37 percent). Other factors included roadway characteristics (13 percent), traffic operations (12 percent), and requests (6 percent).

Figure A-4 summarizes the responses provided under location criteria. As shown, schools received the highest number of responses (45 percent), followed by downtown or urban areas (12 percent), pedestrian access routes/pedestrian activity centers (12 percent), environments with a significant number of seniors (10 percent), and areas adjacent to transit stops/subway stations (8 percent).

Figure A-5 shows the responses provided under the pedestrian characteristics criterion. As shown, "high pedestrian volumes" received the greatest number of responses (more than 57 percent). There was some discussion among respondents that having actual numbers of pedestrians (perhaps daily or hourly) might be useful. Just more than 20 percent of the respondents indicated that PCD signals would be beneficial for senior or very young pedestrians. Other pedestrian characteristics mentioned in lower numbers included pedestrian crash history, ethnic diversity, inexperienced users, high pedestrian pushbutton usage, and high bicycle volumes.

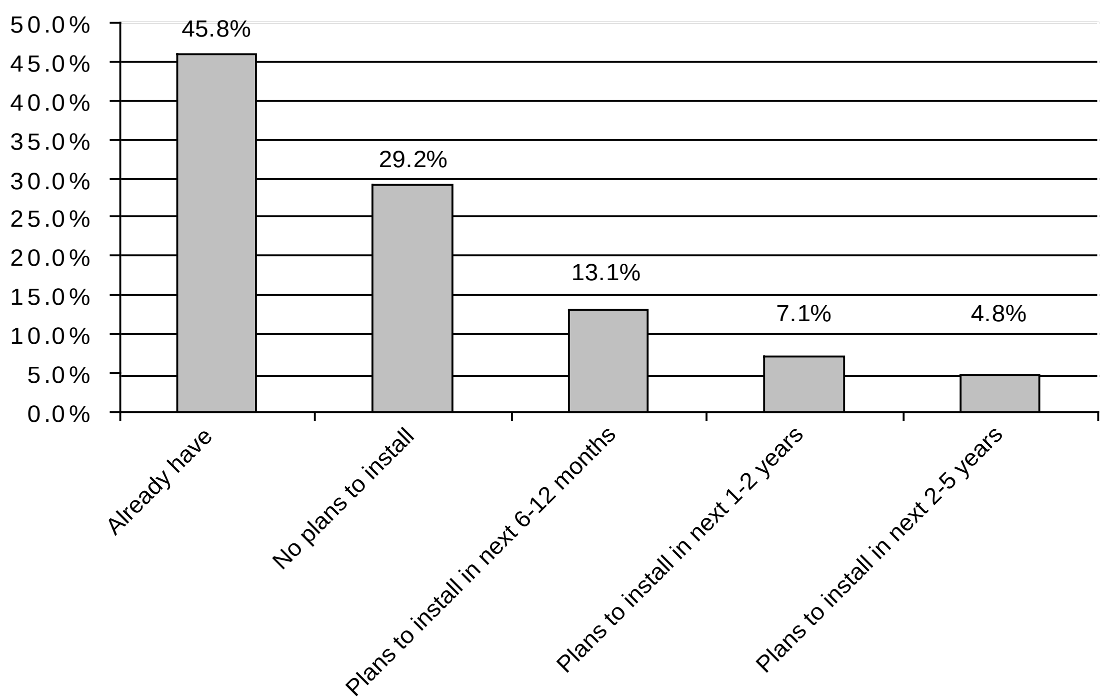


Figure A-2. Distribution of respondents' plans to install pedestrian countdown signals.

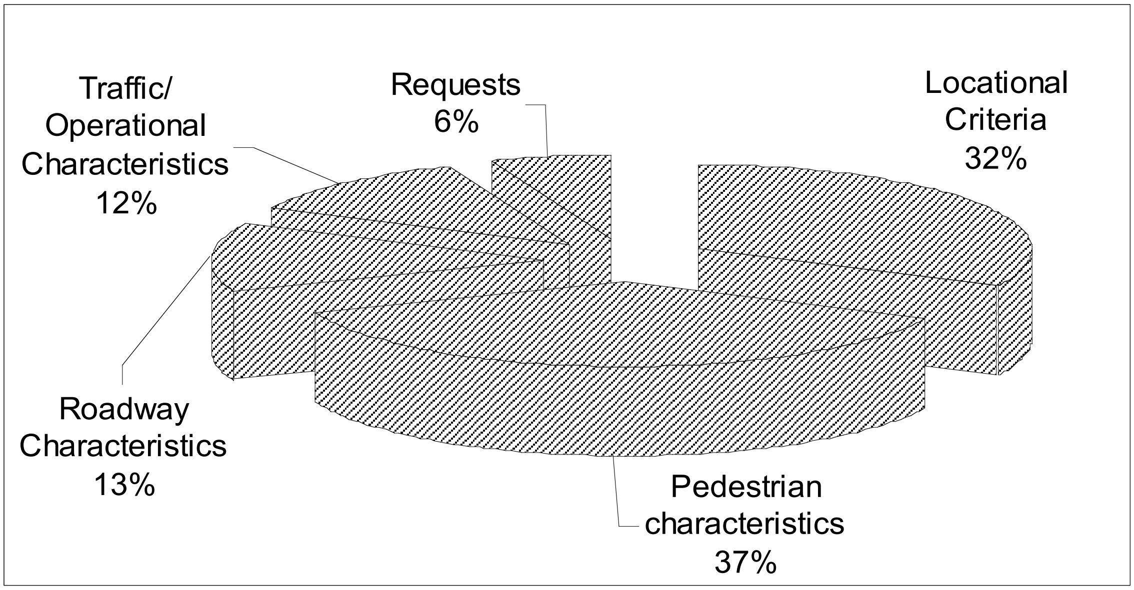


Figure A-3. Factors considered when installing pedestrian countdown signals.

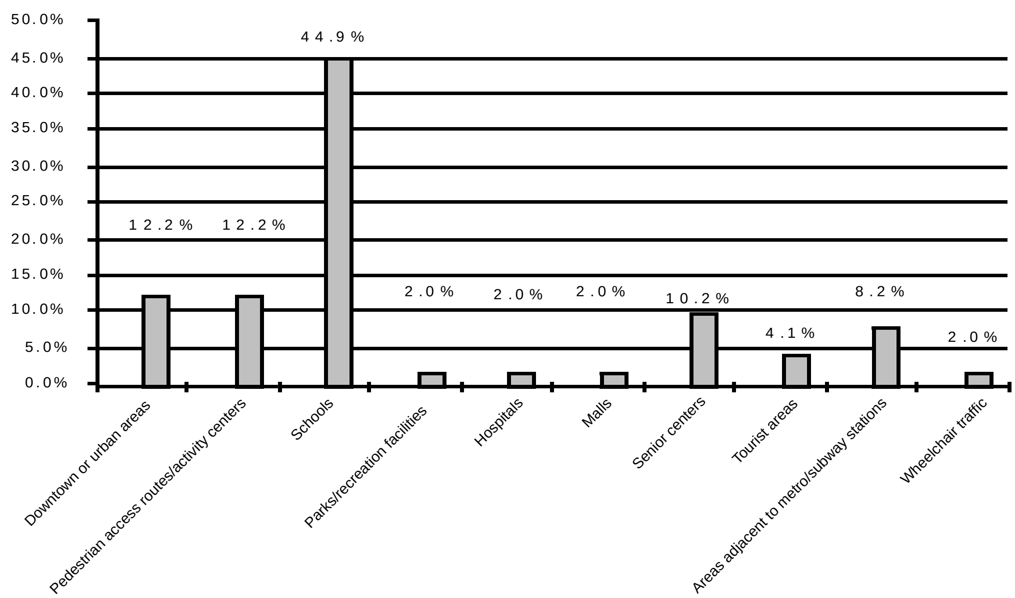


Figure A-4. Location criteria for considering installation of pedestrian countdown signals.

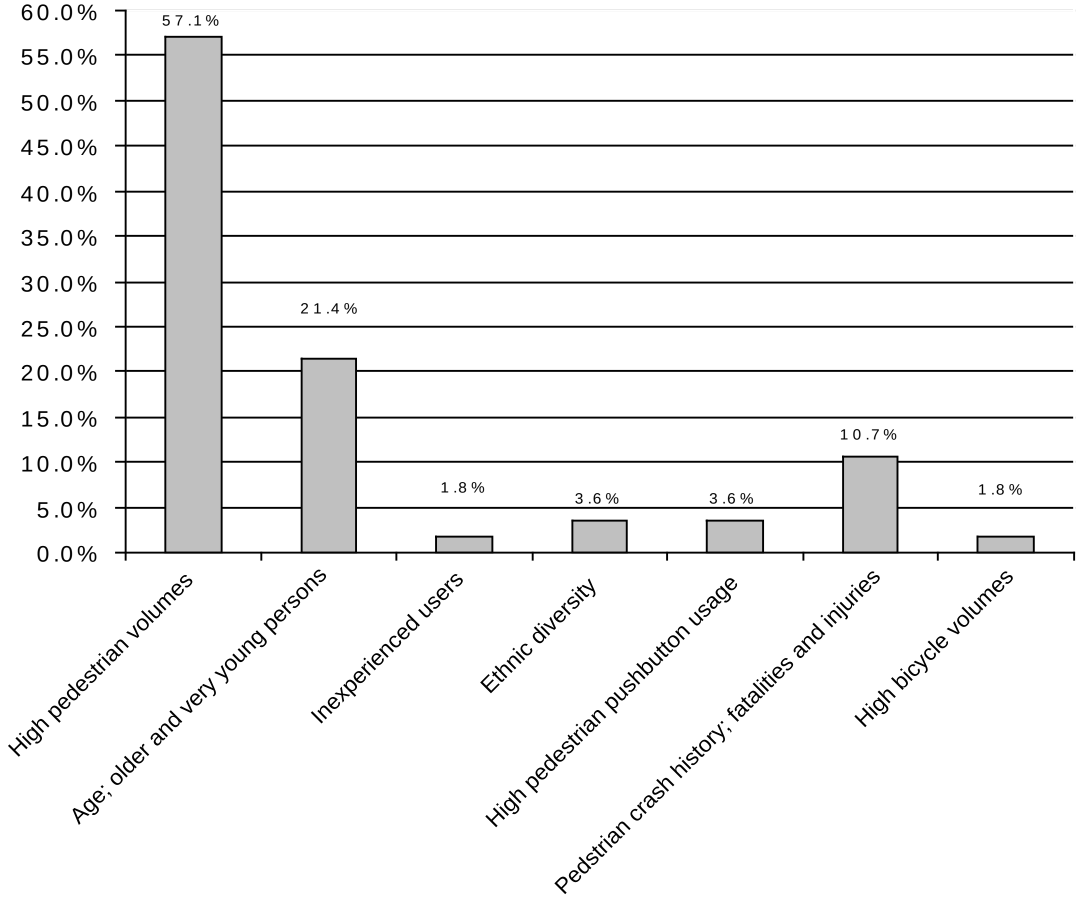


Figure A-5. Pedestrian characteristics considered when proposing pedestrian countdown signals.

Figure A-6 shows the responses provided under the traffic operations criterion. As shown, “high traffic volumes” received the greatest number of responses (33 percent). Other traffic operations characteristics mentioned in lower numbers included high speeds, pedestrian-vehicular conflict areas, and the location of an existing pedestrian-actuated signal at the intersection.

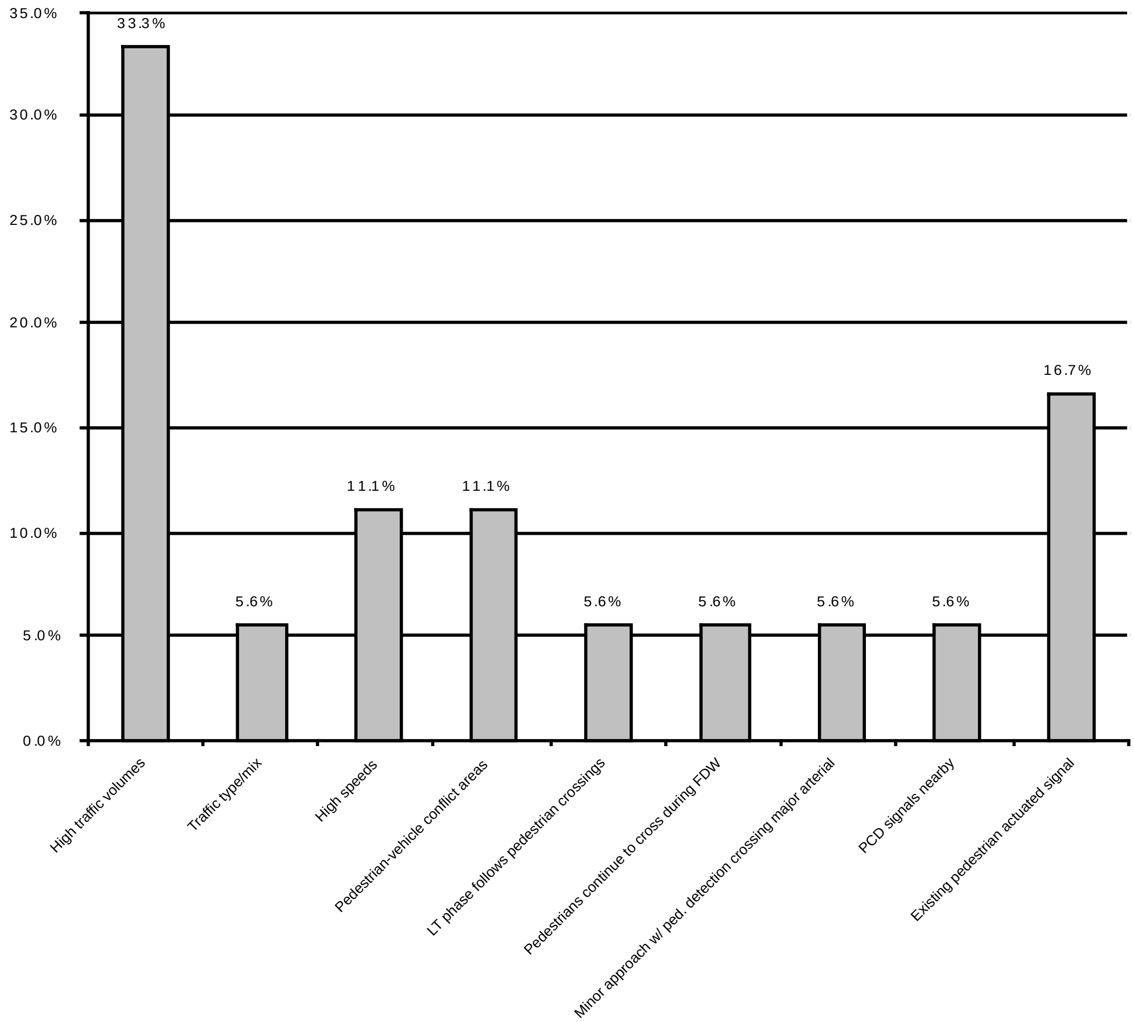


Figure A-6. Traffic operations criteria for considering implementing PCD signals.

Monroe County, New York developed a traffic operational criterion to assist in the decision to use a PCD signal or a traditional pedestrian signal (TPS). The County considers the influence of conflicting vehicles that could delay a pedestrian briefly during the flashing DON'T WALK (FDW) interval. Locations with heavier right-turning and left-turning vehicle volumes have a higher potential to delay a pedestrian's crossing. The time remaining information would be helpful in this situation to reassure a pedestrian that there is still adequate crossing time available for the completion of the crossing. Monroe County developed a draft guideline for when this condition exists: PCD signals are recommended where right-turning and left-turning volumes that conflict with the crosswalk are greater than 400 vehicles per hour.

Figure A-7 shows the responses provided under the roadway characteristics criterion. A total of 20 responses were received for this issue. Wide crossings were mentioned in 80 percent (n = 16) of the responses. Two other responses included multi-lane roadways (this could be another way of stating wide crossings) and complex intersections containing unusual geometrics.

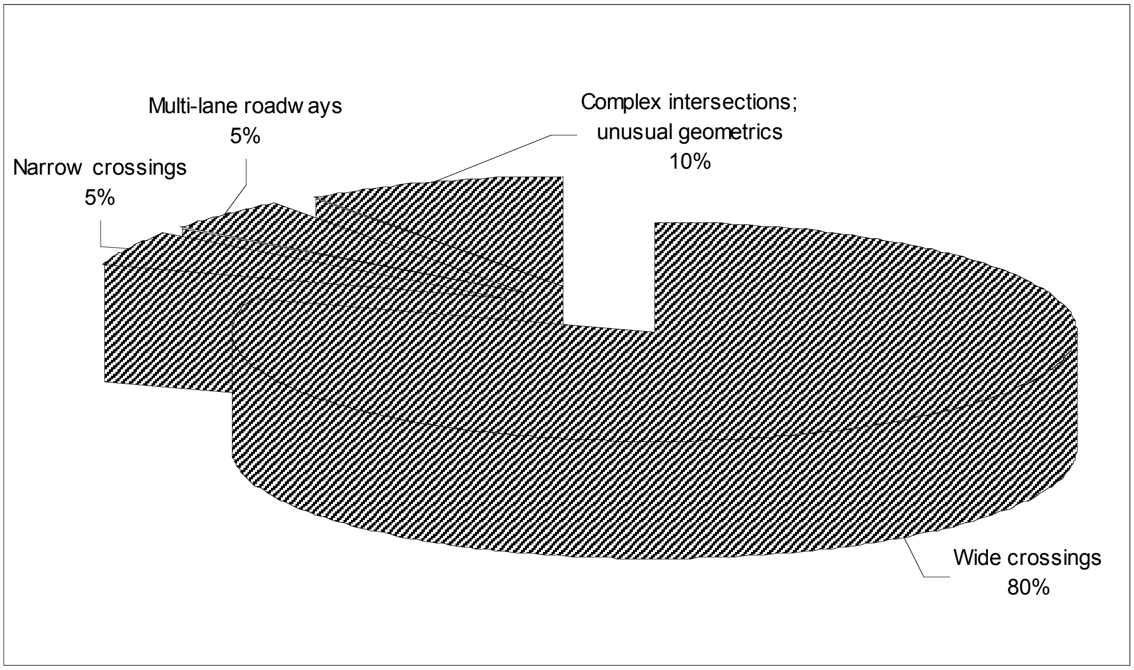


Figure A-7. Roadway characteristics.

LOCATIONS WHERE COUNTDOWN SIGNALS SHOULD NOT BE USED

Table A-3 summarizes the responses in tabular form. When respondents were asked to identify locations where they would recommend that PCD signals should not be used, surprisingly, 41 percent (n = 25) indicated that they would use PCD signals in all cases.

Responses that cited locations where countdown signals should not be used included: areas of low pedestrian volumes (18 percent); cost considerations, including acquisition, energy, and maintenance costs (8 percent); and intersections with wide crossings (10 percent). It appears that there was a divergence of opinion with regard to wide crossings. In question 13 (see Figure A-7), 80 percent of the respondents indicated that PCD signals were appropriate and should be used for wide crossings.

Monroe County, New York considered the issue of providing PCD signal devices based on roadway crossing distance. The County considered crossing distance (number of lanes to cross) and the time required to cross under a 4.00 feet/second (ft./sec.) and 6.0 ft./sec. scenario. The County concluded that there was increased usefulness of the PCD signal as the crosswalk distance increased, especially in cases of extreme length. The County developed a threshold of at least a 60-ft. crossing distance to implement a PCD signal.

Table A-3. Locations where countdown signals should not be used.

Item	Number	Percentage of total
Use in all cases.	25	40.3
Low pedestrian activity; intersections that do not contain the required pedestrian demographics.	11	17.7
Wide streets; if streets are too wide, pedestrians may not have a clue how long it would take to cross, so the numbers displayed could be meaningless. In these cases, education could address this potential issue. Short crossings/narrow roadways with less than three lanes to cross. Smaller, two-phase intersections with one lane per direction.	6	9.7
Funding/cost to acquire/maintain.	5	8.1
Do not use if planning to reduce the pedestrian clearance phase during preemption. Where preempt programming may override countdown operations.	3	4.9
High vehicular speeds.	2	3.2
Where there are no crossing facilities for pedestrians	1	1.7
Do not use with signals where the WALK time varies due to coordination if the countdown begins with the WALK display (unless the countdown signal technology has addressed this issue).	1	1.6
Alternatively, tell pedestrians how long they have to wait rather than scare them into clearing the road.	1	1.6
Where motorists have a clear view of the timer display.	1	1.6
Difficult to use on a main street for a side street crossing.	1	1.6
On main streets; crossing the shorter distance of the side street. There is the concern that the driver on the main street may use them to determine the onset of amber and possibly try to beat the light.	1	1.6
Do not use where the WALK indication is included in the countdown.	1	1.6
Areas where pedestrians are predominantly mobile; FDW becomes meaningless.	1	1.6
Long cycle lengths.	1	1.6
Audible pedestrian signal locations.	1	1.6
TOTAL	62	100.0

PEDESTRIAN COUNTDOWN SIGNAL START/END TIMES

Survey questions 17 and 18 asked respondents about the start and end times of their PCD signals. A total of 78 responses were completed for this set of questions. The objective of these questions was to identify the extent to which jurisdictions were using the PCD devices in accordance with MUTCD guidance. The following guidance is included in MUTCD for PCD timer start and end times:

Guidance

1. The display of the remaining seconds shall begin only at the beginning of the pedestrian change interval [when the FDW symbol appears].

2. The PCD signal shall display the number of seconds remaining until the termination of the pedestrian change interval [FDW].

3. After the countdown displays zero, the display shall remain dark until the beginning of the next countdown.

4. Countdown displays shall not be used during the WALK interval nor during the yellow change interval of a concurrent vehicular phase.

DO PEDESTRIAN COUNTDOWN SIGNALS ENCOURAGE PEDESTRIANS TO BEGIN CROSSING DURING THE FLASHING HAND CLEARANCE INTERVAL?

As shown in Figure A-8, 62 percent of the jurisdictions/organizations surveyed started the countdown (the show of the remaining seconds) at the beginning of the FDW. The countdown was completed at the end of the FDW. Another 3 percent indicated that they started the countdown timer at the beginning of the FDW and ended during the steady DW. Taken together, these two responses show that about two out of three respondents followed the MUTCD guidance and one-third of the respondents were not operating their PCD signals in accordance with MUTCD.

Significant comments related to whether or not PCD signals encourage pedestrians to begin crossing during the flashing hand clearance interval are noted below:

- PCD signals encourage pedestrians to begin crossing during the FDW interval. That is illegal in California. It essentially encourages jaywalking.

- For some pedestrians, yes. Faster pedestrians cross while slower ones wait for the next cycle.

- Yes. It better informs the pedestrians and, in turn, encourages pedestrians to actually push the button and wait for the indication to walk.

- The public believes that they must return to the curb when the flashing hand begins, especially the elderly population. Many ask, “Why can’t the WALK symbol flash instead?” The use of a flashing WALK symbol in the color of orange would be better understood than the flashing hand.

- My observation has shown that they actually discourage, more than encourage, crossing, but both are true.

- They do not encourage crossing during the flashing hand clearance interval. However, pedestrians who would normally wait to cross now know how much time they have left.

- It works both ways. People who may have attempted to cross when they didn't know how much time was remaining now wait for the next cycle.

- I have not seen an increase in stepping into the crosswalk after the flashing hand has started; however, I could see how someone who had the ability to walk faster could be encouraged to fast-step it if one might see 10 to 12 seconds remaining on the indication. We have not studied it directly.

- No. Our "before and after" studies show improved pedestrian compliance with WALK and FDW indications.

- The countdown signals provide valuable information on the amount of time left to cross. Whether it encourages people to cross during the flashing portion is debatable because most of these people would probably cross anyway if encountering a flashing hand. What it does do is tell them when they shouldn't even try to cross.

- No, our pedestrians start to cross when the walk light is on and before the flashing hand.

- No. The presence of countdown heads does not appear to reduce risky pedestrian behavior.

- Internal studies show that the PCD signal heads do not encourage that behavior any more than that of the standard pedestrian signal head.

- Our studies did not show an increase in pedestrians beginning crossing during the flashing hand. However, our studies do show that the countdown signals encourage pedestrians to complete their crossings before the solid hand is displayed and reduce the conflicts between pedestrians and motor vehicles.

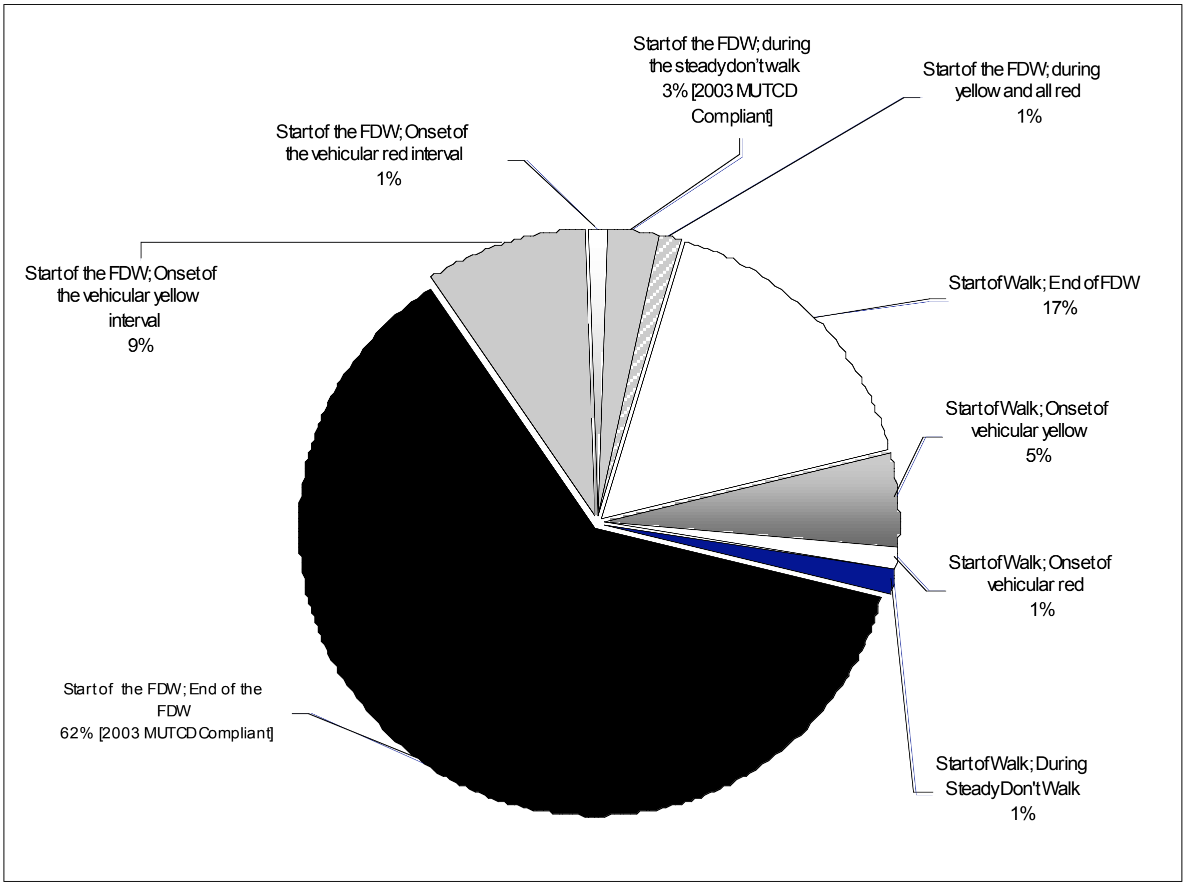


Figure A-8. Pedestrian countdown signal start/end times.

DO PEDESTRIAN COUNTDOWN SIGNALS PROVIDE A HIGHER LEVEL OF SERVICE?

Figure A-9 shows that there was a definite split of opinion or, perhaps, an acknowledgment that additional research is needed in this area. Twenty-five percent of respondents indicated they did not know the answer to the question. The split between “yes” and “no” to this question was 43 percent and 29 percent, respectively. An additional 3 percent indicated “yes and no” or “possibly.”

It appears that the respondents had difficulties understanding what the project team was referring to as a “higher LOS.” Traditional pedestrian LOS can be thought of as the density of pedestrians around you and the amount of space you have relative to a sidewalk, crosswalk, or pedestrian access route.

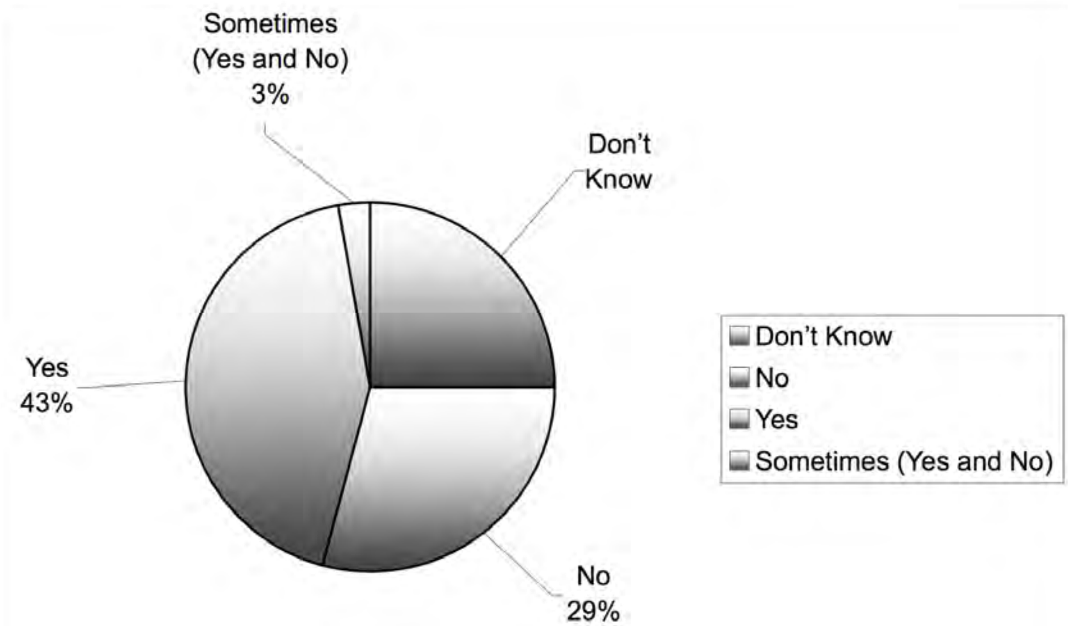


Figure A-9. Do pedestrian countdown signals encourage pedestrians to begin crossing the street during the flashing DON'T WALK interval?

A few of the significant responses as to what a higher pedestrian LOS means are provided below:

- The ability to make a more informed choice that can help them adapt their behavior to the ambient conditions.
- Allowing pedestrians to cross during FDW (pedestrians can enter crosswalk) at a [uniform] walking speed and still complete crossing prior to beginning of the conflicting green.
- Reduced delay for the pedestrian.
- A reduced number of pedestrians in the crosswalk at the onset of amber.
- Improved pedestrian compliance with WALK and FDW indications.

The Minnesota Department of Transportation (MnDOT) completed a market research analysis in 1999 that considered both traditional and PCD indications. A complete summary of the findings can be obtained from ITE. As related to question 19, the Minnesota study developed a series of before (traditional) and after (PCD indications) service levels. Table A-4 shows the five distinct service levels developed. This current study might consider adapting or modifying these service levels based on specific project objectives.

The MnDOT phase I study conclusions relative to service levels were as follows:

1. When pedestrians crossed at intersections where the pedestrian crossing signal showed the international symbols with a flashing hand and numeric countdown, the number of pedestrians successfully served by a pedestrian indication increased over intersections served by pedestrian indications showing only the international symbols or English text.
2. In all age groups—seniors, other adults, and teens—the percentage of successfully served crossings increased when pedestrians crossed with a pedestrian indication showing a flashing hand with a numeric countdown (see Table A-5).

3. Seniors and other adults showed some improvement when crossing at intersections served by a pedestrian indication with a flashing hand and numeric countdown showing. The greatest increase in successful service occured among teens. Twenty percent more teens were successfully served at such intersections. Teens crossing at intersections served by the new pedestrian indication (international symbols with a flashing hand and a numeric countdown) were less likely to be violators—starting and completing a crossing at an intersection when the solid hand is showing. The percentage of teen violations at intersections served by the new pedestrian indications (with the flashing hand and numeric countdown showing) was down by 20 percent.

Table A-4. Minnesota Department of Transportation market research analysis: service levels for traditional and pedestrian countdown signals.

Before condition [traditional]	After condition [countdown signals]
A) SUCCESSFULLY SERVED—APPROPRIATE START	A) SUCCESSFULLY SERVED—APPROPRIATE START
Started crossing and completed crossing when walking person/WALK showing.	Started crossing and completed when walking person showing.
Started crossing when walking person/WALK showing and completed crossing when flashing hand/flashing DON'T WALK showing.	Started crossing when walking person showing and completed crossing when flashing hand with numeric countdown showing.
B) SUCCESSFULLY SERVED—INAPPROPRIATE START	B) SUCCESSFULLY SERVED—INAPPROPRIATE START
Started crossing and completed crossing when flashing hand/flashing DON'T WALK showing.	Started crossing and completed crossing when flashing hand with numeric countdown showing.
C) NOT SUCCESSFULLY SERVED—APPROPRIATE START	C) NOT SUCCESSFULLY SERVED—APPROPRIATE START
Started crossing when walking person/WALK showing and completed crossing when solid hand/solid DON'T WALK showing.	Started crossing when walking person showing and completed crossing when solid hand showing.
D) NOT SUCCESSFULLY SERVED—INAPPROPRIATE START	D) NOT SUCCESSFULLY SERVED—INAPPROPRIATE START
Started crossing when flashing hand/flashing DON'T WALK showing and completed crossing when solid hand/solid DON'T WALK showing.	Started crossing when flashing hand with numeric countdown showing and completed crossing when solid hand showing.
Started crossing when flashing hand/flashing DON'T WALK showing and completed crossing when walking person/WALK showing.	Started crossing when flashing hand with numeric countdown showing and completed crossing when walking person showing.
E) VIOLATORS—INAPPROPRIATE START	E) VIOLATORS—INAPPROPRIATE START
Started crossing when solid hand/solid DON'T WALK showing and completed crossing when walking person/WALK showing.	Started crossing and completed crossing when solid hand showing.
Started crossing and completed crossing when solid hand/solid DON'T WALK showing.	Started crossing when solid hand showing and completed crossing when walking person showing.
Started crossing when solid hand/solid DON'T WALK showing and completed crossing when flashing hand/flashing DON'T WALK showing.	Started crossing when solid hand showing and completed crossing when flashing hand with numeric countdown showing.

Table A-5. Percentage of pedestrians successfully served by traditional and pedestrian countdown indications.

	Total	Seniors	Other adults	Teens
Successfully served by pedestrian indications showing only international symbols or English text	67	57	72	53
Successfully served by pedestrian indications showing international symbols with a flashing hand and a numeric countdown	75	68	78	73

DO PEDESTRIAN COUNTDOWN SIGNALS RESULT IN A HIGHER LEVEL OF SERVICE FOR PEDESTRIANS?

- Yes, if plenty of time remains to cross for faster than average pedestrians.
- It is complicated enough as it is. That is the beauty of the countdown signal; it makes the pedestrian signal understandable.
- Yes; starting to cross during FDW should be allowed if the pedestrian can enter the crosswalk at a walking speed and still complete the crossing prior to the beginning of conflicting green.
- Yes. It appears to give pedestrians the opportunity for a more informed choice.
- It gives pedestrians additional information and they can make an informed choice as to whether they want to cross.
- Fewer pedestrians are in the crosswalk at the onset of clearance interval.
- Yes, pedestrians can gauge their own crossing time by their abilities.
- It tells people the time available and most are prudent once they know it.
- Yes, if a higher LOS means reduced delay.
- Although more pedestrians are starting their crossing during the FDW, more pedestrians also finish during the same interval.
- Yes, with particularly aggressive pedestrians; others wait for the new WALK.
- Yes. Once people see the number of seconds left, and if they believe they can make it across [the street], they will cross with the flashing hand. Teenagers would use it. Seniors and people who do not cross at a location regularly may not cross because of the flashing hand.
- Yes; pedestrians enter at their own risk if they believe they can make it across.
- Yes, but the number of pedestrians in the crosswalk at the onset of amber is also reduced (i.e. the pedestrians speed up to clear the intersection).

- No. Countdown timers encourage able pedestrians to cross on the DW. This is not necessarily a higher LOS.

If the answer to the above question is “yes,” and we also are seeing the same or fewer pedestrians in crosswalks when traffic signal phases change, are changes needed to Section 4E.02 of MUTCD to reflect the actions of reasonable pedestrians? (Q20)

Figure A-10 provides a summary of respondents’ answers to this question. Respondents were completely split in their answers: 42 percent said “yes,” 45 percent said “no,” and 13 percent said “maybe.” However, only 24 of the 182 respondents answered this question. It appears that most respondents did not know the answer to the question. Subsequent phases of this research effort may be able to more specifically identify any changes needed to MUTCD and, perhaps, any ITE recommended practices.

As an example, some communities soon may pass ordinances (similar to Salt Lake City, Utah) that allow pedestrians to enter the crosswalk during a pedestrian clearance phase if there is a countdown signal present.

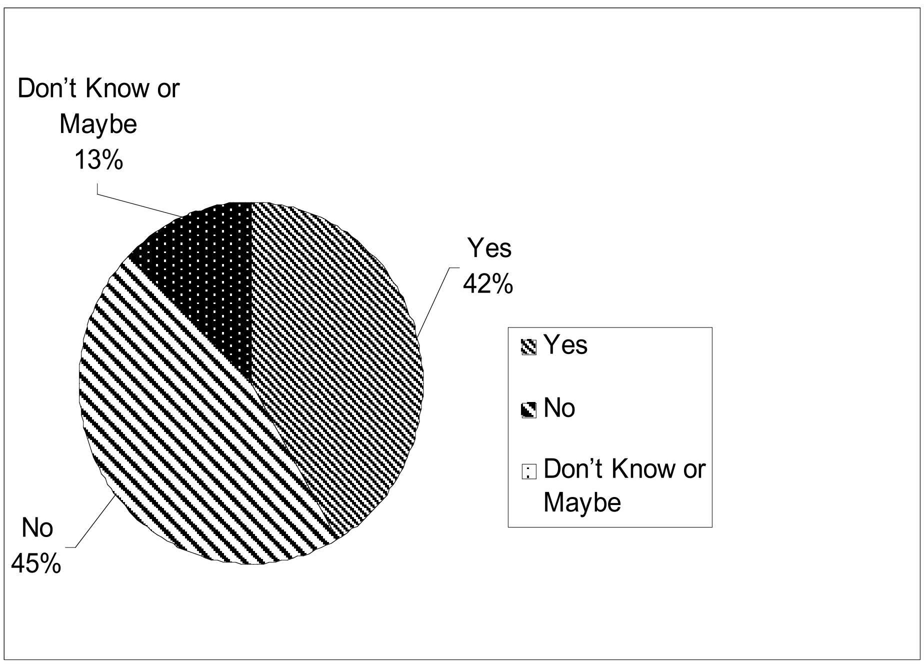


Figure A-10. Are changes needed to Section 4.E.02 of MUTCD?

Significant comments relating to whether there are fewer people in the crosswalk when the traffic signal phase changes and if there is a need to revise Section 4E.02 of MUTCD are summarized below:

- No, leave the section as is.
- Being from Canada, I am not sure about MUTCD. However, I don't think a change in this regulation will have any impact on pedestrian safety or crossing habits.
- Even with the countdown timer associated with the pedestrian head, the use of "hand" and "man" is still confusing to many pedestrians. Yes, we should look at revising.
- Yes. We are considering passing an ordinance similar to Salt Lake City that allows entering the crosswalk during a pedestrian clearance phase if there is a countdown signal present.
- No. Maybe research into a whole new approach for pedestrians to replace the current WALK/FDW/DW approach that is not well understood.

POSSIBLE ERRONEOUS INDICATIONS OF CROSSING TIME REMAINING FOR PEDESTRIAN COUNTDOWN SIGNALS

Question 21 asked, "Has the countdown signal ever provided an erroneous indication of the crossing time remaining?" Question 22 attempted to identify the possible reasons for erroneous countdown indications. Figure A-11 illustrates overwhelmingly (80 percent) that PCD signals did not provide erroneous indications of crossing time remaining (N = 82). For the 20 percent of respondents who indicated that they had seen erroneous indications, key responses are summarized below:

- Timing plan changes when WALK is included.
- When WALK included time varied at the actuated intersection.
- Preemption of the intersection.
- Not set correctly; subsequently fixed; equipment malfunction; solved.
- Device must learn the clearance for the first cycle.
- Once a change to the countdown or cycle is made, it will provide an erroneous indication of the crossing time remaining one time only.
- Phase re-service at fully actuated signal.
- Any transitioning of the intersection.

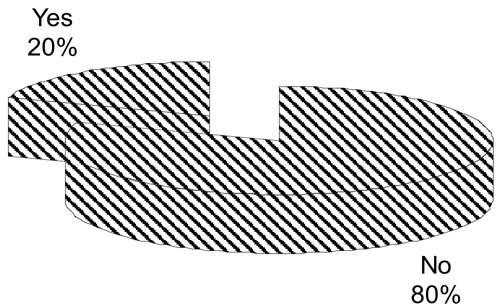


Figure A-11. Has the countdown signal ever provided an erroneous indication of the crossing time remaining?

WHAT POSITIVE EFFECTS, IF ANY, HAVE BEEN OBSERVED WITH PEDESTRIAN COUNTDOWN SIGNALS? (Q24)

(Include effects on pedestrian compliance, safety, walking speed, etc.)

- Favorable public reaction; reduced complaints (n = 25)
- Pedestrian understanding; better decision-making; better comprehension of FDW (n = 23)
- Increased compliance (n = 11)
- Pedestrians adapt their behavior as time runs out (n = 10)
- Benefits to elderly and youth (n = 6)
- Number of pedestrians in the crosswalk of the onset of the amber is reduced; pedestrians not caught in the crosswalk as time ends (n = 5)
- Better student observance in school areas (n = 3)
- Slow walkers are less likely to begin late crossing (n = 2)
- People avoid stopping in medians (n = 2)
- Encourages pedestrians to push the button and wait for the pedestrian indication (n = 2)
- More pedestrians are able to cross during each cycle (n = 2)

WHAT NEGATIVE EFFECTS, IF ANY, HAVE BEEN OBSERVED WITH PEDESTRIAN COUNTDOWN SIGNALS? (Q25)

- None (n = 21)
- Running/leaving curb when not enough time to cross safely; more aggressive pedestrians (n = 10)

- Promotes pedestrian entry during clearance phase (n = 5)
- Drivers tend to start when the countdown is ending; some drivers speed up; drivers focus on the countdown timer (n = 5)
- Pedestrians underestimate time to cross; countdown makes them think they must run (n = 4)
- Cost/cost of maintenance; maintenance is more difficult (n = 2)
- Pedestrians think they need more time when in actuality time given is adequate (n = 2)
- Use of technology for technology's sake (n = 1)
- Encourages jaywalking (n = 1)
- Higher potential for left-turning vehicles to hit a pedestrian (n = 1)
- Pedestrians tend to slow down because they know they have the time (n = 1)

OBSERVED EVIDENCE OF DIFFERENTIAL PEDESTRIAN EXPERIENCE BASED ON AGE AND/OR PHYSICAL ABILITIES

With the use of PCD signals, have you observed any evidence of differential pedestrian experience based on age and/or physical abilities (such as school age children, teenagers, elderly, or wheelchair users)? (Q=26)

- None (n = 37)
- Kids and teenagers cross at any chance they get, equally; adults cross where and when they want (n = 5)
- More calls to city; not enough time to cross (n = 3)
- Yes (n = 2)
- Older people comfortable crossing the street (n = 2)
- Inconclusive (n = 1)
- Pedestrians can react more quickly to the signal indication; additional information helps pedestrians make decisions (n = 1)
- People with reduced/limited mobility appreciate the countdown signals (n = 1)

OBSERVED DIFFERENCES IN MOTORIST BEHAVIOR AT INTERSECTIONS EQUIPPED WITH PEDESTRIAN COUNTDOWND SIGNALS

Have you observed any differences in motorist behavior at intersections equipped with PCD signals? (Q27)

- None (n = 32)
- Motorists speed up (n = 19)
- Motorists tend to slow down (n = 2)
- Yes (n = 2)
- Red-light running violations are down (n = 1)

Table A-6. Areas that conducted evaluations, have policies, or draft policies.

Maryland State Highway Administration	Before/after studies of pedestrians and vehicle reaction; sponsored two evaluations on PCD signals.
City of Thornton, Colorado	When the first PCD head was put up at school locations, they were videotaped and interviews were conducted at the schools 6 weeks after the installation. The response was very favorable and city council wanted them installed at all intersections. There are 4 years left in complete city-wide installation.
City of Fountain Valley, California	Available upon request.
City of Phoenix, Arizona	Before/after studies showed improved pedestrian compliance with countdown heads. Driver behavior was not studied.
Minnesota Department of Transportation	www.dot.state.mn.us/metro/trafficeng/signals/reports.html
Salt Lake City, Utah	A short pedestrian survey was conducted.
Road Commission of Oakland County, Michigan	In process by City; evaluating whether pedestrians are entering late and if they have any issues crossing in the time allotted.
Edmonton, Canada	Pedestrian and motorist behavior surveys.
Boulder, Colorado	Intercept survey shortly after installation of first countdown signals found very high correct understanding of indications and high ratings of usefulness of information provided. Observations of pedestrian behavior found some increase in pedestrians starting after beginning of FDW but little, if any, increase in pedestrians starting to cross late in the FDW when inappropriate.

APPENDIX B:

PEDESTRIAN OBSERVATION SURVEY INSTRUMENT

PEDESTRIAN SAFETY FOR OLDER PEDESTRIANS

Interviewer ____

Intersection ____

Date ____________________ Time period _____ a.m. _____ noon _____ p.m.

Respondent age _____ Under 18 _____ 18–35 _____ 36–65 _____ Over 65

Respondent sex _____ Male _____ Female

Mobility impairment? _____ Yes _____ No

Describe ____

Visual impairment? _____ Yes _____No

Describe ____

1. While you were crossing this intersection, did you notice anything different about the pedestrian signal at this intersection than at other intersections in the surrounding area? _____ Yes _____ No

1b. If yes, explain what is different: ____________________________________

(If the pedestrian responds “no” to question 1a, explain that there is a PCD signal at this intersection and have them view the signal briefly so that they can continue with the rest of the survey.)

2. Can you explain what the numbers on the countdown signal mean? (Circle the response that most reflects how the pedestrian responds.)

The seconds remaining to complete the crossing or reach the median (if it exists)

The seconds remaining until the light turns red

The seconds remaining for you to start crossing

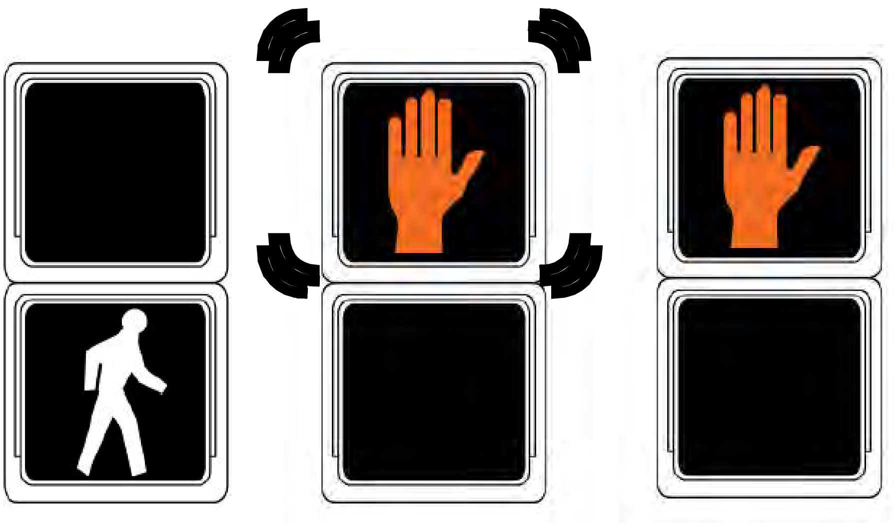
The seconds remaining until you can cross

Other ____

3. When should you start your crossing at this intersection? ______________________________

4. Do you prefer one type of pedestrian signal display to the other? (A standard pedestrian signal is displayed below this question for the pedestrian's reference.)

Standard Countdown



"Flashing"

5. Is the PCD signal helpful to you in crossing the intersection safely?

_____ Yes _____ No

If no, please provide an explanation ____

____

APPENDIX C:

BROWARD COUNTY, FLORIDA CASE STUDY

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BACKGROUND

Broward County is located along the eastern coast of Florida and is home to many popular vacation destinations. Both Broward County (16.1 percent) and the state of Florida (17.6 percent) have a higher percentage of residents age 65 and older than the United States (12.4 percent). In fact, the percentage of residents age 85 and older in Broward county (2.7 percent) is almost double that of the United States (1.5 percent), as shown in Table C-1.

Table C-1. Broward County, Florida population distribution by age.

Age	Broward County		Florida		United States	
	Population	Percent of total	Population	Percent of total	Population	Percent of total
Under 18	382,929	23.6	3,646,340	22.8	72,293,812	25.7
18–34	348,245	21.5	3,414,702	21.4	67,035,178	23.8
35–54	493,633	30.4	4,554,726	28.5	82,826,479	29.4
55–64	137,102	8.4	1,559,013	9.8	24,274,684	8.6
65–84	*218,058*	*13.4*	*2,476,310*	*15.5*	*30,752,166*	*10.9*
85 and older	*43,051*	*2.7*	*331,287*	*2.1*	*4,239,587*	*1.5*
Total	1,623,018	100	15,982,378	100	281,421,906	100

SITE SELECTION

Broward County maintains approximately 1,300 signalized intersections, of which 1,200 have pedestrian signals. The Florida Department of Transportation also uses pedestrian countdown (PCD) signals. Broward County began using PCD signals in January 2004. At the time of the study, PCD signals were installed at five county intersections. Broward County installed the PCD signals at intersections with heavy pedestrian traffic. The signals were compliant with the *Manual on Uniform Traffic Control Devices* (MUTCD) and displayed the countdown during the flashing DON'T WALK (FDW) interval.

Walking speed was used as part of the calculation to determine the pedestrian signal intervals, varying between 3.50 and 4.00 feet/second (ft./sec.), depending on the presence of schools, older populations, tourist volumes, and level of pedestrian activity. The county concentrated its placement of PCD signals at high-volume/high-pedestrian intersections in tourist areas near the beach. There were no formal criteria for defining high-volume crossing distances; county engineers used their judgment regarding which intersections should be equipped with countdown signals.

Jon Kleinedler from the Broward County Traffic Engineering Division recommended 20 intersections for the study, including the intersections equipped with PCD signals and traditional pedestrian signals (TPS). Kleinedler selected intersections that had high pedestrian volumes and were in the immediate vicinity of the PCD signals. The project engineer reviewed these 20 intersections for the following aspects:

- pedestrian volumes, particularly older pedestrian volumes;
- lack of any construction or other temporary impediments (such as street closures) that may affect pedestrian behavior;
- ability to sufficiently collect data (such as utility poles located close to the intersection);
- conventional intersection design; and
- surrounding land use.

Based on field observations, discussions with the engineering staff, and the recommendations of the AAA representative, four intersections were selected for the study:

- A1A (Ocean Boulevard) and 36th Street (traditional);
- A1A (Ocean Boulevard) and Oakland Park Boulevard (traditional);
- A1A (Ocean Boulevard) and Commercial Boulevard; and
- A1A (Ocean Boulevard) and Datura Avenue.

Figure C-1 displays the type of pedestrian signal at each of the four intersections. As shown, the intersections were in close proximity to one another and were located along the Ocean Boulevard/A1A corridor. The two farthest intersections were located 1.5 miles apart. The land use surrounding these intersections was characterized by office buildings, restaurants, and commercial storefronts. There also were a few senior high-rise communities toward the southern end of the corridor.

Figure C-1. Study intersections in Broward County, Florida.

DATA COLLECTION METHODOLOGY

Pedestrian Behavior Data

Data were collected in Broward County during the week of January 17, 2005. At each intersection, Portable Archival Traffic History (PATH) cameras were deployed for one full day of recording for one minor leg and one major leg. PATH systems record pedestrian activity at an intersection without interfering with pedestrians. The pedestrian behavior data were collected without any major difficulties.

Surveys

The project team developed a brief survey to be administered to pedestrians at the study intersections. The purpose of the survey was to gauge pedestrian understanding and preference for PCD signals and TPS.

Survey administration took approximately 1 minute. Surveys were administered at the two PCD study intersections to pedestrians who had completed their crossing at the intersections. The targets of the survey were pedestrians over 18 years of age.

Almost 50 percent (49 out of 100) of the people approached regarding the survey agreed to participate. Older pedestrians were much more willing to participate than younger pedestrians. The survey administrator noted that this was because many of the older pedestrians were long-time residents of the area and were happy to share their input because they felt they had a stake in the area.

RESULTS

Walking Speeds

The walking speeds of 702 pedestrians were observed at the four intersections. This included 261 pedestrians estimated to be 65 or older based on visual observations. Pedestrian walking speeds were measured from when they left the curb to when they returned to the curb on the other side of the street. Pedestrians who left the influence area of the crosswalk (within 2 to 3 ft. of the edge of the crosswalk) during their crossing were not included in the analysis. The mean (average), 50th-percentile (median), and 15th-percentile walking speeds were calculated for both groups of pedestrians. These values are presented in Table C-2 individually for each intersection’s minor and major approach. The mean, median, and 15th percentile also are represented collectively for all four traditional crossings and all four countdown crossings.

Table C-2. Walking speeds for pedestrians at intersections in Broward County, Florida.

Intersection	Crossing	Observed walking speeds (ft./sec.)							
		Younger pedestrians				Older pedestrians			
		Sample	Mean	Median	15th percentile	Sample	Mean	Median	15th percentile
36th at A1A (traditional)	Major	14	5.5	5.0	4.2	31	4.6	4.4	4.4
	Minor	39	5.5	4.9	4.4	31	4.3	4.3	3.4
A1A at Oakland (traditional)	Major	70	5.5	5.3	4.7	30	5.4	4.8	4.1
	Minor	70	4.9	4.8	4.3	33	4.3	4.3	3.7
Traditional approaches combined		**193**	**5.3**	**5.0**	**4.4**	**125**	**4.6**	**4.4**	**3.8**
A1A at Commercial (countdown)	Major	30	4.4	4.5	3.8	40	3.8	3.7	3.3
	Minor	72	5.1	5.0	4.5	32	4.6	4.6	3.9
Datura at A1A (countdown)	Major	71	5.4	5.1	4.5	32	4.2	4.1	3.5
	Minor	75	5.3	4.9	4.2	32	4.2	4.1	3.5
PCD signal approaches combined		**248**	**5.1**	**4.9**	**4.3**	**136**	**4.2**	**4.1**	**3.4**

For younger pedestrians, the mean walking speed (MWS) was 5.30 ft/.sec. at traditional intersections and 5.10 ft./sec. at intersections equipped with countdown signals. As presented in Table C-3, this difference in MWS was not statistically significant at a 95-percent confidence interval. The median walking speed was 5.00 ft./sec. at traditional intersections and 4.90 ft./sec. at intersections equipped with PCD signals. The 15th-percentile walking speed represents the slower pedestrians at the intersection. The 15th-percentile speed was slightly slower at traditional signals (4.30 ft./sec.) than at PCD signals (4.50 ft./sec.).

For older pedestrians, MWS at PCD signals was 4.20 ft./sec., slightly slower than the MWS of 4.60 ft./sec. at TPS. As presented in Table C-3, this difference was significant at a 95-percent confidence level. The median walking speed was slightly slower at PCD signal crossings. The 15th-percentile speed also was slightly slower at countdown signals (4.10 ft./sec.) compared to traditional signals (4.40 ft./sec.).

Table C-3. Significance testing of difference in mean walking speed at traditional and pedestrian countdown signals for two age groups.

Subjects	Intersection type	Mean	Standard deviation	T_{calc}	Outcome
Pedestrians under 65	Traditional	5.30	1.25	1.583	The difference between means **is not** significant at 95 percent.
	Countdown	5.10	1.13		
Pedestrians 65 and older	Traditional	4.60	1.25	3.413	The difference between means **is** significant at 95 percent.
	Countdown	4.20	0.76		

Table C-4 presents the results of significance testing of the difference in MWS for younger pedestrians and older pedestrians. As would be expected, the walking speed of older pedestrians was significantly slower than the walking speed of younger pedestrians, regardless of the type of pedestrian signal.

Table C-4. Significance testing of difference in mean walking speed for pedestrians under 65 and pedestrians 65 and older for two types of pedestrian signal.

Intersection type	Subjects	Mean	Standard deviation	T_{calc}	Outcome
Traditional	Pedestrians under 65	5.30	1.25	4.878	The difference between means **is** significant at 95 percent.
	Pedestrians 65 and older	4.60	1.25		
Countdown	Pedestrians under 65	5.10	1.13	9.838	The difference between means **is** significant at 95 percent.
	Pedestrians 65 and older	4.20	0.76		

Pedestrians with Impairments

Pedestrians with discernable mobility or visual impairments were recorded separately, regardless of their age. At the Broward County intersections, 12 pedestrians with impairments were observed for walking speeds during the study periods. The walking speeds categorized by impairments are listed in Table C-5. These data are not stratified by age due to the small sample size.

Table C-5. Walking speeds of pedestrians with impairments, regardless of age, in Broward County, Florida.

Observed impairment	Pedestrians	MWS
Visually impaired	1	4.60
Mobility impaired (walked with a cane, crutch, or push cart)	10	3.40
Motorized wheelchair assisted	1	3.60

Ten pedestrians with mobility impairments were observed during the study period. MWS for these pedestrians was only 3.40 ft./sec. The walking speed was slower than the 15th percentile for pedestrians 65 and older for all but one leg of the four intersections.

Start-Up Times

Pedestrians who approached the intersection during the steady DON'T WALK (DW) interval and waited for the WALK interval were observed to determine their start-up lost time. This is the time from when the WALK indication is displayed on the pedestrian signal until the pedestrian leaves the curb and starts his or her crossing. This start-up time is related to the pedestrian's reaction to the signal timing. However, there could be other factors, such as turning vehicles still in the intersection, that may cause a pedestrian to delay his or her start across the intersection. No distinction was made between those who waited for turning vehicles and those who simply did not react to the signal as quickly. Only pedestrians who arrived prior to the onset of the WALK interval were included in this analysis.

Observations were recorded for pedestrians across the major leg of A1A (Ocean Boulevard) and Oakland Park (traditional). Based on a sample of 41 younger pedestrians, younger pedestrians had a mean start-up time of 2.42 sec. at this crossing. Based on a sample of 23 older pedestrians, older pedestrians had a start-up time of 2.94 sec. This is a difference of 0.52 sec.

Compliance

Pedestrians at each intersection were observed during two hours of peak vehicle and pedestrian activity using the PATH system. For each pedestrian, observers recorded the pedestrian signal indication (WALK, FDW, or DW) that was displayed when the pedestrian entered the intersection. Observations were recorded separately for younger pedestrians and those 65 and older. Observations were recorded during the three hours of peak vehicle activity because vehicle volumes at intersections likely affect pedestrian compliance to the signal. This is related to the opportunity to cross. That is, at an intersection with low vehicle volume, pedestrians are more likely to violate the pedestrian signal because there are more available crossing gaps.

Pedestrians Under 65

Table C-6 shows the frequency and percentage of younger pedestrians entering during each signal indication for the two intersections equipped with TPS.

Table C-6. Frequency and percentage of younger pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at traditional signals in Broward County, Florida.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
36th at A1A (traditional)	Major	5	36	0	0	9	64
	Minor	23	72	5	16	4	13
A1A at Oakland (traditional)	Major	20	47	0	0	23	53
	Minor	23	56	0	0	18	44
Total at traditional signals		**71**	**55**	**5**	**4**	**54**	**42**

The compliance for pedestrians under 65 at traditional signals varied from 36 percent to 72 percent entering during the WALK indication. When the four intersection legs were considered together, 55 percent entered during the WALK interval. The intersection with the lowest compliance, 36th Street and A1A (Ocean Boulevard), was the lowest pedestrian and volume intersection of the four intersections studied. As noted previously, intersections with lower vehicle volumes are likely to have lower pedestrian signal compliance because of the availability of gaps in vehicle traffic. Additionally, this intersection was pedestrian actuated. Often, pedestrians were observed crossing the street without actuating the pedestrian signal.

Table C-7 shows the frequency and percentage of younger pedestrians entering during each signal indication for the two intersections equipped with PCD signals. As with the traditional intersections, the compliance varied by intersection and leg. However, 61 percent of the pedestrians entered during the WALK indication and 30 percent entered during the DW indication. This was slightly higher compliance than at the traditional signals. This finding will be compared to other cities.

Table C-7. Frequency and percentage of younger pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at pedestrian countdown signals in Broward County, Florida.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
A1A at Commercial (countdown)	Major	76	52	21	14	48	33
	Minor	35	64	1	2	19	35
Datura at A1A (countdown)	Major	35	81	3	7	5	12
	Minor	21	66	1	3	10	31
Total at countdown signals		**167**	**61**	**26**	**9**	**82**	**30**

Older Pedestrians

Table C-8 shows the frequency and percentage of older pedestrians entering during each signal indication for the two intersections equipped with TPS. During the two hours of peak vehicle activity, 70 older pedestrians were observed crossing at these intersections. The compliance varied greatly by intersection leg; however, the sample sizes for individual legs were too small to be considered individually. When all four traditional legs were considered together, 51 percent of older pedestrians entered the intersection during the WALK indication.

Table C-8. Frequency and percentage of older pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at traditional signals in Broward County, Florida.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
36th at A1A (traditional)	Major	2	11	1	6	15	83
	Minor	13	76	0	0	4	24
A1A at Oakland (traditional)	Major	9	82	0	0	2	18
	Minor	12	50	2	8	10	42
Total at traditional signals		**36**	**51**	**3**	**4**	**31**	**44**

Table C-9 shows the frequency and percentage of older pedestrians entering during each signal indication for the two intersections equipped with PCD signals. During the two hours of peak vehicle activity, 150 older pedestrians were observed crossing at these intersections. As with traditional signals, compliance at PCD signals varied by intersection leg. When all four PCD legs were considered together, 59 percent of older pedestrians entered the intersection during the WALK indication. This was higher compliance than at the traditional signals and was consistent with the compliance of their younger counterparts.

Table C-9. Frequency and percentage of older pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at pedestrian countdown signals in Broward County, Florida.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
A1A at Commercial (countdown)	Major	34	60	5.0	9	18.0	32
	Minor	21	64	0.0	0	12.0	36
Datura at A1A (countdown)	Major	19	61	8.0	26	4.0	13
	Minor	14	48	2.0	7	13.0	45
Total at countdown signals		**88**	**59**	**15**	**10**	**47**	**31**

Pedestrians Left in Intersection

At the end of each FDW interval, the number of pedestrians remaining in the intersection was noted. Only pedestrians who entered during the WALK or FDW interval were included. Table C-10 displays the results of this data collection. The number of pedestrians left in the intersections was very low. The low pedestrian count may be because the signals were pedestrian actuated. Because pedestrians often did not press the crossing button, there were fewer opportunities for them to leave during a WALK or FDW phase and to get caught in the steady DW phase.

Table C-10. Pedestrians remaining in the intersection at the start of the DON'T WALK interval in Broward County, Florida.

Intersection	Leg	Pedestrians under 65		Pedestrians 65 and older	
		Total pedestrians	Pedestrians left in intersection	Total pedestrians	Pedestrians left in intersection
Hamilton and Church (traditional)	Major	14	0	18	0
	Minor	32	0	17	0
Mamaroneck and Post (traditional)	Major	43	0	11	0
	Minor	41	0	24	0
Total at traditional signals		**130**	**0**	**70**	**0**
Mamaroneck and Maple (countdown)	Major	145	1	57	1
	Minor	55	0	33	0
Mamaroneck and Martine (countdown)	Major	43	0	31	0
	Minor	32	0	29	0
Total at countdown signals		**275**	**1**	**150**	**1**

SURVEY RESULTS

A total of 49 pedestrians were surveyed in Broward County, including 11 ages 18–35, 14 ages 36–65, and 24 ages 65 and older. Pedestrians were intercepted after they completed their crossing at countdown-equipped intersections and asked if they would like to participate in a brief survey on pedestrian safety. Pedestrians were asked if they noticed anything different about crossing at this intersection than at similar intersections in the Broward County area. A follow-up question confirmed that the difference noted was the countdown signal. Thirty-five (approximately 71 percent) of the pedestrians noticed the PCD signals.

Several respondents added that their response was based on the fact that they did not notice anything different because PCD signals were at several signalized intersections in the immediate area. All surveyed pedestrians were asked to explain the meaning of the countdown indication. All of the pedestrians provided a satisfactory explanation of the countdown indication. Of those pedestrians who had a preference regarding the use of TPS or countdown signals, all preferred the PCD signals. In addition, 94 percent (47 out of 49 respondents) indicated that the PCD signal was helpful in crossing the street safely.

EFFECT OF CHANGING WALKING SPEEDS ON PEDESTRIAN CLEARANCE TIMES

Table C-11 displays the required pedestrian signal times for different walking speeds and the time available for that movement at each of the intersections studied. The pedestrian clearance time is the time needed to cross a specified crosswalk for a given walking speed; in other words, the length of the crosswalk divided by the crossing speed. The total time allotted for pedestrians to completely traverse a crosswalk is the sum of the clearance time and WALK time. A 7-sec. WALK time was used as recommended in the 2003 edition of MUTCD.

The available green time is the maximum time that can be allotted to the pedestrian signal interval based on existing signal timings and phasing. The available green represents the green intervals for the parallel streets. The available green times do not add up to the cycle length because of time allotted to exclusive phasing for turn movements, concurrent phasing for approaches on the same street (such as northbound and southbound approaches), and yellow and red intervals.

Table C-11 presents the ☒ symbol where the total pedestrian signal time exceeded the available minimum green time. Key findings related to pedestrian WALK clearance time durations for the case study intersections included:

- The pedestrian intervals exceeded the available green times for the 3.00 ft./sec. scenario in the case study intersection in Broward County in one of three crosswalks (the northbound approach, or south crosswalk).

- A walking speed of 3.00 ft./sec. yielded a pedestrian interval of 32 sec. Because this was less than the available minimum green time (30 sec.), the pedestrian interval for this approach could not be serviced adequately during the time available. In this case, the minimum green could be increased to meet the time required for the pedestrian interval; however, this action potentially could take time away from other movements served by other phases. Consequently, this may increase vehicular delay, depending upon traffic volumes.

Table C-11. Pedestrian WALK and clearance time durations for case study intersection in Broward County, Florida.

Approach/ crosswalk	Length (ft.)	Clearance time (sec.)			Clearance time with 7-sec. WALK (sec.) [total WALK time]			Available green (sec.)
		3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	
Northbound/ south	75	25	21	19	32☒	28	26	30
Soutbound/ north	N/A	N/A: There is no pedestrian crossing across this leg.						30
Eastbound/ west	68	23	19	17	30	26	24	30
Westbound/ east	48	16	14	12	23	21	19	30

TRAFFIC OPERATIONS ANALYSIS

Table C-12 shows the intersection operational and geometric characteristics for the Broward County case study intersection. Figure C-2 shows the overall average vehicle delay (AVD) and intersection level of service (LOS) under various peak-hour traffic volume and pedestrian walking speed scenarios (3.00, 3.50, 4.00 ft./sec. and base conditions).

Figures C-3, C-4, and C-5 show the major street and minor street approach AVD (in sec.) under walking speeds of 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec., respectively. Table C-13 shows the overall, major street approach, and minor street approach intersection LOS and AVD (in sec.) under various peak-hour traffic volume scenarios and under pedestrian walking speeds of 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec.

For the overall intersection, there was no change in LOS (LOS C remained the same) and a minor increase of 2 to 3 sec. in terms of average delay per vehicle (ADPV) when comparing existing volume conditions to a modeled increase of 15 percent above existing volumes. From a practical standpoint, this would not be noticeable to the average driver. Because the LOS was relatively good (LOS C) in the base condition, the trends in LOS and ADPV showed a uniform and relatively small incremental delay for each of the walking speeds simulated.

For the major street approach, there was no change in LOS (LOS C remained the same) for any of the volume and pedestrian walking speed scenarios analyzed. The range in ADPV under existing volume conditions as compared to a modeled increase of 15 percent above existing volumes for the 3.00 ft./sec. walking speed assumption was 22 to 25 sec. For the 3.50 ft./sec. and 4.00 ft./sec. pedestrian walking speed scenarios, the range in average delay on the major street approach was 23 to 24 sec. and 21 to 23 sec., respectively.

The minimum green time available for the major approach, 30 sec., was adequate time for a PCI for the crosswalk on the southern leg of the intersection based on 4.00 ft./sec. and 3.50 ft./sec. assumed walking speeds. For a 3.00 ft./sec. pedestrian walking speed, a minimum green time of 32 sec. was required for the parallel street phase. Even after the signal timings were adjusted based on the 3.00 ft./sec. pedestrian walking speed, because of the lower volumes at the intersection, the delays on the major and minor street did not increase noticeably.

For the minor street approach, LOS ranged from LOS B to C for each of the volume and pedestrian walking speed scenarios analyzed. The range in ADPV under existing volume conditions as compared to a modeled increase of 15 percent above existing volumes was 19 to 22 sec. for the 3.00 ft./sec. walking speed assumption. For the 3.50 ft./sec. and 4.00 ft./sec. pedestrian walking speed scenarios, the range in average delay on the minor street approaches was 19 to 20 sec. and 20 to 23 sec., respectively.

Table C-12. Broward County, Florida intersection characteristics: approach lane usage, peak-hour traffic volumes, and cycle length.

Approach	**Number of approach lanes**						**Peak-hour traffic volumes (existing and modeled)**					
	L	**LT**	**T**	**TR**	**R**	**Total**	**-10 percent**	**Existing**	**+5 percent**	**+10 percent**	**+15 percent**	**Volume range**
Northbound (MJ)	2	0	2	0	0	4	698	776	815	854	892	698
Southbound (MJ)	1	0	2	0	1	4	955	1,061	1,114	1,167	1,220	
Eastbound (MN)	1	1	0	0	1	3	538	598	628	658	688	
Westbound (MN)	0	1	0	0	1	2	36	40	42	44	46	
MJ approach	3	0	4	0	1	**8**	1,653	1,857	1,929	2,042	2,112	1,653 – 2,112
MN approach	1	2	0	0	2	**5**	574	**638**	670	702	734	574 – 734
Total	4	2	4	0	3	**13**	2,227	**2,475**	2,599	2,723	2,846	2,227 – 2,846
Cycle length: 110 sec.												

* Note: L = left; LT = left-through; T = through; TR = through-right; R = right.

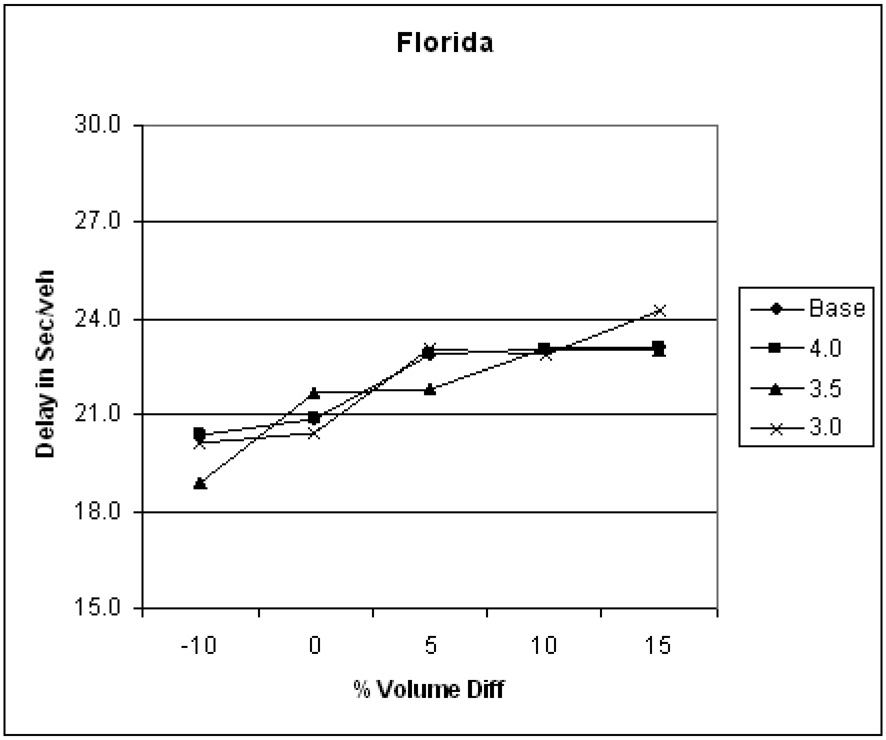

Figure C-2. Delay vs. volumes at case study intersections for walking speeds of 3.00, 3.50, 4.00 ft./sec. and base conditions.

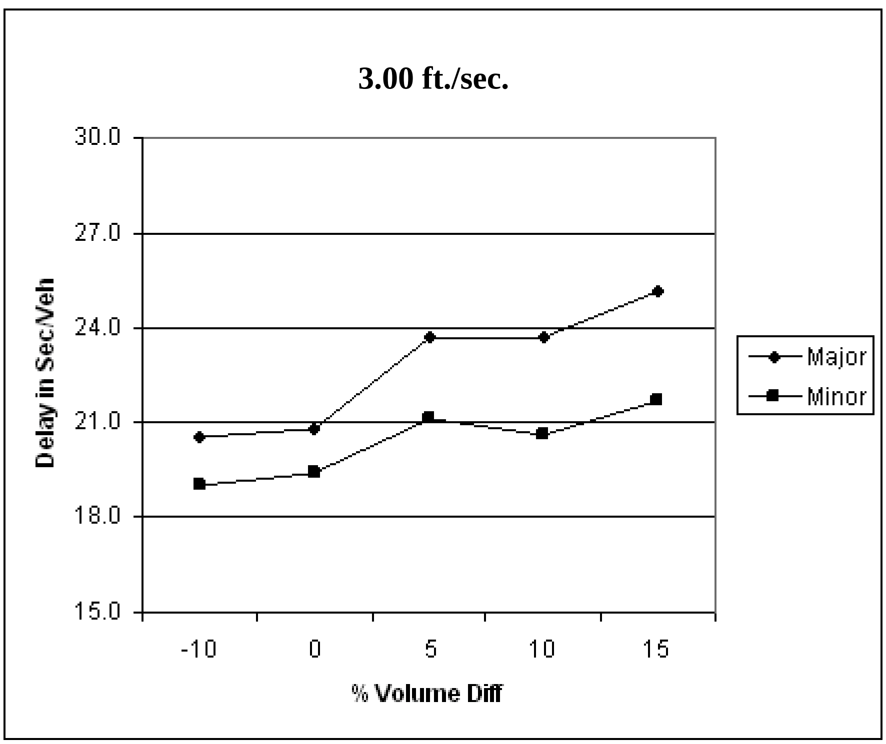

Figure C-3. Intersection delay for major and minor street approaches, 3.00 ft./sec. walking speed, Broward County, Florida.

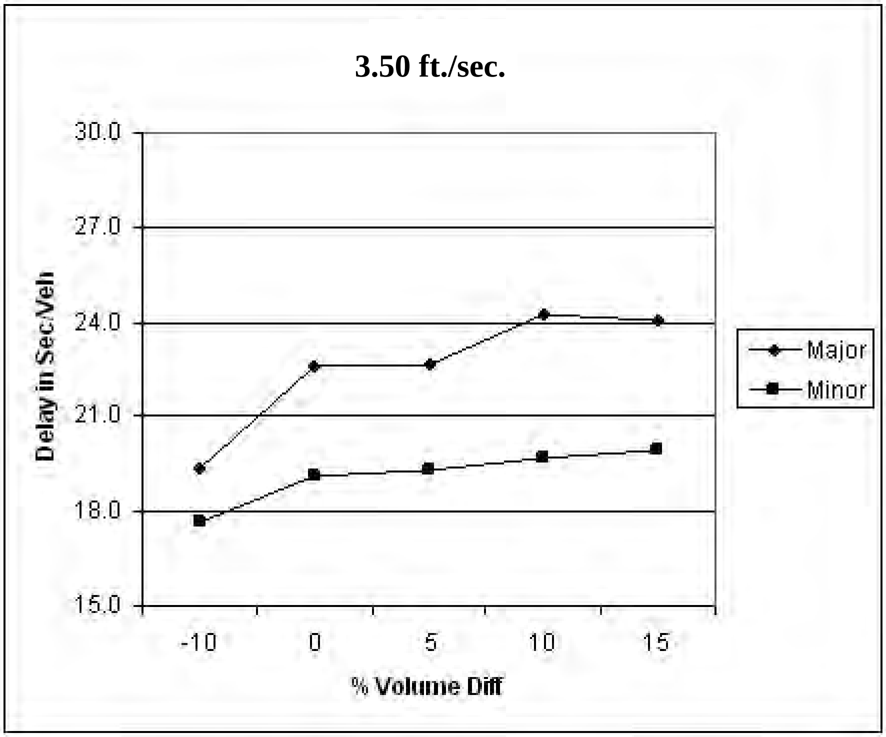

Figure C-4. Intersection delay for major and minor street approaches, 3.50 ft./sec. walking speed, Broward County, Florida.

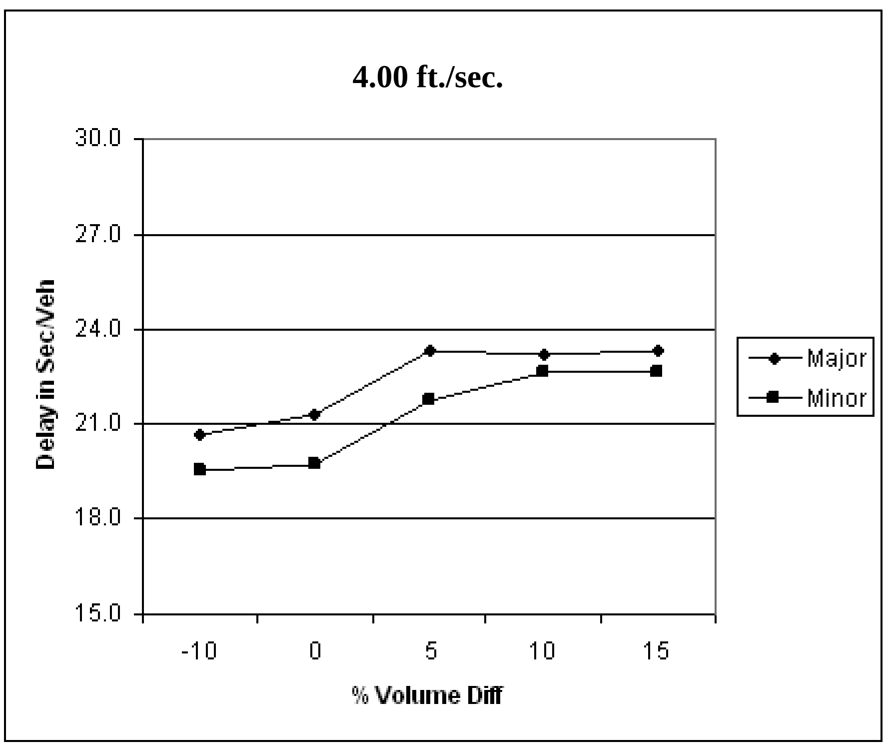

Figure C-5. Intersection delay for major and minor street approaches, 4.00 ft./sec. walking speed, Broward County, Florida.

Table C-13. Broward County, Florida: intersection level of service under various peak-hour traffic volume and pedestrian walking speed scenarios.

Walking speed scenario	LOS (and average delay, in sec.)				
	-10-percent volume	Existing volume	+5-percent volume	+10-percent volume	+15-percent volume
3.00 ft./sec.	C (20)	C (21)	C (23)	C (23)	C (24)
3.50 ft./sec.	B (19)	C (21)	C (21)	C (23)	C (23)
4.00 ft./sec.	C (20)	C (21)	C (23)	C (23)	C (23)
Major street LOS (and average delay, in sec.)					
3.00 ft./sec.	C (21)	C (22)	C (24)	C (24)	C (25)
3.50 ft./sec.	C (19)	C (23)	C (23)	C (24)	C (24)
4.00 ft./sec.	C (21)	C (21)	C (23)	C (23)	C (23)
Minor street LOS (and average delay, in sec.)					
3.00 ft./sec.	B (19)	B (19)	C (21)	C (21)	C (22)
3.50 ft./sec.	B (18)	B (19)	B (19)	B (20)*	B (20)*
4.00 ft./sec.	B (20)*	B (20)*	C (22)	C (23)	C (23)

* Note: Cycle length = 110 sec.

SUMMARY

In summary, the key results are as follows for Broward County:

- Walking speeds for older pedestrians were slower than for pedestrians under 65 by approximately 0.70 ft./sec. at traditional signals and 1.00 ft./sec. at countdown signals.

- The differences in MWS were not statistically significant at the 95-percent confidence level between traditional and PCD signals for younger pedestrians. There was a statistically significant difference between traditional and PCD signals for older pedestrians.

- Pedestrians with mobility impairments and without motorized wheelchairs had appreciably slower walking speeds than pedestrians without mobility impairments—their mean was 3.40 ft./sec. compared to about 4.40 ft./sec. for older pedestrians in general and 5.20 ft./sec. for younger pedestrians. A small sample size is recognized.

- Older pedestrians had a slower start-up time, but this will vary by intersection and leg of intersection.

- The level of compliance (entering crosswalk on WALK display) was consistent among the age groups and higher for PCD signals regardless of age.

- Very few pedestrians were left in the intersection at any of the study intersections.

- Surveyed pedestrians generally preferred the PCD signal to traditional signals, with 94 percent of pedestrians understanding the indication.

- Operational analysis:

    - For the overall intersection, there was no change in LOS (LOS C remained the same) and a minor increase of 2 to 3 sec. in terms of ADPV when comparing existing volume conditions to a modeled increase of 15 percent above existing volumes.

    - From a practical standpoint, this would not be noticeable to the average driver. Because the LOS was relatively good (LOS C) in the base condition, the trends in LOS and ADPV showed a uniform and relatively small incremental delay for each of the walking speeds simulated.

APPENDIX D:

MINNEAPOLIS/ST. PAUL, MINNESOTA CASE STUDY

LIST OF TABLES

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BACKGROUND

Minneapolis, in southeastern Minnesota, is situated at the head of navigation for the Mississippi River and surrounded by a rich agricultural area. St. Paul is adjacent to Minneapolis to the east, as shown in Figure D-1. Although St. Paul had a slightly smaller in population in 2000 (287,151) than Minneapolis (382,618), St. Paul is the capital of Minnesota (U.S. Census Bureau State and County QuickFacts).

Due to the concentration of colleges and universities, a much higher proportion of the population is between 18 and 34 years old in the Twin Cities than in the state of Minnesota or the United States. As shown in Table D-1, 35.0 percent of the population of Minneapolis is 18–34; St. Paul is slightly lower at 29.3 percent. Both of these percentages are considerably higher than the state of Minnesota (23.2 percent) and the United States (23.8 percent).

Due to this high concentration, the proportion of the population age 65 and older is smaller in both cities. In Minneapolis, 7.4 percent of the population is 65–84. An additional 1.7 percent is older than 85, meaning that 9.1 percent of the population is older than 65. In St. Paul, 8.5 percent of the population is 65–84. An additional 1.8 percent is older than 85, totaling 10.3 percent. This is considerably lower than the state of Minnesota (10.3 percent aged 65–84 and 1.7 percent older than 85) and the Unites States as a whole (10.9 percent aged 65–84 and 1.5 percent older 85, totaling 12.4 older than 65).

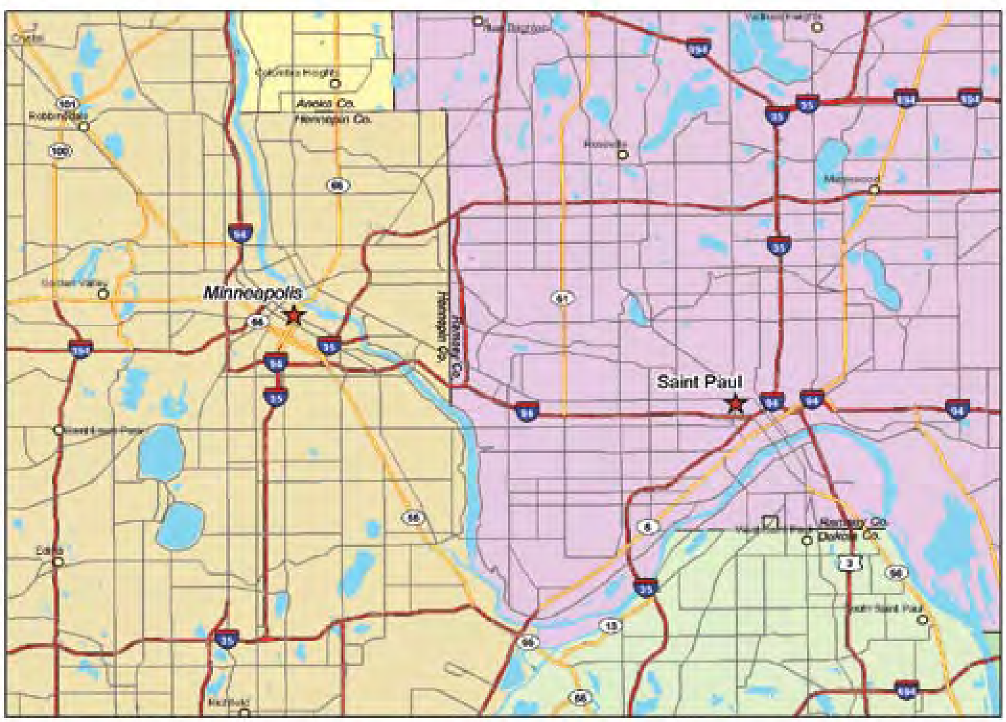

Figure D-1. Geographic location of Minneapolis and St. Paul, Minnesota.

Table D-1. Population distribution by age for Minneapolis and St. Paul, Minnesota.

Age	Minneapolis		St. Paul		Minnesota		United States	
	Population	Percent of total	Population	Percent of total	Population	Percent of total	Population	Percent of total
Under 18	84,169	22.0	77,827	27.1	1,286,894	26.2	72,293,812	25.7
18–34	134,066	35.0	84,155	29.3	1,143,572	23.2	67,035,178	23.8
35–54	106,865	27.9	77,827	27.1	1,489,878	30.3	82,826,479	29.4
55–64	22,640	5.9	17,695	6.2	404,869	8.2	24,274,684	8.6
65-84	*28,504*	*7.4*	*24,472*	*8.5*	*508,665*	*10.3*	*30,752,166*	*10.9*
85 and older	*6,374*	*1.7*	*5,175*	*1.8*	*85,601*	*1.7*	*4,239,587*	*1.5*
Total	382,618	100	287,151	100	4,919,479	100	281,421,906	100

SITE SELECTION

Minneapolis initially was selected for the study. Minneapolis recently started using pedestrian countdown (PCD) signals. At the time of the data collection, the city had PCD signals at three intersections. One of the intersections was in a residential and commercial neighborhood. The other two intersections were located near a light rail station. The city traffic engineer recommended not using the two intersections near the light rail station because the intersection design, trip purposes, and pedestrian activity at these intersections were unusual. The local AAA representatives agreed with this recommendation. However, this left only one PCD signal for the study. Additionally, the remaining intersection was equipped with PCD signals across only one approach.

The project engineer contacted the City of St. Paul to seek its involvement in the study. The City of St. Paul agreed to participate. One intersection equipped with a countdown signal and one intersection equipped with a traditional signal was selected in each city. In the selection of study intersections, the project engineer considered the following aspects:

- Pedestrian volumes, particularly older pedestrian volumes;
- Lack of any construction or other temporary impediments (such as street closures) that may affect pedestrian behavior;
- Ability to sufficiently collect data (such as utility poles located close to the intersection);
- Conventional intersection design; and
- Surrounding land use.

Based on field observations, discussions with the engineering staff, and the recommendations of the AAA representative, two intersections in Minneapolis and two intersections in St. Paul were selected for this study. In Minneapolis:

- Lyndale Avenue and Franklin Avenue (traditional); and
- Lyndale Avenue and Groveland Avenue (countdown).

In St. Paul:

- University Avenue and Hamline Avenue (traditional); and
- University Avenue and Snelling Avenue (countdown).

Figure D-2 illustrates the two Minneapolis intersections. Figure D-3 illustrates the two St. Paul intersections. The figures display the type of pedestrian signal at each of the four intersections. As shown, for each of the cities, the intersections were in close proximity to one another. The two Minneapolis intersections were approximately one-third-mile apart; the two St. Paul intersections were approximately one-half-mile apart. The Minneapolis intersections were located near a center for the visually impaired.

Figure D-2. Signalized intersections in Minneapolis, Minnesota.

Figure D-3. Signalized intersections in St. Paul, Minnesota.

DATA COLLECTION METHODOLOGY

Pedestrian Behavior Data

Data were collected in the Twin Cities during the week of October 11, 2004. At each intersection, Portable Archival Traffic History (PATH) cameras were deployed for one full day of recording for one minor leg and one major leg. PATH systems record pedestrian activity at the intersection without interfering with pedestrians. At the Groveland Avenue and Lyndale Avenue intersection in Minneapolis, only the major leg was equipped with a PATH camera system because it was the only leg with a PCD signal.

During the week of October 11, the Twin Cities experienced cool temperatures and intermittent rain. This greatly reduced pedestrian activity at the study intersections. At all but two approaches, the project team was not able to collect a desirable sample size of older pedestrians.

Surveys

The project team developed a brief survey to be administered to pedestrians at the study intersections. The purpose of the survey was to gauge pedestrian understanding and preference for PCD signals and traditional pedestrian signals (TPS).

Survey administration took approximately 1 minute. Surveys were administered at the two PCD study intersections to pedestrians who had completed their crossing at the intersections. The targets of the survey were pedestrians over 18 years of age.

The survey response was much lower than anticipated, particularly for older pedestrians. Approximately 75 percent of older pedestrians who were approached regarding the survey declined to participate. This was similar to the findings in White Plains, New York.

RESULTS

Walking Speeds

The walking speeds of 896 pedestrians were observed at the four intersections. This included 101 pedestrians estimated to be 65 or older based on visual observations. Pedestrian walking speeds were measured from when they left the curb to when they returned to the curb on the other side of the street. Pedestrians who left the influence area of the crosswalk (within 2 to 3 feet of the edge of the crosswalk) during their crossing were not included in the analysis. The mean (average), 50th-percentile (median), and 15th-percentile walking speeds were calculated for both groups of pedestrians. These values are presented in Table D-2 individually for each intersection’s minor and major approach. The mean, median, and 15th percentile also are represented collectively for all four traditional crossings and all three PCD crossings.

Table D-2. Walking speeds for pedestrians at intersections in Minneapolis and St. Paul, Minnesota.

Intersection	Leg	Observed walking speeds (ft./sec.)							
		Younger pedestrians				Older pedestrians			
		Sample	**Mean**	**Median**	**15th percentile**	**Sample**	**Mean**	**Median**	**15th percentile**
Lyndale and Franklin (traditional)	Major	78	4.8	4.8	4.3	11	3.8	3.9	3.4
	Minor	115	5.0	4.9	4.2	15	3.9	4.0	3.5
University and Hamline (traditional)	Major	46	4.7	4.7	4.1	4	3.7	3.6	3.4
	Minor	54	4.7	4.6	3.9	3	5.1	4.6	4.0
Traditional approaches combined		**293**	**4.9**	**4.8**	**4.2**	**33**	**4.0**	**4.0**	**3.4**
Lyndale and Groveland (countdown)	Major	124	4.9	4.8	4.1	11	4.4	4.4	3.8
University and Snelling (countdown)	Major	174	5.1	5.1	4.5	30	4.0	3.9	3.5
	Minor	136	5.1	5.1	4.5	27	4.6	4.1	3.7
PCD signal approaches combined		**434**	**5.0**	**5.0**	**4.4**	**68**	**4.3**	**4.1**	**3.7**

For younger pedestrians, the mean walking speed (MWS) was 4.90 feet/second (ft./sec.) at traditional intersections and 5.00 ft./sec. at countdown signals. As presented in Table D-3, the difference in MWS was significant at the 95-percent confidence level. The median walking speeds were comparable to MWS. The 15th-percentile walking speed represents the slower pedestrians at the intersection. The 15th-percentile speed was slightly slower at traditional signals (4.20 ft./sec.) than at PCD signals (4.40 ft./sec).

Based on the combined approaches, a walking speed of 4.00 ft./sec. would accommodate the 15th-percentile pedestrian who was under 65 years of age. However, one intersection approach, the minor approach of University and Hamline, had a 15th-percentile speed lower than 4.00 ft./sec.

Table D-3. Significance testing of difference in mean walking speed at traditional and pedestrian countdown signals for two age groups.

Subjects	Intersection type	Mean	Standard deviation	T_{calc}	Outcome
Pedestrians under 65	Traditional	4.85	0.67	-3.659	The difference between means **is** significant at 95 percent.
	Countdown	5.03	0.62		
Pedestrians 65 and older	Traditional	3.98	0.66	-1.855	The difference between means **is not** significant at 95 percent.
	Countdown	4.31	1.10		

For older pedestrians, MWS at PCD signals was 4.00 ft./sec., slightly slower than the MWS of 4.30 ft./sec. at TPS. This relationship is opposite the relationship seen in the walking speeds of their younger counterparts. However, as presented in Table D-3, this difference was not significant at the 95-percent confidence level.

The 15th-percentile speed also was slightly slower at countdown intersections (3.70 ft./sec.) compared to traditional signals (3.40 ft./sec.). Note that this was based on very small sample sizes. When the approaches are considered together, a walking speed of 4.00 ft./sec. would accommodate older pedestrians at these intersections. It would not accommodate the 15th-percentile speed.

Table D-4 presents the results of significance testing of the difference in MWS for younger pedestrians and older pedestrians. As would be expected, the walking speed of older pedestrians was significantly slower than the walking speed of younger pedestrians, regardless of the type of pedestrian signal.

Table D-4. Significance testing of difference in mean walking speed for younger pedestrians and older pedestrians for two types of pedestrian signal.

<table>
<tr><th>Intersection type</th><th>Subjects</th><th>Mean</th><th>Standard deviation</th><th>T_{calc}</th><th>Outcome</th></tr>
<tr><td rowspan="2">Traditional</td><td>Pedestrians under 65</td><td>4.85</td><td>0.67</td><td rowspan="2">7.185</td><td rowspan="2">The difference between means is significant at 95 percent.</td></tr>
<tr><td>Pedestrians 65 and older</td><td>3.98</td><td>0.66</td></tr>
<tr><td rowspan="2">Countdown</td><td>Pedestrians under 65</td><td>5.03</td><td>0.62</td><td rowspan="2">5.310</td><td rowspan="2">The difference between means is significant at 95 percent.</td></tr>
<tr><td>Pedestrians 65 and older</td><td>4.31</td><td>1.10</td></tr>
</table>

Pedestrians with Impairments

Pedestrians with discernable mobility or visual impairments were recorded separately, regardless of their age. At the study intersections, 35 pedestrians with impairments were observed for walking speeds during the study periods. The walking speeds categorized by impairments are listed in Table D-5. These data are not stratified by age due to the small sample size.

Table D-5. Walking speeds of pedestrians with impairments, regardless of age, in Minneapolis and St. Paul, Minnesota.

Observed impairment	Pedestrians	MWS
Visually impaired	15	4.2
Mobility impaired (walked with a cane, crutch, or push cart)	15	3.6
Motorized wheelchair assisted	2	5.5
Non-motorized wheelchair assisted	3	3.5

Fifteen pedestrians with visual impairments were observed during the study period. MWS for these pedestrians was 4.20 ft./sec. This was similar to MWS for older pedestrians at the study intersections. Fifteen pedestrians with mobility impairments also were observed during the study period. MWS for these pedestrians was 3.60 ft./sec.

Start-Up Times

Pedestrians who approached the intersection during the steady DON'T WALK (DW) interval and waited for the WALK interval were observed to determine their start-up lost time. This is the time from when the WALK indication is displayed on the pedestrian signal until the pedestrian leaves the curb and starts his or her crossing. This start-up time is related to the pedestrian's reaction to the signal timing. However, there could be other factors, such as turning vehicles still in the intersection, that may cause a pedestrian to delay his or her start across the intersection. No distinction was made between those who waited for turning vehicles and those who simply did not react to the signal as quickly. Only pedestrians who arrived prior to the onset of the WALK interval were included in this analysis.

Observations were recorded for pedestrians at the minor approach of University and Snelling. Based on a sample of 100 younger pedestrians, younger pedestrians had a start-up time of 2.10 sec. at this crossing. Based on a sample of 19 older pedestrians at the same crossing, older pedestrians had a start-up time of 2.90 sec. This is a difference of 0.80 sec.

Compliance

Pedestrians at each intersection were observed during two hours of peak vehicle and pedestrian activity using the PATH system. For each pedestrian, observers recorded the pedestrian signal indication (WALK, FDW, or DW) that was displayed when the pedestrian entered the intersection. Observations were recorded separately for younger pedestrians and those 65 and older. Observations were recorded during the three hours of peak vehicle activity because vehicle volumes at intersections likely affect pedestrian compliance to the signal. This is related to the opportunity to cross. That is, at an intersection with low vehicle volume, pedestrians are more likely to violate the pedestrian signal because there are more available crossing gaps.

Pedestrians Under 65

Table D-6 shows the frequency and percentage of younger pedestrians entering during each signal indication for two intersections equipped with TPS.

Table D-6. Frequency and percentage of younger pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at traditional signals in Minneapolis and St. Paul, Minnesota.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Lyndale and Franklin (traditional)	Major	80	84	14	15	1	1
	Minor	52	63	7	9	23	28
University and Hamline (traditional)	Major	8	44	3	17	7	39
	Minor	21	75	5	18	2	7
Total at traditional signals		**161**	**72**	**29**	**13**	**33**	**15**

The compliance for younger pedestrians at traditional signals varied from 44 percent to 84 percent entering during the WALK indication. When the four intersection legs were considered together, 72 percent entered during the WALK indication.

Table D-7 shows the frequency and percentage of younger pedestrians entering during each signal indication for the two intersections equipped with PCD signals. As with the traditional intersections, the compliance varied by intersection and leg from 36 percent to 76 percent. The combined percentage was slightly lower (62 percent) than at traditional signals.

Table D-7. Frequency and percentage of younger pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at pedestrian countdown signals in Minneapolis and St. Paul, Minnesota.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Lyndale and Groveland (countdown)	Major	30	36	10	12	43	52
University and Snelling (countdown)	Major	75	76	18	18	6	6
	Minor	89	69	8	6	32	25
Total at countdown signals		**194**	**62**	**36**	**12**	**81**	**26**

Older Pedestrians

Pedestrian compliance was observed at the traditional signals for two hours of peak activity. During the two hours observed, only 12 older pedestrians were observed crossing at these intersections combined. All of these pedestrians entered during the WALK interval.

Table D-8 shows the frequency and percentage of older pedestrians entering during each signal indication for the two intersections equipped with PCD signals. During the two hours of peak vehicle activity, 30 older pedestrians were observed crossing at these intersections. The compliance varied by intersection leg; however, the sample sizes for individual legs were too small to be considered individually. When all four PCD legs were considered together, 67 percent of older pedestrians entered the intersection during the WALK indication. This was lower compliance than at traditional signals; however, the sample size in both groups was very small.

Table D-8. Frequency and percentage of older pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at pedestrian countdown signals in Minneapolis and St. Paul, Minnesota.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Lyndale and Groveland (countdown)	Major	1	25	0	0	3	75
University and Snelling (countdown)	Major	12	80	2	13	1	7
	Minor	7	64	1	9	3	27
Total at countdown signals		**20**	**67**	**3**	**10**	**7**	**23**

Pedestrians Left in Intersection

At the end of each FDW interval, the number of pedestrians remaining in the intersection was noted. Only pedestrians who entered during the WALK or FDW interval were included. Table D-9 displays the results of this data collection. The total number of pedestrians left in the intersection during the observation period is noted as a percentage of the number of pedestrians crossing at the intersection during the same period. The results are combined for traditional and PCD signals. For younger pedestrians, 13 percent of pedestrians crossing at the intersection were left in the intersection at traditional signals, compared to 2 percent at PCD signals. There were similar results for older pedestrians: one of 12 of the pedestrians crossing at the intersection was left in the intersection at traditional signals, compared to none of the 30 pedestrians at PCD signals. However, the sample sizes were very small for older pedestrians.

Table D-9. Pedestrians remaining in the intersection at the start of the DON'T WALK interval in Minneapolis and St. Paul, Minnesota.

Intersection	Leg	Younger pedestrians		Older pedestrians	
		Total pedestrians	Pedestrians left in intersection	Total pedestrians	Pedestrians left in intersection
Lyndale and Franklin (traditional)	Major	95	3 (3 percent)	5	0 (0 percent)
	Minor	82	10 (12 percent)	6	0 (0 percent)
University and Hamline (traditional)	Major	18	11 (61 percent)	1	1 (100 percent)
	Minor	28	4 (14 percent)	0	0 (0 percent)
Total at traditional signals		**223**	**28 (13 percent)**	**12**	**1 (8 percent)**
Lyndale and Groveland (countdown)	Major	83	3 (4 percent)	4	0 (0 percent)
University and Snelling (countdown)	Major	99	2 (2 percent)	15	0 (0 percent)
	Minor	129	1 (1 percent)	11	0 (0 percent)
Total at countdown signals		**311**	**6 (2 percent)**	**30**	**0 (0 percent)**

SURVEY RESULTS

A total of 150 pedestrians were surveyed in the Minneapolis and St. Paul area, including 16 pedestrians 65 and older. Pedestrians were intercepted after they completed their crossing at countdown-equipped intersections and asked if they would like to participate in a brief survey on pedestrian safety. Pedestrians were asked if they noticed anything different about crossing at this intersection than at similar intersections in the Minneapolis/St. Paul area. A follow-up question confirmed that the difference noted was the countdown signal. Ninety-three (approximately 62 percent) of the pedestrians noticed the PCD signals.

All surveyed pedestrians were asked to explain the meaning of the countdown indication. Approximately 93 percent (140 out of 150) provided a satisfactory explanation of the countdown indication. Of those pedestrians who had a preference regarding the use of TPS or countdown signals, only 25 percent preferred PCD signals. However, approximately 75 percent of all pedestrians surveyed indicated that the PCD signal was helpful in crossing the street safely. Many of those surveyed who preferred the traditional signal noted that the PCD signal did not provide enough time to cross.

EFFECT OF CHANGING WALKING SPEEDS ON PEDESTRIAN CLEARANCE TIMES

Table D-10 displays the required pedestrian signal times for different walking speeds and the time available for that movement at each of the intersections studied. Table D-10 presents the ☒ symbol where the total pedestrian signal time exceeded the available minimum green time. Key findings related to pedestrian WALK clearance time durations for the case study intersections included:

- The pedestrian intervals exceeded the available green times for the 3.00 ft./sec. scenario in four of four crosswalks.

- It should be noted that if this jurisdiction used the 7-sec. [minimum] WALK time recommended in the 2003 edition of the *Manual on Uniform Traffic Control Devices* (MUTCD), of instead of the policy-based 12-sec. WALK time used by the City of Minneapolis, the available green time would be adequate at 3.00 ft./sec. The City's use of a greater minimum WALK time interval in this case implies a proactive policy to provide greater level of service (LOS) to pedestrians.

Table D-10. Pedestrian WALK and clearance time durations for case study intersection in Minneapolis, Minnesota.

Approach/ crosswalk	Length (ft.)	Clearance time (sec.)			Clearance time with 12-sec. WALK (sec.)			Available green (sec.)
		3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	
Northbound/ south	75	25	21	19	37⊠	33	31	34
Southbound/ north	78	26	22	20	38⊠	34	32	34
Eastbound/ west	3	18	15	13	30⊠	27	25	28
Westbound/ east	50	17	14	13	29⊠	26	25	28

TRAFFIC OPERATIONS ANALYSIS

Table D-11 shows the intersection operational and geometric characteristics for the Minneapolis/ St. Paul case study intersection. Figure D-4 shows the overall average vehicle delay (AVD) and intersection LOS under various peak-hour traffic volume and pedestrian walking speed scenarios (3.00, 3.50, 4.00 ft./sec. and base conditions).

Figures D-5, D-6, and D-7 show the major street and minor street approach AVD (in sec.) under walking speeds of 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec., respectively. Table D-12 shows the overall, major street approach, and minor street approach intersection LOS and AVD (in sec.) under various peak-hour traffic volume scenarios and under pedestrian walking speeds of 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec.

When comparing existing volume conditions to a modeled increase of 10 percent above existing volume conditions, there was a decrease of one LOS designation (from LOS C to LOS D) with a corresponding increase in average delay per vehicle (ADPV) of 14 sec. under the 3.00 ft./sec. walking speed scenario. An incremental increase of another 5 percent of peak-hour volume to the 3.00 ft./ sec. walking speed lowered the LOS from D to E and added 7 sec. to the ADPV. Thus, from existing volume conditions to a modeled increase of 15 percent over existing volumes, there was a reduction of two LOS designations (from LOS C to E) and a corresponding increase of approximately 21 sec. for ADPV.

Under the 3.50 ft./sec. and 4.00 ft./sec. walking speed scenarios, under existing volumes to an increase of 15 percent of existing volumes, there was no change in LOS (LOS C remained the same); however, there was a corresponding increase in ADPV of approximately 5 sec. and 4 sec. under the 3.50 ft./sec. and 4.00 ft,/sec. walking speed scenarios, respectively.

In summary, the 3.00 ft./sec. pedestrian walking speed, as compared to the 3.50 ft./sec. and 4.00 ft./sec. pedestrian walking speeds, had a greater negative impact on vehicular traffic operations at the case study intersection.

For the major street approaches, LOS and AVD remained constant (LOS C) under existing volume conditions as compared to a modeled increase of 15 percent above existing volumes at the 3.50 ft./sec. and 4.00 ft./sec. pedestrian walking speeds. For these walking speeds, there was only a 2-sec. and 5-sec. modeled difference, respectively, for the 3.50 ft./sec. and 4.00 ft./sec. pedestrian walking speeds. For the 3.00 ft./sec. walking speed assumption, LOS was reduced from LOS C under existing volume conditions to LOS E under a modeled increase of 15 percent above existing volumes. There was a 29-sec. increase in ADPV under the 3.00 ft./sec. walking speed.

The major street delay increased exponentially with the increase in traffic volume for the 3.00 ft./sec. walking speed.

For the minor street approaches, LOS ranged from LOS B to C for all volume and pedestrian walking speed scenarios analyzed. The range in ADPV under existing volume conditions as compared to a modeled increase of 15 percent above existing volumes at the 3.00 ft./sec. and 3.50 ft./sec. walking speed assumption was 1 sec. and 2 sec., respectively. For the 4.00 ft./sec. walking speed, under the same volume comparison, LOS was reduced by one designation (from LOS B to LOS C) and there was a corresponding increase in AVD of 7sec.

Table D-11. Minneapolis/St. Paul, Minnesota intersection characteristics: approach lane usage, peak-hour traffic volumes, and cycle length.

Approach	Number of approach lanes						Peak-hour traffic volumes (existing and modeled)					
	L	LT	T	TR	R	Total	-10 percent	Existing	+5 percent	+10 percent	+15 percent	Volume range
Northbound (MJ)	1	1	0	1	0	**3**	1,013	**1,126**	1,182	1,239	1,295	
Southbound (MJ)	1	0	1	1	1	**4**	934	**1,038**	1,090	1,142	1,194	
Eastbound (MN)	0	1	0	1	0	**2**	336	**373**	392	410	429	
Westbound (MN)	0	1	0	1	0	**2**	535	**594**	624	653	683	
MJ approach	2	1	1	2	1	**7**	1,947	**2,164**	2,272	2,380	2,489	1,947 – 2,489
MN approach	0	2	1	2	1	**4**	871	**967**	1,016	1,063	1,112	871 – 1,112
Total	2	3	2	4	2	**11**	2,818	**3,131**	3,288	3,444	3,601	**2,818 – 3,601**
Cycle length: 90 sec.												

* Note: l = Left; LT = left-through; T = through; TR = through-right; R = right.

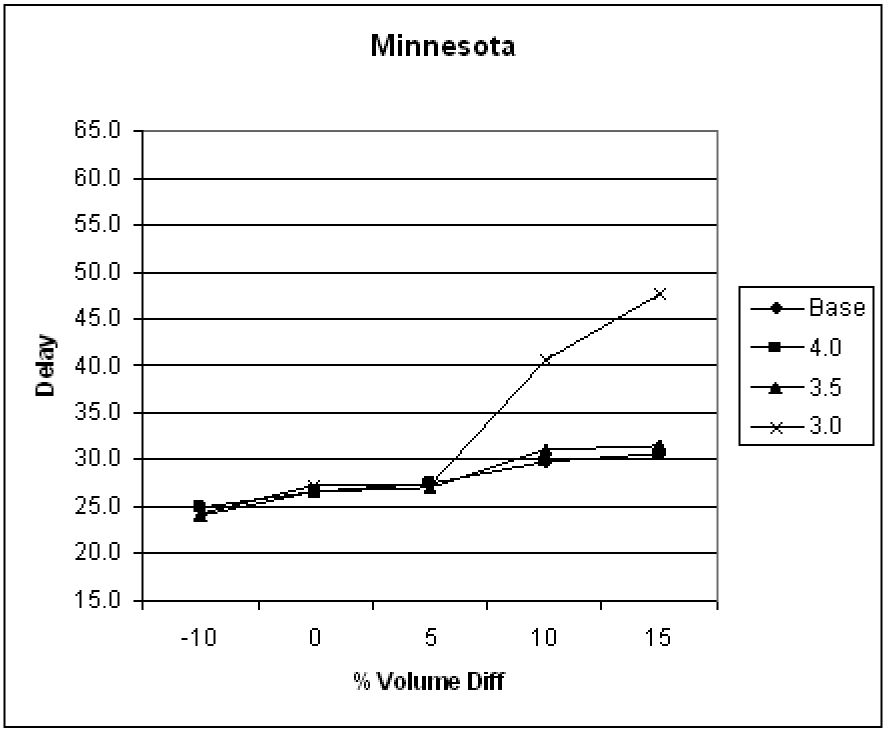

Figure D-4. Delay vs. volumes at case study intersections for walking speeds of 3.00, 3.50, 4.00 ft./sec. and base conditions.

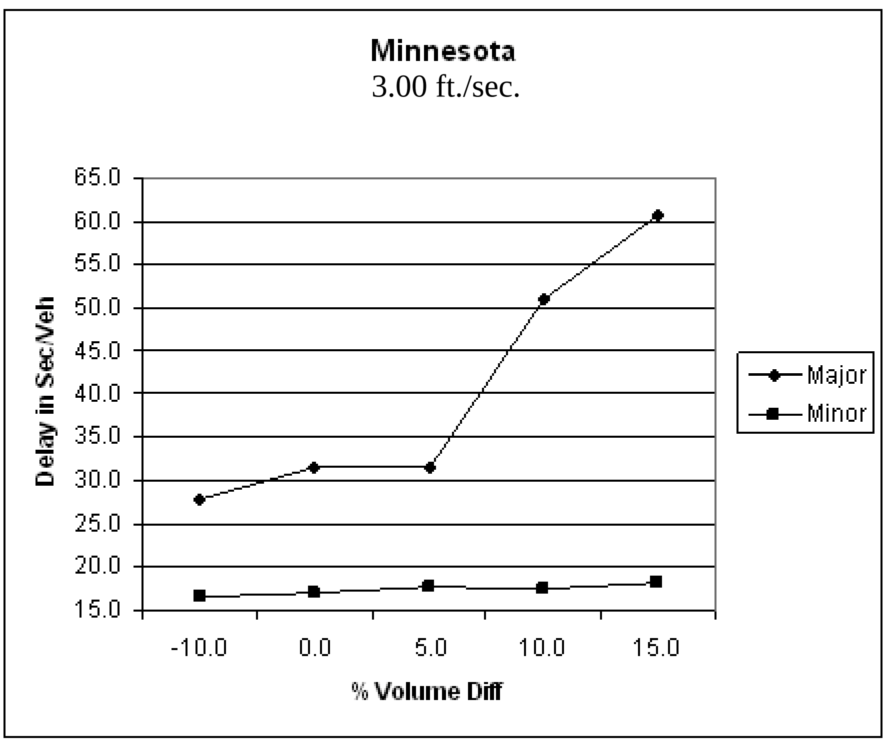

Figure D-5. Intersection delay for major and minor street approaches, 3.00 ft./sec. walking speed, Minneapolis/St. Paul, Minnesota.

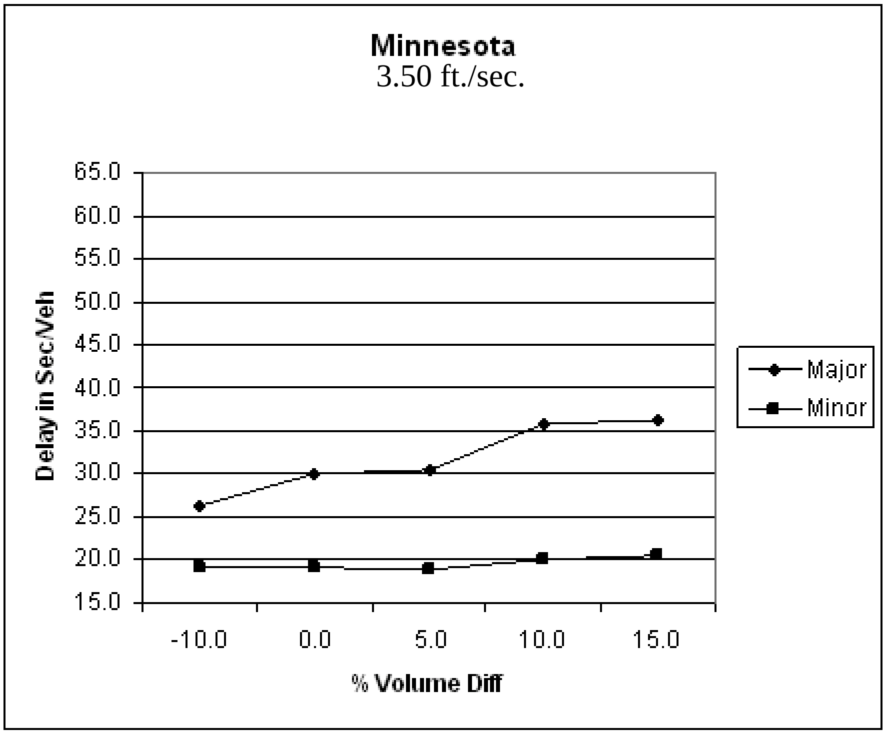

Figure D-6. Intersection delay for major and minor street approaches, 3.50 ft./sec. walking speed, Minneapolis/St. Paul, Minnesota.

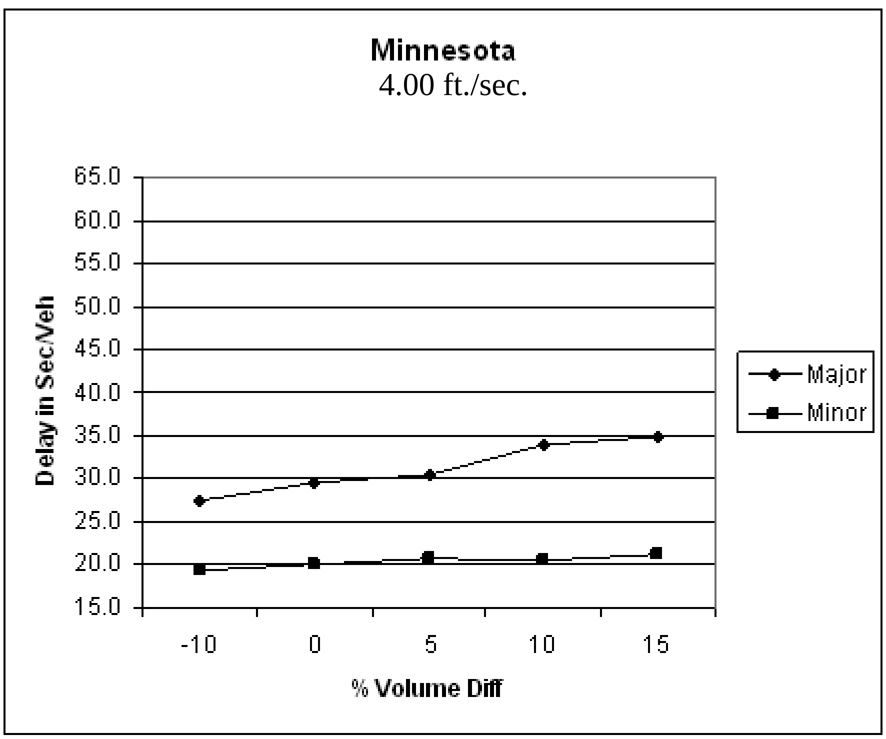

Figure D-7. Intersection delay for major and minor street approaches, 4.00 ft./sec. walking speed, Minneapolis/St. Paul, Minnesota.

Table D-12. Minneapolis/St. Paul intersection level of service under various peak-hour traffic volume and pedestrian walking speed scenarios.

Walking speed scenario	LOS (and average delay, in sec.)				
	-10-percent volume	Existing volume	+5-percent volume	+10-percent volume	+15-percent volume
3.00 ft./sec.	C (24)	C (27)	C (27)	D (41)	E (48)
3.50 ft./sec.	C (24)	C (27)	C (27)	C (31)	C (32)
4.00 ft./sec.	C (25)	C (27)	C (28)	C (30)	C (31)
Major street LOS (and average delay, in sec.)					
3.00 ft/sec.	C (28)	C (32)	C (32)	D (51)	E (61)
3.50 ft/sec.	B (17)	C (19)	C (19)	C (21)	C (21)
4.00 ft/sec.	C (28)	C (30)	C (31)	C (34)	C (35)
Minor street LOS (and average delay, in sec.)					
3.00 ft./sec.	B (17)	B (17)	B (18)	B (18)	B (18)
3.50 ft./sec.	B (19)	B (19)	B (19)	B (20)	C (21)
4.00 ft./sec.	B (19)	B (20)	C (21)	C (21)	C (35)

SUMMARY

In summary, the key results are as follows for Minneapolis and St. Paul:

- MWS for younger pedestrians was faster at PCD intersections (5.00 ft./sec.) than at traditional signals (4.90 ft./sec.).
- Walking speeds for older pedestrians were generally slower than for younger pedestrians. MWS for pedestrians 65 and older was faster at PCD intersections (4.30 ft./sec.) than at traditional signals (4.00 ft./sec.).
- Pedestrians with mobility impairments and without wheelchairs had appreciably slower walking speeds than pedestrians without mobility impairments—their mean was 3.60 ft./sec. A small sample size is recognized.
- Pedestrians with visual impairments had an MWS similar to older pedestrians—their mean was 4.20 ft./sec. A small sample size is recognized.
- Older pedestrians had a slower start-up time, but this will vary by intersection and leg of intersection.
- A slightly higher level of compliance (entering crosswalk on WALK display) was found at traditional intersections for the younger group of pedestrians. The sample size of the older group of pedestrians was too small to draw conclusions.
- PCD signals had a much lower occurrence of younger pedestrians being left in the intersection.
- The majority of surveyed pedestrians understood the PCD signal indication. Interestingly, of those who had a preference, the majority of pedestrians surveyed preferred TPS.
- Operational analysis:
    - The 3.00 ft./sec pedestrian walking speed, as compared to the 3.50 ft./sec. and 4.00 ft./sec. pedestrian walking speeds, had a greater negative impact on vehicular traffic operations at the case study intersection. From existing volume conditions to a modeled increase of 15 percent over existing volumes, there was a reduction of two LOS designations (from LOS C to LOS E) and a corresponding increase of 21 sec. for ADPV. Under the 3.50 ft./sec. and 4.00 ft./sec. walking speed scenarios, there was no change in LOS (LOS C remained the same) and the ADPV was 5 sec. and 4 sec. under the 3.50 ft./sec. and 4.00 ft./sec. walking speed scenarios, respectively.
    - The major street delay increased exponentially with the increase in traffic volume for the 3.00 ft./sec. walking speed.

APPENDIX E:

MONTGOMERY COUNTY, MARYLAND CASE STUDY

LIST OF TABLES

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BACKGROUND

As shown in Figure E-1, Montgomery County is located adjacent to Washington, DC, and is the most populous county in Maryland. Table E-1 shows the population distribution by age for Montgomery County, the state of Maryland, and the United States. A large portion of the population (33 percent) consists of 35–54 year-olds. Persons 65–84 comprise 9.8 percent of the population, which is slightly lower than the state of Maryland (10.1 percent) and the United States (10.9 percent). Persons 85 and older comprise 1.5 percent of the population, which is the same as the state of Maryland and the United States (Montgomery Country, Maryland County Map).

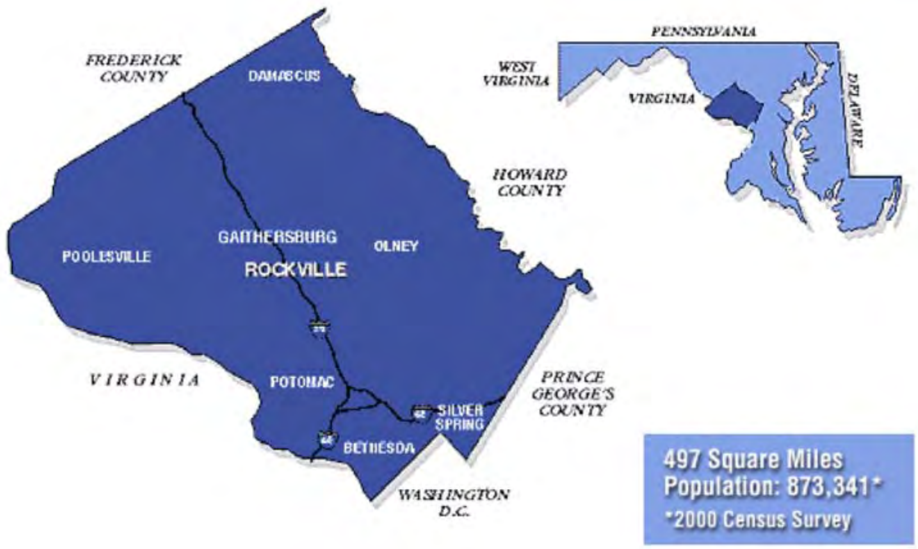

Figure E-1. Map of Montgomery County, Maryland.

Table E-1. Montgomery County, Maryland population distribution by age.

Age	Montgomery County		Maryland		United States	
	Population	Percent of total	Population	Percent of total	Population	Percent of total
Under 18	221,758	25.4	1,356,172	25.6	72,293,812	25.7
18-34	186,706	21.4	1,199,443	22.6	67,035,178	23.8
35-54	288,578	33.0	1,671,188	31.6	82,826,479	29.4
55-64	78,142	8.9	470,376	8.9	24,274,684	8.6
65-84	*85,174*	*9.8*	*532,405*	*10.1*	*30,752,166*	*10.9*
85 and older	*12,983*	*1.5*	*66,902*	*1.3*	*4,239,587*	*1.5*
Total	873,341	100	5,296,486	100	281,421,906	100

SITE SELECTION

Engineering staff from Montgomery County recommended approximately 20 intersections for the study, including intersections equipped with pedestrian countdown (PCD) signals and traditional pedestrian signals (TPS). The project engineer met with engineers from the county and with the AAA representative to discuss the potential sites for the study. The AAA representative recommended five additional intersections. Based on this discussion, eight potential candidates for the study were identified. The project engineer collected some sample volume data at each intersection and reviewed them for the following aspects:

- pedestrian volumes, particularly older pedestrian volumes;
- lack of any construction or other temporary impediments (such as street closures) that may affect pedestrian behavior;
- ability to sufficiently collect data (such as utility poles located close to the intersection);
- conventional intersection design; and
- surrounding land use.

Based on field observations, discussions with the engineering staff, and the recommendations of the AAA representative, four intersections were selected for the study:

- Bethesda Avenue and Arlington Road (traditional);
- Colesville Road and 2nd/Wayne (traditional);
- Elm Street and Woodmont Avenue (countdown); and
- Colesville Road and E. West Highway (countdown).

Two of the intersections, Bethesda Avenue and Arlington Road and Elm Street and Woodmont Avenue, were located in Bethesda, Maryland. As shown in Figure E-2, the intersections were in very close proximity to one another. The land use around these intersections was dense commercial and retail. The other two intersections were located in Silver Spring, Maryland. As shown in Figure E-3, they also were located in a dense commercial and retail environment. The intersections were 0.15 miles apart. The figures display the type of pedestrian signal at each of the four intersections.

Figure E-2. Study intersections in Bethesda, Maryland.

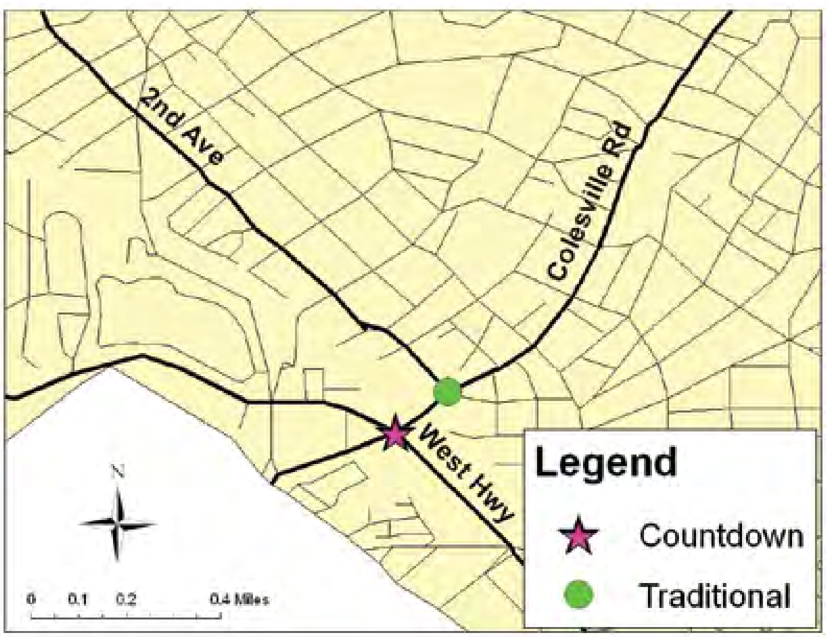

Figure E-3. Study intersections in Silver Spring, Maryland.

DATA COLLECTION METHODOLOGY

Pedestrian Behavior Data

Data were collected in Montgomery County during the month of November 2004. At each intersection, Portable Archival Traffic History (PATH) cameras were deployed for one full day of recording for one minor leg and one major leg. PATH systems record pedestrian activity at an intersection without interfering with pedestrians. The pedestrian behavior data were collected without any major difficulties.

Surveys

Pedestrians in Montgomery County were surveyed at one of the intersections in Silver Spring equipped with PCD signals a few months after PCD signals were introduced there. The survey gauged pedestrian understanding and preference for the signals. Because PCD signals now are commonplace in the study areas, the findings of the original survey were used for this analysis instead of re-surveying pedestrians.

RESULTS

Walking Speeds

The walking speeds of 958 pedestrians were observed at the four intersections. This included 264 pedestrians estimated to be 65 or older based on visual observations. Pedestrian walking speeds were measured from when they left the curb to when they returned to the curb on the other side of the street. Pedestrians who left the influence area of the crosswalk (within 2 to 3 feet of the edge of the crosswalk) during their crossing were not included in the analysis. The mean (average), 50th percentile (median), and 15th-percentile walking speeds were calculated for both groups of pedestrians. These values are presented in Table E-2 individually for each intersection’s minor and major approach. The mean, median, and 15th percentile also are represented collectively for all four traditional crossings and all four countdown crossings.

Table E-2. Walking speeds for pedestrians at intersections in Montgomery County, Maryland.

Intersection	Crossing	Observed walking speeds (ft./sec.)							
		Pedestrians under 65				Pedestrians 65 and older			
		Sample	**Mean**	**Median (50th percentile)**	**15th percentile**	**Sample**	**Mean**	**Median (50th percentile)**	**15^{th} percentile**
Bethesda and Arlington (traditional)	Major	63	5.6	5.4	4.7	24	4.3	4.1	3.4
	Minor	144	4.9	4.9	4.1	42	4.4	4.3	3.6
Colesville and 2nd/Wayne (traditional)	Major	70	5.7	5.6	4.9	30	4.7	4.7	3.9
	Minor	77	5.5	5.3	5.0	25	4.5	4.6	3.7
Traditional approaches combined		**354**	**5.3**	**5.2**	**4.6**	**121**	**4.5**	**4.4**	**3.6**
Elm and Woodmont (countdown)	Major	69	5.1	5.0	4.3	29	4.0	4.1	3.2
	Minor	95	5.4	5.4	4.9	35	4.6	4.6	3.7
Colesville and E.West Highway (countdown)	Major	76	5.4	5.3	4.9	31	3.9	3.8	3.1
	Minor	100	5.1	5.0	4.1	48	4.3	4.2	3.5
Countdown approaches combined		**340**	**5.3**	**5.2**	**4.6**	**143**	**4.2**	**4.2**	**3.5**

For younger pedestrians, the mean walking speed (MWS) was 5.30 feet/second (ft./sec.) at traditional intersections and at intersections equipped with PCD signals. As presented in Table E-3, there was no significant difference in the walking speeds for younger pedestrians at traditional and PCD signals. The median walking speed was 5.20 ft./sec. at traditional intersections and at countdown signals. The 15th-percentile walking speed represents the slower pedestrians at the intersection. The 15th-percentile speed was 4.60 ft./sec. at traditional signals and at countdown signals. A walking speed of 4.00 ft./sec. would accommodate the 15th-percentile younger pedestrian at any of these four intersections.

For older pedestrians, MWS at PCD signals was 4.20 ft./sec., slightly slower than the MWS of 4.50 ft./sec. at TPS. As presented in Table E-3, this difference was significant at a 95-percent confidence level. The median walking speed was slower at the countdown signal crossings (4.20 ft./sec.) than at traditional signal crossings (4.40 ft./sec.). The 15th-percentile speed also was slightly slower at PCD signals (3.50 ft./sec.) compared to TPS (3.60 ft./sec.).

A walking speed of 3.50 ft./sec. would accommodate 15th-percentile older pedestrians at the traditional and countdown intersections based on their combined 15th-percentile speed. At the PCD intersections, the major approach of both intersections had a 15th-percentile walking speed below 3.50 ft./sec.

Table E-3. Significance testing of difference in mean waking speed at traditional and pedestrian countdown signals for two age groups.

Subjects	Intersections	Mean	Standard deviation	T_{calc}	Outcome
Pedestrians under 65	Traditional	5.32	0.93	1.057	The difference between means **is not significant** at 95 percent.
	Countdown	5.25	0.75		
Pedestrians 65 and older	Traditional	4.45	0.85	2.342	The difference between means **is significant** at 95 percent.
	Countdown	4.22	0.79		

Table E-4 presents the results of significance testing of the difference in MWS for younger pedestrians and older pedestrians. As would be expected, the walking speed for older pedestrians was significantly slower than the walking speed for younger pedestrians, regardless of the type of pedestrian signal.

Table E-4. Significance testing of difference in mean walking speed for younger and older pedestrians for two types of pedestrian signal.

Intersection type	Subjects	Mean	Standard deviation	T_{calc}	Outcome
Traditional	Pedestrians under 65	5.32	0.93	9.438	The difference between means **is** significant at 95 percent.
	Pedestrians 65 and older	4.45	0.85		
Countdown	Pedestrians under 65	5.25	0.75	13.284	The difference between means **is** significant at 95 percent.
	Pedestrians 65 and older	4.22	0.79		

Pedestrians with Impairments

Pedestrians with discernable mobility or visual impairments were recorded separately, regardless of their age. At the Montgomery County intersections, 34 pedestrians with impairments were observed for walking speeds during the study periods. The walking speeds categorized by impairments are listed in Table E-5. These data are not stratified by age due to the small sample size.

Table E-5. Walking speeds of pedestrians with impairments, regardless of age, in Montgomery County, Maryland.

Observed impairment	Pedestrians	MWS
Visually impaired	1	4.70
Mobility impaired (walked with a cane, crutch, push cart, or with a limp)	22	3.10
Motorized wheelchair assisted	11	5.80

Twenty-two pedestrians with mobility impairments were observed during the study period. MWS for these pedestrians was 3.10 ft./sec. This walking speed was slower than the 15th-percentile for pedestrians 65 and older for all but one leg (Colesville Road and E. West Highway, major approach) of the four intersections.

Start-Up Times

Pedestrians who approached the intersection during the steady DON'T WALK (DW) interval and waited for the WALK interval were observed to determine their start-up lost time. This is the time from when the WALK indication is displayed on the pedestrian signal until the pedestrian leaves the curb and starts his or her crossing. This start-up time is related to the pedestrian's reaction to the signal timing. However, there could be other factors, such as turning vehicles still in the intersection, that may cause a pedestrian to delay his or her start across the intersection. No distinction was made between those who waited for turning vehicles and those who simply did not react to the signal as quickly. Only pedestrians who arrived prior to the onset of the WALK interval were included in this analysis.

Observations were recorded for pedestrians across the minor leg of Bethesda and Arlington (traditional), the minor leg of Elm and Woodmont (countdown), and the minor leg of Colesville and E. West Highway (countdown).

Based on a sample of 267 younger pedestrians at the three intersection legs, younger pedestrians had an average start-up time of 2.19 sec. Based on a sample of 58 older pedestrians at the three intersections, older pedestrians had a start-up time of 2.38 sec. This is a difference of .19 sec.

Compliance

Pedestrians at each intersection were observed during two hours of peak vehicle and pedestrian activity using the PATH system. For each pedestrian, observers recorded the pedestrian signal indication (WALK, FDW, or DW) that was displayed when the pedestrian entered the intersection. Observations were recorded separately for younger pedestrians and those 65 and older. Observations were recorded during the three hours of peak vehicle activity because vehicle volumes at intersections likely affect pedestrian compliance to the signal. This is related to the opportunity to cross. That is, at an intersection with low vehicle volume, pedestrians are more likely to violate the pedestrian signal because there are more available crossing gaps.

Pedestrians Under 65

Table E-6 shows the frequency and percentage of younger pedestrians entering during each signal indication for the two intersections equipped with TPS.

Table E-6. Frequency and percentage of younger pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at traditional signals in Montgomery County, Maryland.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Bethesda and Arlington (traditional)	Major	132	90	5	3	10	7
	Minor	63	79	7	9	10	13
Colesville and 2nd/Wayne (traditional)	Major	150	42	42	12	166	46
	Minor	358	36	146	15	493	49
Total at traditional signals		**703**	**44**	**200**	**13**	**679**	**43**

The compliance for younger pedestrians at traditional signals varied from 36 percent to 90 percent entering during the WALK indication. When the four intersection legs were considered together, 44 percent entered during the WALK indication. The intersection with the lowest compliance, Colesville Road and 2nd/Wayne, had the highest volume of pedestrians of the four intersections studied.

Table E-7 shows the frequency and percentage of younger pedestrians entering during each signal indication for the two intersections equipped with PCD signals. As with traditional intersections, the compliance varied by intersection and leg. However, 67 percent of pedestrians entered during the WALK indication. This was higher compliance than at traditional signals. This finding will be compared to other cities.

Table E-7. Frequency and percentage of younger pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at pedestrian countdown signals in Montgomery County, Maryland.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Elm and Woodmont (countdown)	Major	111	62	30	17	39	22
	Minor	295	78	26	7	59	16
Colesville and E. West Highway (countdown)	Major	171	49	47	14	130	37
	Minor	130	84	16	10	9	6
Total at countdown signals		**707**	**67**	**119**	**11**	**237**	**22**

Older Pedestrians

Table E-8 shows the frequency and percentage of older pedestrians entering during each signal indication for the two intersections equipped with TPS. During the two hours of peak vehicle activity, 78 older pedestrians were observed crossing at these intersections. The compliance varied by intersection leg; however, the sample sizes for individual legs were too small to be considered individually. When all four traditional legs were considered together, 71 percent of older pedestrians entered the intersection during the WALK indication.

Table E-8. Frequency and percentage of older pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at traditional signals in Montgomery County, Maryland.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Bethesda and Arlington (traditional)	Major	29	81	2	6	5	14
	Minor	5	83	0	0	1	17
Colesville and 2nd/Wayne (traditional)	Major	9	75	1	8	2	17
	Minor	12	50	0	0	12	50
Total at traditional signals		**55**	**71**	**3**	**4**	**20**	**26**

Table E-9 shows the frequency and percentage of older pedestrians entering during each signal indication for the two intersections equipped with PCD signals. During the two hours of peak vehicle activity, 72 older pedestrians were observed crossing at these intersections. As with traditional signals, compliance varied by intersection leg. When all four pedestrian countdown legs were considered together, 74 percent of older pedestrians entered the intersection during the WALK indication. This was slightly higher compliance than at the traditional signals. This finding will be compared to other cities.

Table E-9. Frequency and percentage of older pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at pedestrian countdown signals in Montgomery County, Maryland.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Elm and Woodmont (countdown)	Major	6	50	1	8	5	42
	Minor	23	79	2	7	4	14
Colesville and E. West Highway (countdown)	Major	6	55	3	27	2	18
	Minor	18	90	1	5	1	5
Total at countdown signals		**53**	**74**	**7**	**10**	**12**	**17**

Pedestrians Left in Intersection

At the end of each FDW interval, the number of pedestrians remaining in the intersection was noted. Only pedestrians who entered during the WALK or FDW interval were included. Table E-10 displays the results of this data collection. The total number of pedestrians left in the intersection during the observation period is noted as a percentage of the number of pedestrians crossing at the intersection during the same period. The results are combined for traditional signals and for PCD signals. For younger pedestrians, 0.9 percent of the pedestrians crossing at the intersection were left in the intersection at TPS, compared to 4.9 percent at PCD signals. For older pedestrians, the results were much closer. At traditional signals, 1.3 percent of the pedestrians crossing at the intersection were left in the intersection at traditional signals, compared to 1.4 percent at PCD signals.

Table E-10. Pedestrians remaining in the intersection at the start of the DON'T WALK interval in Montgomery County, Maryland.

Intersection	Leg	Pedestrians under 65		Pedestrians 65 and older	
		Total pedestrians	**Pedestrians left in intersection**	**Total pedestrians**	**Pedestrians left in intersection**
Bethesda and Arlington (traditional)	Major	147	0 (0.0 percent)	36	0 (0.0 percent)
	Minor	80	2 (2.5 percent)	6	0 (0.0 percent)
Colesville Road and 2nd/Wayne (traditional)	Major	358	0 (0.0 percent)	12	0 (0.0 percent)
	Minor	997	12 (3.2 percent)	24	1 (4.2 percent)
Total at traditional signals		**1582**	**14 (0.9 percent)**	**78**	**1 (1.3 percent)**
Elm and Woodmont (countdown)	Major	180	11 (6.1 percent)	12	0 (0.0 percent)
	Minor	380	14 (3.7 percent)	29	1 (3.4 percent)
Colesville and E. West Highway (countdown)	Major	348	14 (4.0 percent)	11	0 (0.0 percent)
	Minor	155	13 (8.4 percent)	20	0 (0.0 percent)
Total at countdown signals		**1063**	**52 (4.9 percent)**	**72**	**1 (1.4 percent)**

EFFECT OF CHANGING WALKING SPEEDS ON PEDESTRIAN CLEARANCE TIMES

Table E-11 displays the required pedestrian signal times for different walking speeds and the time available for that movement at each of the intersections studied. The pedestrian clearance time is the time needed to cross a specified crosswalk for a given walking speed, or, in other words, the length of the crosswalk divided by the crossing speed. The total time allotted for pedestrians to completely traverse a crosswalk is the sum of the clearance time and WALK time. A 7-sec. WALK time was used as recommended in the 2003 edition of MUTCD.

The available green time is the maximum time that can be allotted to the pedestrian signal interval based on existing signal timings and phasing. The available green represents the green intervals for the parallel streets. The available green times do not add up to the cycle length because of time allotted to exclusive phasing for turn movements, concurrent phasing for approaches on the same street (such as northbound and southbound approaches), and yellow and red intervals.

Table E-11 presents the ☒ symbol where the total pedestrian signal time exceeded the available minimum green time. Key findings related to pedestrian WALK clearance time durations for the case study intersections included:

- The pedestrian intervals exceeded the available green times for the 3.00 ft./sec. scenario in four of four crosswalks.

- The pedestrian intervals exceeded the available green times for both the 3.50 ft./sec. and the 4.00 ft./sec. scenarios in three of four crosswalks, indicating that the clearance time was determined using a walking speed greater than 4.00 ft./sec. or the WALK time used was less than 7 sec. for those crosswalks.

Table E-11. Pedestrian WALK and clearance time durations for case study intersection in Montgomery County, Maryland.

Approach/ crosswalk	Length (ft.)	Clearance time (sec.)			Clearance time with 7-sec. WALK (sec.) [total WALK time]			Available green (sec.)
		3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	
Northbound/ south	80	27	23	20	34☒	30	27	30
Southbound/ north	105	35	30	26	42☒	37☒	33☒	30
Eastbound/ west	117	39	33	29	46☒	40☒	36☒	31
Westbound/ east	106	35	30	27	42☒	37☒	34☒	31

TRAFFIC OPERATIONS ANALYSIS

Table E-12 shows the intersection operational and geometric characteristics for the Montgomery County case study intersection. Figure E-4 shows the overall average vehicle delay (AVD) and intersection level of service (LOS) under various peak-hour traffic volume and pedestrian walking speed scenarios (3.00, 3.50, 4.00 ft./sec. and base conditions).

Figures E-5, E-6, and E-7 show the major street and minor street approach AVD (in sec.) under walking speeds of 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec., respectively. Table E-13 shows the overall, major street approach, and minor street approach intersection LOS and AVD (in sec.) under various peak-hour traffic volume scenarios and under pedestrian walking speeds of 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec.

The modeled peak-hour volumes at the Montgomery County case study intersection ranged from a decrease of 10 percent to an increase of 10 percent of existing peak-hour volumes. The existing LOS at this case study intersection for the 3.00 ft./sec. pedestrian walking speed scenario was at capacity (LOS E with a corresponding average delay of 60 sec. per vehicle).

When comparing existing volume conditions to a modeled increase of 5 percent above existing volume conditions, the LOS designation (LOS E) did not change; however, there was a corresponding increase in average delay per vehicle (ADPV) of approximately 9 sec. under the 3.00 ft./sec. walking speed scenario. An incremental increase of another 5 percent of peak-hour volume (to 10 percent above existing volumes) at the 3.00 ft./sec. walking speed lowered the LOS from E to F and added 49 sec. to the ADPV. Thus, from existing volume conditions to a modeled increase of 10 percent over existing volumes, there was a reduction of two LOS designations (from LOS D to LOS F) and a corresponding increase in 58 sec. to ADPV.

Under the 3.50 ft./sec. and 4.00 ft./sec. walking speed scenarios, under existing volumes to an increase of 10 percent of existing volumes, there was no change in LOS (LOS D); however, there was a corresponding increase in ADPV of 6 sec. and 4 sec. under the 3.50 ft./sec. and 4.00 ft./sec. walking speeds, respectively.

Thus, under the conditions analyzed, the 3.00 ft./sec. pedestrian walking speed, as compared to the 3.50 ft./sec. and 4.00 ft./sec. pedestrian walking speeds, had a greater negative impact on vehicular traffic operations at the case study intersection.

For the major street approach, under existing conditions, LOS ranged from LOS D for the 3.50 ft./sec. and 4.00 ft./sec. walking speed assumptions to LOS E for the 3.00 ft./sec. assumption. The mean vehicle delay under existing volume conditions for the 3.50 and 4.00 ft./sec. walking speed assumptions was 45 sec.

For the 3.00 ft./sec. walking speed assumption, AVD was 66 sec. This represents an increase of 21 sec. in AVD under the 3.00 ft./sec. walking speed assumption. In comparison to some of the other case study intersections analyzed, this delay would be noticeable to a driver.

The range in ADPV under existing volume conditions as compared to a modeled increase of 10 percent above existing volumes for the 3.00 ft./sec. walking speed scenario was 66 sec. to 140 sec. (this represents an increase in AVD of 74 sec.). LOS was reduced from LOS E under existing volume conditions to LOS F when the volumes were increased to 10 percent above existing volumes.

As shown in Table E-12, major street delay increased exponentially with the increase in traffic volume for the 3.00 ft./sec. walking speed. There was no change in LOS (LOS D remained the same) under existing volume conditions as compared to a modeled increase of 10 percent above existing volumes for the 3.50 ft./sec. and 4.00 ft./sec. walking speed scenarios. The range in ADPV was from 42 sec. to 54 sec.

For the minor street approach, there was no change in LOS (LOS D remained the same) under existing volume conditions as compared to a modeled increase of 10 percent above existing volumes for the 3.50 ft./sec. and 4.00 ft./sec. walking speed scenarios. The range in ADPV was from 41 sec. to 49 sec. Minimum green time required for the concurrent traffic along the minor street approaches was less than the pedestrian clearance time required to cross the crosswalks. Additional green time based on the pedestrian clearance time was acquired from the major street green times.

Table E-12. Montgomery County, Maryland intersection characteristics: approach lane usage, peak-hour traffic volumes, and cycle length.

Approach	**Number of approach lanes**						**Peak-hour traffic volumes (existing and modeled)**					
	L	**LT**	**T**	**TR**	**R**	**Total**	**-10 percent**	**-5 percent**	**Existing**	**+5 percent**	**+10 percent**	**Volume range**
Northbound (MN)	1	1	0	1	0	**3**	338	357	**376**	395	414	
Southbound (MN)	1	0	2	0	1	**4**	230	242	**255**	268	281	
Eastbound (MJ)	1	0	3	0	1	**5**	768	810	**853**	892	934	
Westbound (MJ)	1	0	2	1	0	**4**	1,248	1,318	**1,387**	1,456	1,526	
MJ approach	2	0	5	1	1	**9**	2,016	2128	**2,240**	2352	2,464	2,016 – 2,464
MN approach	2	1	2	1	1	**7**	568	599	**631**	663	694	568 – 694
Total	4	1	7	2	2	**16**	2,584	2,727	**2,871**	3,015	3,158	2,584 – 3,158
Cycle length: 150 sec.												

* Note: L = left; LT = left-through; T = through; TR = through-right; R = right.

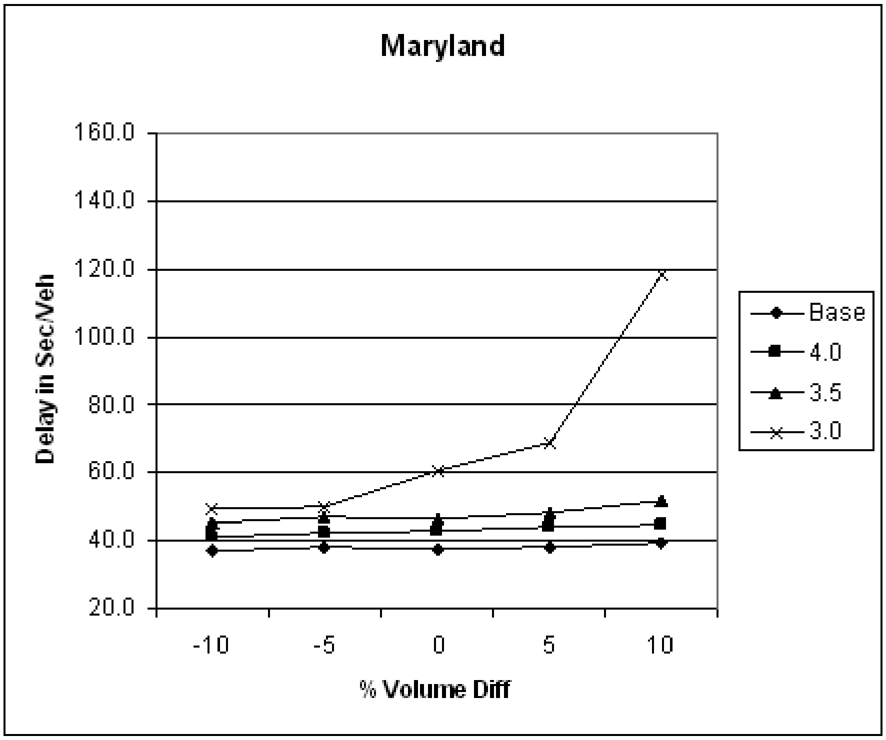

Figure E-4. Delay vs. volumes at case study intersections for walking speeds of 3.00, 3.50, 4.00 ft./sec. and base conditions.

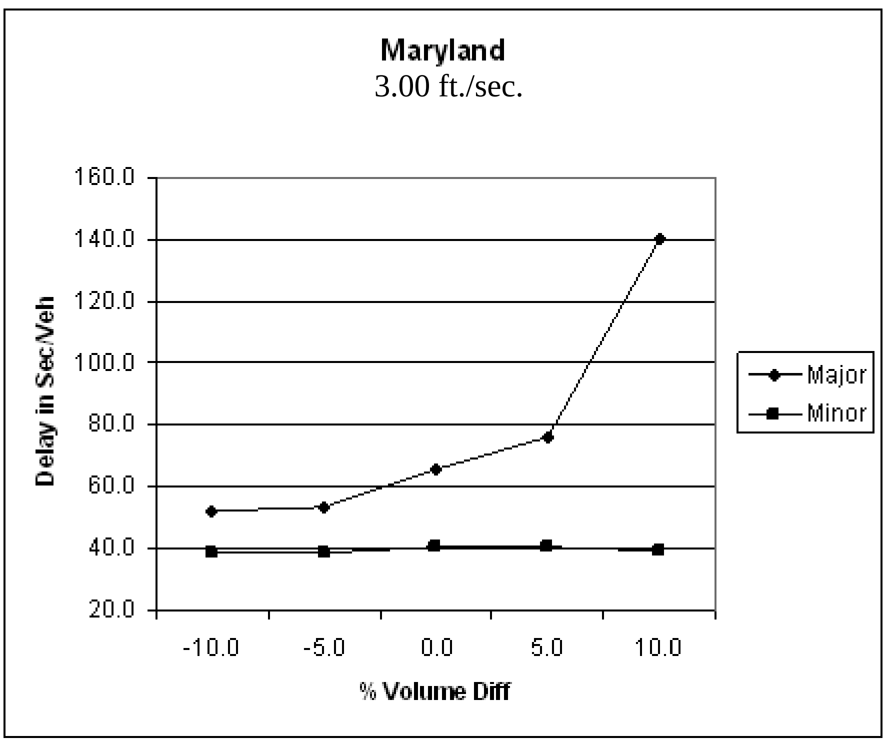

Figure E-5. Intersection delay for major and minor street approaches, 3.00 ft./sec. walking speed, Montgomery County, Maryland.

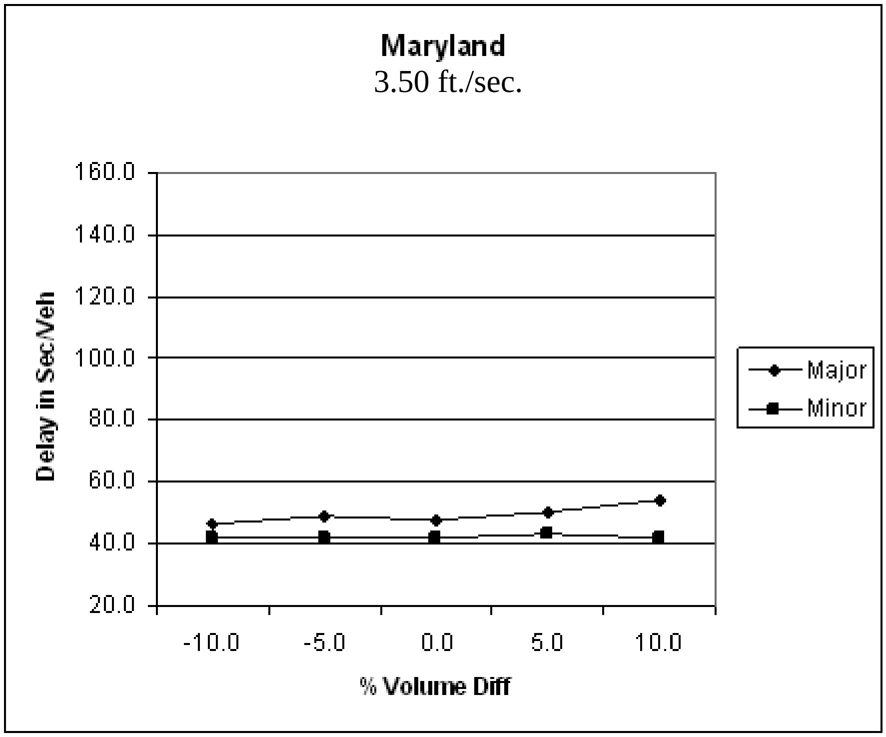

Figure E-6. Intersection delay for major and minor street approaches, 3.50 ft./sec. walking speed, Montgomery County, Maryland.

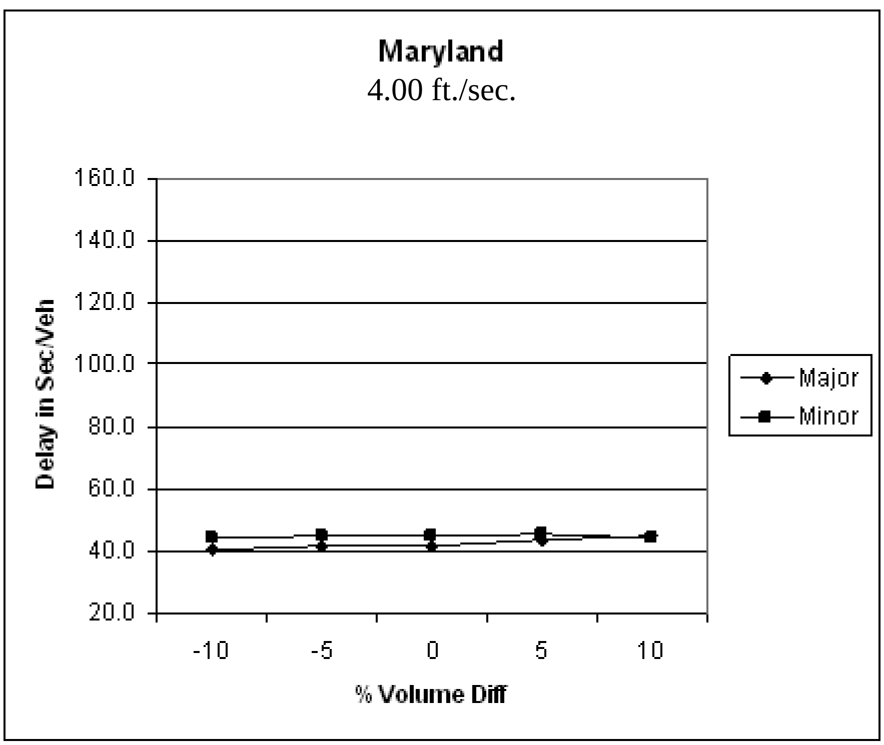

Figure E-7. Intersection delay for major and minor street approaches, 4.00 ft./sec. walking speed, Montgomery County, Maryland.

Table E-13. Montgomery County, Maryland: intersection level of service under various peak-hour traffic volume and pedestrian walking speed scenarios.

Walking speed scenario	LOS (and average delay, in sec.)				
	-10-percent volume	-5-percent volume	Existing volume	+5-percent volume	+10-percent volume
3.00 ft./sec.	D (49)	D (50)	E (60)	E (69)	F (118)
3.50 ft./sec.	D (46)	D (47)	D (47)	D (49)	D (52)
4.00 ft./sec.	D (41)	D (43)	D (43)	D (45)	D (45)
Major street LOS (and average delay, in sec.)					
3.00 ft./sec.	D (52)	D (53)	E (66)	E (76)	F (140)
3.50 ft./sec.	D (47)	D (49)	D (48)	D (50)	D (54)
4.00 ft./sec.	D (40)	D (42)	D (42)	D (44)	D (45)
Minor street LOS (and average delay, in sec.)					
3.00 ft./sec.	D (39)	D (39)	D (41)	D (46)	D (39)
3.50 ft./sec.	D (42)	D (42)	D (42)	D (49)	D (42)
4.00 ft./sec.	D (45)	D (45)	D (45)	D (47)	D (44)

SUMMARY

In summary, the key results are as follows for Montgomery County:

- Walking speeds for older pedestrians were generally slower than for pedestrians under 65 by approximately 0.80 ft./sec. at traditional intersections and 1.10 ft./sec. at PCD signals.

- There was no appreciable difference between walking speeds at traditional and PCD signals for younger pedestrians. MWS for older pedestrians was 0.30 ft./sec. faster at intersections equipped with TPS.

- Pedestrians with mobility impairments and without motorized wheelchairs had appreciably slower walking speeds—their mean speed was 3.10 ft./sec. compared to about 4.20 ft./sec. for older pedestrians. A small sample size is recognized.

- Older pedestrians had a slower start-up time, but this varied by intersection and leg of intersection.

- Compliance with pedestrian signals (entering crosswalk on WALK display) was found at PCD signals for younger pedestrians. Compliance was similar at TPS and PCD signals for older pedestrians.

- A higher percentage of younger pedestrians were left of the intersection at PCD signal intersections than at TPS intersections. There was no appreciable difference for the percentage of older pedestrians who were left in the intersection at traditional and PCD intersections.

- Operational analysis:

    - The existing overall LOS at the Montgomery County case study intersection for the 3.00 ft./sec. pedestrian walking speed scenario was at capacity (LOS E with a corresponding average delay of 60 sec. per vehicle).

    - From existing volume conditions to a modeled increase of 10 percent over existing volumes, there was a reduction of two LOS designations (from LOS D to LOS F) and a corresponding increase of 58 sec. to ADPV.

    - For the major street approach, AVD increased exponentially with the increase in traffic volume for the 3.00 ft./sec. walking speed.

    - On the minor street approach, there was no change in LOS (LOS D remained the same) under existing volume conditions as compared to a modeled increase of 10 percent above existing volumes for the 3.50 ft./sec. and 4.00 ft./sec. walking speed scenarios. There was a maximum increase in ADPV of 8 sec.

APPENDIX F:

WHITE PLAINS, NEW YORK CASE STUDY

LIST OF TABLES

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BACKGROUND

As shown in Figure F-1, White Plains, New York is located 25 miles north of Manhattan and serves as the Westchester County seat. Because of its increasing popularity, the city's population grew from 48,718 in 1990 to 53,077 in 2000. Of the 53,077 residents in 2000, 12.8 percent were between the ages of 65 and 84 and 2.4 percent were 85 and older. This means that 15.2 percent of the population was 65 and older. This is higher than the state of New York (12.9 percent) and the United States as a whole (12.4 percent), as shown in Table F-1 (U.S. Census Bureau American Fact Finder).

Figure F-1. Geographic location of White Plains, New York.

Table F-1. White Plains, New York population distribution by age.

Age	White Plains		New York		United States	
	Population	Percent of total	Population	Percent of total	Population	Percent of total
Under 18	11,262	21.2	4,690,107	24.7	72,293,812	25.7
18–34	12,443	23.4	4,522,777	23.8	67,035,178	23.8
35–54	16,161	30.4	5,627,234	29.7	82,826,479	29.4
55–64	5,153	9.7	1,687,987	8.9	24,274,684	8.6
65–84	*6,772*	*12.8*	*2,136,864*	*11.3*	*30,752,166*	*10.9*
85 and older	*1,286*	*2.4*	*311,488*	*1.6*	*4,239,587*	*1.5*
Total	53,077	100.0	18,976,457	100.0	281,421,906	100.0

SITE SELECTION

The City of White Plains maintains 132 signalized intersections, of which 101 have pedestrian signals. White Plains began installing pedestrian countdown (PCD) signals in its jurisdiction in December 2003. At the time of the study, it had signals installed at 15 intersections, mainly in its central business district, where there was a large volume of pedestrians. The signals were compliant with the *Manual on Uniform Traffic Control Devices* (MUTCD) and displayed the countdown during the flashing DON'T WALK (FDW) interval.

Walking speed was used as part of the calculation to determine the pedestrian signal intervals, varying between 3.00 and 4.00 feet/second (ft./sec.), depending on the presence of schools and known older populations. The city concentrated its placement of PCD signals at high-volume/high-pedestrian intersections with long crossing distances. There were no formal criteria for defining high volume or long crossing distances; city engineers used their judgment regarding which intersections were longer or had high volumes.

White Plains Commissioner of Traffic Thomas Soyk recommended 20 intersections for the study, including intersections equipped with PCD signals and with traditional pedestrian signals (TPS). Soyk selected intersections that had high pedestrian volumes and had been counted for pedestrian and vehicle volume in the last few years. The project engineer reviewed these 20 intersections for the following aspects:

- pedestrian volumes, particularly older pedestrian volumes;
- lack of any construction or other temporary impediments (such as street closures) that may affect pedestrian behavior;
- ability to sufficiently collect data (such as utility poles located close to the intersection);
- conventional intersection design; and
- surrounding land use.

Based on field observations, discussions with the engineering staff, and the recommendations of the AAA representative, four intersections were selected for the study:

- Mamaroneck Avenue and Martine Avenue (countdown);
- Mamaroneck Avenue and Maple Avenue (countdown);
- Mamaroneck Avenue and Post Avenue (traditional); and
- Hamilton Avenue and Church Street (traditional).

Figure F-2 displays the type of pedestrian signal at each of the four intersections. As shown, the intersections were in close proximity to one another, with the farthest two intersections only one-half-mile apart. The intersections all were located in the White Plains central business district, which was characterized by office buildings and commercial storefronts.

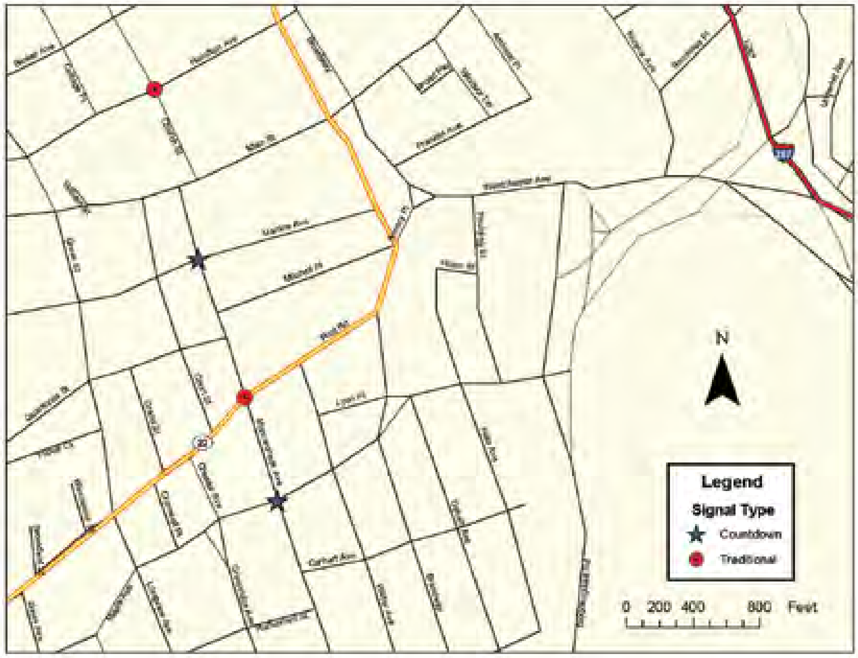

Figure F-2. Study intersections in White Plains, New York.

DATA COLLECTION METHODOLOGY

Pedestrian Behavior Data

Data were collected in White Plains during the week of September 20, 2004. At each intersection, Portable Archival Traffic History (PATH) cameras were deployed for one full day of recording for one minor leg and one major leg. PATH systems record pedestrian activity at the intersection without interfering with pedestrians. The pedestrian behavior data were collected without any major difficulties.

Surveys

The project team developed a brief survey to be administered to pedestrians at the study intersections. The purpose of the survey was to gauge pedestrian understanding and preference for PCD signals and TPS.

Survey administration took approximately 1 minute. Surveys were administered at the two PCD study intersections to pedestrians who had completed their crossing at the intersections. The targets of the survey were pedestrians over 18 years of age.

The survey response was much lower than anticipated, particularly for older pedestrians. Approximately 90 percent of the people who were approached regarding the survey declined to participate.

RESULTS

Walking Speeds

The walking speeds of 1,304 pedestrians were observed at the four intersections. This included 270 pedestrians estimated to be 65 or older based on visual observations. Pedestrian walking speeds were measured from when they left the curb to when they returned to the curb on the other side of the street. Pedestrians who left the influence area of the crosswalk (within 2 to 3 feet of the edge of the crosswalk) during their crossing were not included in the analysis. The mean (average), 50th-percentile (median), and 15th-percentile walking speeds were calculated for both groups of pedestrians. These values are presented in Table F-2 individually for each intersection's minor and major approach. The mean, median, and 15th percentile also are represented collectively for all four traditional crossings and all four PCD crossings.

Table F-2. Walking speeds for pedestrians at intersections in White Plains, New York.

Intersection	Crossing	Observed walking speeds (ft./sec.)							
		Pedestrian under 65				Pedestrians 65 or older			
		Sample	Mean	Median (50th percentile)	15th percentile	Sample	Mean	Median (50th percentile)	15th percentile
Hamilton and Church (traditional)	Major	141	5.1	5.0	4.3	28	4.8	4.6	3.3
	Minor	119	5.0	4.9	4.2	18	4.5	4.4	3.3
Mamaroneck and Post (traditional)	Major	132	5.0	4.8	4.1	30	4.3	4.2	3.7
	Minor	80	4.7	4.7	4.1	34	4.0	4.0	3.4
Traditional approaches combined		**472**	**5.0**	**4.9**	**4.2**	**110**	**4.3**	**4.2**	**3.5**
Mamaroneck and Maple (countdown)	Major	104	5.1	5.0	4.2	32	5.0	4.7	4.3
	Minor	185	5.0	4.9	4.2	49	4.5	4.7	3.7
Mamaroneck and Martine (countdown)	Major	120	5.2	5.1	4.3	42	4.1	3.9	3.3
	Minor	153	4.8	4.7	3.7	37	4.5	4.3	3.7
Countdown approaches combined		**562**	**5.0**	**4.9**	**4.1**	**160**	**4.5**	**4.4**	**3.6**

For younger pedestrians, the mean walking speed (MWS) was 5.00 ft./sec. at traditional intersections and intersections equipped with PCD signals. As presented in Table F-3, there was no difference in the walking speed. The median walking speed was 4.90 ft./sec. at traditional intersections and PCD signals. The 15th-percentile walking speed represents the slower pedestrians at the intersection. The 15th-percentile speed was similar at traditional signals and PCD signals. A walking speed of 4.00 ft./sec. would accommodate the 15th-percentile younger pedestrian at any of these four intersections.

For older pedestrians, MWS at PCD signals was 4.50 ft./sec., slightly faster than the MWS of 4.30 ft./sec. at TPS. As presented in Table F-3, this difference was not significant at the 95-percent confidence level. The median walking speed was slightly faster at the countdown signal crossings. The 15th-percentile speed was also slightly faster at countdown signals (3.60 ft./sec.) compared to traditional signals (3.50 ft./sec.). A walking speed of 4.00 ft./sec. would accommodate the average older pedestrian at these intersections but would not accommodate the 15th-percentile older pedestrian.

Table F-3. Significance testing of difference in mean walking speed at traditional and pedestrian countdown signals for two age groups.

Subjects	Intersection type	Mean	Standard deviation	T_{calc}	Outcome
Pedestrians under 65	Traditional	5.0	1.05	-0.199	The difference between means **is not** significant at 95 percent.
	Countdown	5.0	1.01		
Pedestrians 65 and older	Traditional	4.3	1.06	-1.272	The difference between means **is not** significant at 95 percent.
	Countdown	4.5	1.02		

Table F-4 presents the results of significance testing of the difference in MWS for younger pedestrians and older pedestrians. As would be expected, the walking speed for older pedestrians was significantly slower than the walking speed for younger pedestrians, regardless of the type of pedestrian signal.

Table F-4. Significance testing of difference in mean walking speed for younger pedestrians and older

Intersection type	Subjects	Mean	Standard deviation	T_{calc}	Outcome
Traditional	Pedestrians under 65	5.0	1.05	5.631	The difference between means **is** significant at 95 percent.
	Pedestrians 65 and older	4.3	1.06		
Countdown	Pedestrians under 65	5.0	1.01	5.246	The difference between means **is** significant at 95 percent.
	Pedestrians 65 and older	4.5	1.02		

Pedestrians with Impairments

Pedestrians with discernable mobility or visual impairments were recorded separately, regardless of their age. At the White Plains intersections, 21 pedestrians with impairments were observed for walking speeds during the study periods. The walking speeds categorized by impairments are listed in Table F-5. These data are not stratified by age because of the small sample size.

Table F-5. Walking speeds of pedestrians with impairments, regardless of age, in White Plains, New York.

Observed impairment	Pedestrians	MWS
Visually impaired	4	4.7
Mobility impaired (walked with a cane, crutch, or push cart)	15	3.0
Motorized wheelchair assisted	2	4.4

Fifteen pedestrians with mobility impairments were observed during the study period. MWS for these pedestrians was only 3.00 ft./sec. This walking speed was slower than the 15th-percentile speed for older pedestrians at any of the four intersections.

For younger pedestrians, MWS at intersections equipped with TPS was the same as those intersections equipped with PCD signals, 5.00 ft./sec. For older pedestrians, MWS was slighter faster at intersections equipped with PCD signals.

Start-Up Times

Pedestrians who approached the intersection during the steady DON'T WALK (DW) interval and waited for the WALK interval were observed to determine their start-up lost time. This is the time from when the WALK indication is displayed on the pedestrian signal until the pedestrian leaves the curb and starts his or her crossing. This start-up time is related to the pedestrian's reaction to the signal timing. However, there could be other factors, such as turning vehicles still in the intersection, that may cause a pedestrian to delay his or her start across the intersection. No distinction was made between those who waited for turning vehicles and those who simply did not react to the signal as quickly. Only pedestrians who arrived prior to the onset of the WALK interval were included in this analysis.

Observations were recorded for pedestrians across the major leg of Mamaroneck and Post (traditional). Based on a sample of 153 younger pedestrians, younger pedestrians had a start-up time of 1.13 sec. at this crossing. Based on a sample of 30 older pedestrians, older pedestrians had a start-up time of 1.80 sec. This is a difference of 0.67 sec.

Compliance

Pedestrians at each intersection were observed during two hours of peak vehicle and pedestrian activity using the PATH system. For each pedestrian, observers recorded the pedestrian signal indication (WALK, FDW, or DW) that was displayed when the pedestrian entered the intersection. Observations were recorded separately for younger pedestrians and those 65 and older. Observations were recorded during the three hours of peak vehicle activity because vehicle volumes at intersections likely affect pedestrian compliance to the signal. This is related to the opportunity to cross. That is, at an intersection with low vehicle volume, pedestrians are more likely to violate the pedestrian signal because there are more available crossing gaps.

Younger Pedestrians

Table F-6 shows the frequency and percentage of younger pedestrians entering during each signal indication for the two intersections equipped with TPS.

Table F-6. Frequency and percentage of younger pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at traditional signals in White Plains, New York.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Hamilton and Church (traditional)	Major	39	31	13	10	74	59
	Minor	42	40	41	39	21	20
Mamaroneck and Post (traditional)	Major	274	64	67	16	87	20
	Minor	565	71	111	14	125	16
Total at traditional signals		**920**	**63**	**232**	**16**	**307**	**21**

The compliance for younger pedestrians at traditional signals varied from 31 percent to 71 percent entering during the WALK indication. When the four intersection legs were considered together, 63 percent entered during the WALK interval. The intersection with the lowest compliance, Hamilton and Church, was the lowest volume intersection of the four studied intersections. As noted previously, intersections with lower vehicle volumes are likely to have lower pedestrian signal compliance because of the availability of gaps in vehicle traffic.

Table F-7 shows the frequency and percentage of younger pedestrians entering during each signal for the two intersections equipped with PCD signals. As with the traditional intersections, the compliance varied by intersection and leg. However, only 53 percent of pedestrians entered during the WALK indication and 36 percent entered during the DW indication. This was lower compliance than at the traditional signals. This may be due to a difference in the availability of gaps during the DW interval at the countdown intersection. This finding will be compared to other cities.

Table F-7. Frequency and percentage of younger pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at pedestrian countdown signals in White Plains, New York.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Mamaroneck and Maple (countdown)	Major	42	55	14	18	21	27
	Minor	174	47	47	13	147	40
Mamaroneck and Martine (countdown)	Major	149	58	29	11	80	31
	Minor	532	54	96	10	351	36
Total at countdown signals		**897**	**53**	**186**	**11**	**599**	**36**

Older Pedestrians

Table F-8 shows the frequency and percentage of older pedestrians entering during each signal indication for the two intersections equipped with TPS. During the three hours of peak vehicle activity, 87 older pedestrians were observed crossing at these intersections. The compliance varied by intersection leg; however, the sample sizes for individual legs were too small to be considered individually. When all four traditional legs were considered together, 72 percent of older pedestrians entered the intersection during the WALK indication.

Table F-8. Frequency and percentage of older pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at traditional signals in White Plains, New York.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Hamilton and Church (traditional)	Major	5	42	0	0	7	58
	Minor	9	90	1	10	0	0
Mamaroneck and Post (traditional)	Major	9	60	2	13	4	27
	Minor	40	80	7	14	3	6
Total at traditional signals		**63**	**72**	**10**	**11**	**14**	**16**

Table F-9 shows the frequency and percentage of older pedestrians entering during each signal indication for the two intersections equipped with PCD signals. During the three hours of peak vehicle activity, 164 older pedestrians were observed crossing at these intersections. As with traditional signals, the compliance varied by intersection leg. When all four pedestrian countdown legs were considered together, 62 percent of older pedestrians entered the intersection during the WALK indication. This was lower compliance than at the traditional signals. As with their younger counterparts, this difference in compliance may be due to a difference in the availability of gaps during the DW interval at the countdown intersection. This finding will be compared to other cities.

Table F-9. Frequency and percentage of older pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at pedestrian countdown signals in White Plains, New York.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Mamaroneck and Maple (countdown)	Major	9	90	1	10	0	0
	Minor	14	47	6	20	10	33
Mamaroneck and Martine (countdown)	Major	25	81	3	10	3	10
	Minor	54	58	6	6	33	35
Total at countdown signals		**102**	**62**	**16**	**10**	**46**	**28**

Pedestrians Left in Intersection

At the end of each FDW interval, the number of pedestrians remaining in the intersection was noted. Only pedestrians who entered during the WALK or FDW interval were included. Table F-10 displays the results of this data collection. The total number of pedestrians left in the intersection during the observation period is noted as a percentage of the number of pedestrians crossing at the intersection during the same period. The results are combined for traditional signals and for PCD signals. For younger pedestrians, 10 percent of the pedestrians crossing at the intersection were left in the intersection at TPS, compared to 8 percent at PCD signals. For older pedestrians, the results were reversed. At TPS, 9 percent of the pedestrians crossing at the intersection were left in the intersection, compared to 10 percent at PCD signals. However, the sample sizes were very small for older pedestrians.

Table F-10. Pedestrians remaining in the intersection at the start of the DON'T WALK interval in White Plains, New York.

Intersection	Leg	Pedestrians under 65		Pedestrians 65 and older	
		Total pedestrians	Pedestrians left in intersection	Total pedestrians	Pedestrians left in intersection
Hamilton and Church (traditional)	Major	126	12 (10 percent)	12	0 (0 percent)
	Minor	104	7 (7 percent)	10	1 (10 percent)
Mamaroneck and Post (traditional)	Major	428	52 (12 percent)	15	2 (13 percent)
	Minor	801	72 (9 percent)	50	5 (10 percent)
Total at traditional signals		**1459**	**143 (10 percent)**	**87**	**8 (9 percent)**
Mamaroneck and Maple (countdown)	Major	77	7 (9 percent)	10	2 (20 percent)
	Minor	368	28 (8 percent)	30	5 (17 percent)
Mamaroneck and Martine (countdown)	Major	258	22 (9 percent)	31	1 (3 percent)
	Minor	979	75 (8 percent)	93	9 (10 percent)
Total at countdown signals		**1682**	**132 (8 percent)**	**164**	**17 (10 percent)**

SURVEY RESULTS

A total of 67 pedestrians were surveyed in White Plains, including 19 older pedestrians. Approximately 90 percent of those approached declined to be surveyed. Pedestrians were intercepted after they completed their crossing at PCD-equipped intersections and asked if they would like to participate in a brief survey on pedestrian safety. Pedestrians were asked if they noticed anything different about crossing at this intersection than at similar intersections in White Plains. A follow-up question confirmed that the difference noted was the countdown signal. Forty-seven (approximately 70 percent) of the pedestrians noticed the PCD signals.

All surveyed pedestrians were asked to explain the meaning of the countdown indication. Approximately 90 percent of the pedestrians provided a satisfactory explanation of the countdown indication. Of those pedestrians who had a preference regarding the use of TPS or PCD signals, 90 percent preferred the PCD signals. Similarly, approximately 85 percent of all pedestrians surveyed indicated that the PCD signal was helpful in crossing the street safely.

EFFECT OF CHANGING WALKING SPEEDS ON PEDESTRIAN CLEARANCE TIMES

Table F-11 displays the required pedestrian signal times for different walking speeds and the time available for that movement at each of the intersections studied. Table F-11 presents the ☒ symbol where the total pedestrian signal time exceeded the available minimum green time. Key findings related to the pedestrian WALK clearance time durations for the case study intersections included:

- The White Plains case study intersection did not have pedestrian intervals that exceeded the available green time for any crosswalk and/or WALK time scenarios.

Table F-11. Pedestrian WALK and clearance time durations for case study intersection in White Plains, New York.

Approach/ crosswalk	Length (ft.)	Clearance time (sec.)			Clearance time with 7-sec. WALK (sec.) [total WALK time]			Available green (sec.)
		3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	
Northbound/ south	67	22	19	17	29	26	24	35
Southbound/ north	67	22	19	17	29	26	24	35
Eastbound/ west	64	21	18	16	28	25	23	55
Westbound/ east	62	21	18	16	28	25	23	55

TRAFFIC OPERATIONS ANALYSIS

Table F-12 shows the intersection operational and geometric characteristics for the White Plains case study intersection. Figure F-3 shows the overall average vehicle delay (AVD) and intersection level of service (LOS) under various peak-hour traffic volume and pedestrian walking speed scenarios (3.00, 3.50, 4.00 ft./sec. and base conditions).

The traffic volumes modeled at the White Plains case study intersection ranged from existing conditions to an increase of 25 percent of existing conditions. Traffic volumes at this intersection were substantially lower than capacity, and even increasing the traffic volumes on each approach by 25 percent did not cause any impact on the AVD along major and minor street approaches.

Table F-13 shows the overall intersection LOS and AVD (in sec.) under various peak-hour traffic volume scenarios and under pedestrian walking speeds of 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec.

As shown in Table F-13, LOS and vehicular delay for each walking speed scenario essentially did not differ from the existing conditions. This intersection had adequate signal time available for all pedestrian phases with lower walking speeds and each of the concurrent traffic movements. Therefore, vehicular delay was not affected when the green times were adjusted based on the lower walking speeds.

For major street and minor street approaches, there was no change in LOS (LOS C and LOS B, respectively) under all volume and pedestrian walking speed scenarios analyzed.

Table F-12. White Plains, New York intersection characteristics: approach lane usage, peak-hour traffic volumes, and cycle length.

Approach	Number of approach lanes						Peak-hour traffic volumes (existing and modeled)					
	L	LT	T	TR	R	Total	Existing	+5 percent	+10 percent	+15 percent	+25 percent	Volume range
Northbound (MN)	0	0	1	1	0	**2**	513	539	564	590	641	
Southbound (MN)	0	0	1	1	0	**2**	457	480	503	526	571	
Eastbound (MJ)	0	0	0	1	1	**2**	300	315	330	345	375	
Westbound (MJ)	0	0	0	1	1	**2**	341	358	375	392	426	
MJ approach	0	0	2	2	0	**4**	970	1,019	1,067	1,116	1,213	970–1,213
MN approach	0	0	0	2	2	**4**	641	673	705	737	801	641–801
Total	0	0	2	4	4	**8**	1,611	1,692	1,772	1,853	2,014	1,611 – 2,014
Cycle length: 100 sec.												

* Note: L = left; LT = left-through; T = through; TR = through-right; R = right.

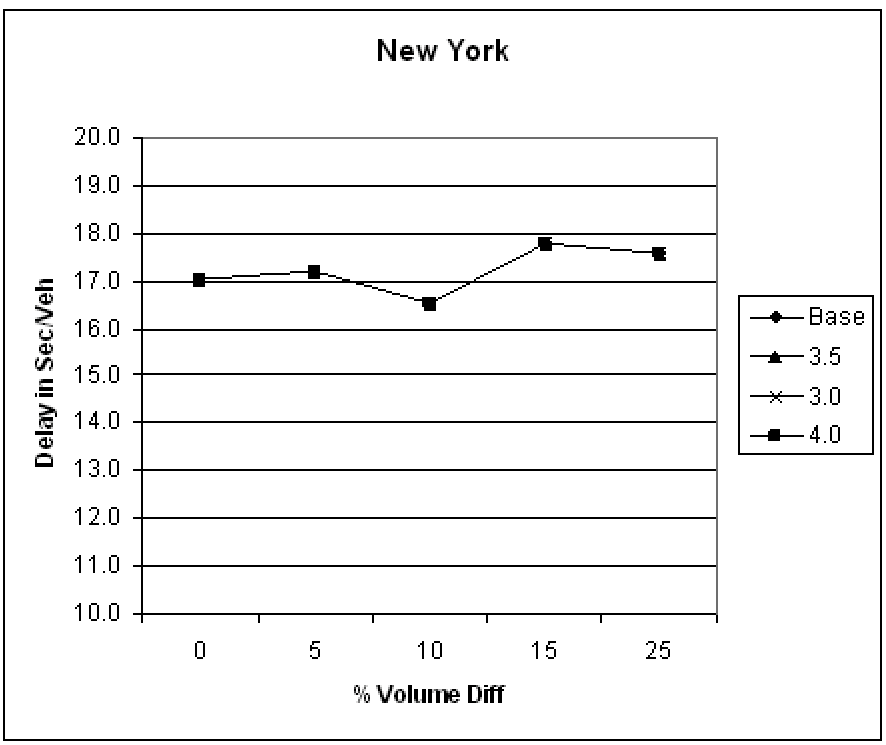

Figure F-3. Delay vs. volumes at case study intersection for walking speeds of 3.00, 3.50, 4.00 ft./sec. and base conditions.

Table F-13. White Plains, New York: intersection level of service under various peak-hour traffic volume and pedestrian walking speed scenarios.

Walking speed scenario	LOS (and average delay, in sec.)				
	Existing volume	+5 percent volume	+10 percent volume	+15 percent volume	+25 percent volume
3.00 ft./sec.	B (17)	B (17)	B (17)	B (18)	B (18)
3.50 ft./sec.	B (17)	B (17)	B (17)	B (18)	B (18)
4.00 ft./sec.	B (17)	B (17)	B (17)	B (18)	B (18)
Major street LOS (and average delay, in sec.)					
3.00 ft./sec.	C (23)	C (23)	C (23)	C (23)	C (24)
3.50 ft./sec.	C (23)	C (23)	C (23)	C (23)	C (24)
4.00 ft./sec.	C (23)	C (23)	C (23)	C (23)	C (24)
Minor street LOS (and average delay, in sec.)					
3.00 ft./sec.	B (13)	B (13)	B (13)	B (14)	B (13)
3.50 ft./sec.	B (13)	B (13)	B (13)	B (14)	B (13)
4.00 ft./sec.	B (13)	B (13)	B (13)	B (14)	B (13)

* Note: Cycle length= 100 sec.

SUMMARY

In summary, the key results are as follows for White Plains:

- Walking speeds for older pedestrians were generally slower than for pedestrians younger than 65 by about 0.50 to 0.70 ft./sec. These differences were statistically significant at the 95-percent confidence level for both traditional and countdown signals. There was no statistically significant difference between traditional and PCD signals for both age groups.

- Pedestrians with mobility impairments and without motorized wheelchairs had appreciably slower walking speeds—their mean was 3.00 ft./sec. compared to about 4.40 ft./sec. for older pedestrians in general and 5.00 ft./sec. for younger pedestrians. A small sample size is recognized.

- Older pedestrians had a slower start-up time, but this will vary by intersection and leg of intersection.

- A higher level of non-compliance (entering crosswalk on DW display) was found with the younger group and with countdown signals regardless of age.

- No statistically significant differences were found for the percentage of pedestrians left in the intersection when comparing age or type of pedestrian signal.

- Surveyed pedestrians generally preferred the PCD signal to traditional signals, with 90 percent of pedestrians understanding the indication.

- Operational analysis:
    - Traffic volumes at this intersection were substantially lower than capacity and even increasing the traffic volumes on each approach by 25 percent did not cause any impact on the overall AVD and along major and minor street approaches. LOS and vehicular delay for each walking speed scenario essentially did not differ from the existing conditions (the overall intersection LOS and minor street LOS remained at LOS B and the major approach LOS remained at LOS C for all volume and pedestrian walking speed scenarios analyzed).

APPENDIX G:

SALT LAKE CITY, UTAH CASE STUDY

LIST OF TABLES

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BACKGROUND

Salt Lake City is Utah's capital and is located in the upper northwest corner of the state, as shown in Figure G-1. The city's population grew from 159,936 in 1990 to 181,743 in 2000. Of the 181,743 residents in 2000, 9.2 percent were between the ages of 65 and 84 and 1.7 percent were 85 and older. This means that 10.9 percent of the population was 65 and older. This is higher than the state of Utah (8.5 percent) but slightly lower than the United States as a whole (12.4 percent), as shown in Table G-1 (Utah Travel Industry Website).

Figure G-1. Map of Salt Lake City, Utah.

Table G-1. Salt Lake City, Utah population distribution by age.

Age	Salt Lake City		Utah		United States	
	Population	Percent of total	Population	Percent of total	Population	Percent of total
Under 18	42,970	23.6	718,698	32.2	72,293,812	25.7
18–34	63,404	34.9	644,495	28.9	67,035,178	23.8
35–54	44,651	24.6	537,246	24.1	82,826,479	29.4
55–64	10,797	5.9	142,508	6.4	24,274,684	8.6
65–84	*16,766*	*9.2*	*168,471*	*7.5*	*30,752,166*	*10.9*
85 and older	*3,155*	*1.7*	*21,751*	*1.0*	*4,239,587*	*1.5*
Total	181,743	100	2,233,169	100	281,421,906	100

SITE SELECTION

Pedestrian countdown (PCD) signals are used almost exclusively at signalized intersections maintained by Salt Lake City. Some city-maintained signal intersections have traditional pedestrian signals (TPS), but these intersections generally are characterized by low pedestrian volumes. In the city limits, a number of signalized intersections are maintained by the state of Utah. At the time the data were collected for this study, some state-maintained signalized intersections with moderate pedestrian volumes were equipped with TPS.

Therefore, for the study intersections, the PCD intersections were selected from city-maintained signalized intersections, and the TPS intersections were selected from state-maintained signalized intersections. The state-maintained intersections were those on state-maintained roadways. As such, these were likely to be higher-volume, higher-speed roadways and may have differed slightly in character from the city-maintained signals.

A traffic engineer from Salt Lake City provided a list of approximately 20 city- and state-maintained intersections that had significant pedestrian activity. The project engineer reviewed these 20 intersections for the following aspects:

- pedestrian volumes, particularly older pedestrian volumes;
- lack of any construction or other temporary impediments (such as street closures) that may affect pedestrian behavior;
- ability to sufficiently collect data;
- conventional intersection design;
- surrounding land use; and
- comparability in walking environment at intersections.

Based on these field observations, discussions with the engineering staff, and the recommendations of the AAA representatives in the area, three intersections were selected for the study:

- State Street and 2100 South (traditional);
- State Street and 200 South (countdown); and
- 1300 East and 500 South (countdown).

Initially, data were collected only at these three intersections. The data collection team returned to Salt Lake City in early May 2005. The engineering staff in Salt Lake City assisted the project team in the selection of a fourth study intersection. A list of five intersections equipped with TPS was provided to the research team. These intersections were located in the Salt Lake City metropolitan area, but not necessarily in the city limits. Based on the criteria specified for study intersections, a fourth intersection was selected:

- State Street and 3300 South (traditional).

Figure G-2 displays the type of pedestrian signal at each of the four intersections. As shown, three of the four intersections were located along a 4.5-mile stretch of the State Street corridor. The land use around these intersections varied by intersection. The 2100 South and 3300 South intersections were bordered by mostly commercial land use. The vehicle speed on these roadways was approximately 45 miles per hour. The State Street and 200 South intersection, the northernmost of the intersections, was located in the central business district. The land use was dense commercial and retail and the vehicle speeds were lower. The fourth intersection was located approximately 2 miles to the east of the northernmost intersection, near the University of Utah's campus. Although not located on the same corridor as the other intersections, the intersection of 1300 East and 500 South was recommended by the AAA representatives because of its proximity to senior housing. This intersection was surrounded by dense residential land use. Notably, there were high-rise senior complexes on two corners at the intersection. Additionally, a light-rail system operated through this intersection.

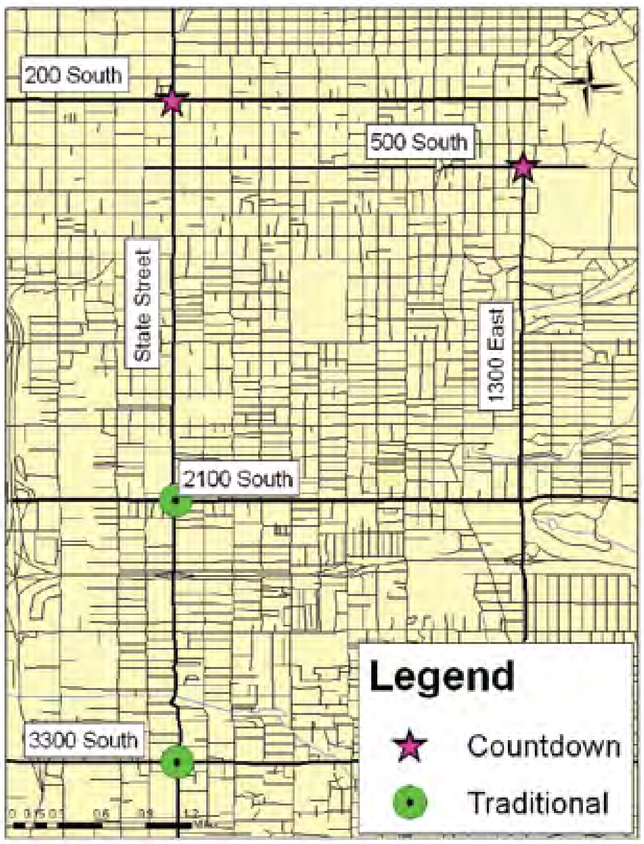

Figure G-2. Study intersections in Salt Lake City, Utah.

The authors acknowledge that the land use and trip purposes may have differed at the two traditional intersections and the two PCD intersections. This may lead to different pedestrian characteristics, such as walking speeds. Although identifying intersections with comparable walking environments was one of the goals in the site selection, this goal had to be balanced with the other intersection aspects of interest, particularly sufficient pedestrian volumes to collect a suitable sample size.

DATA COLLECTION METHODOLOGY

Pedestrian Behavior Data

Data were collected at three of the four intersections during the week of October 18, 2004. Salt Lake City experienced a record amount of rainfall during that week. This severely limited data collection and reduced pedestrian activity. Data were collected using a Portable Archival Traffic History (PATH) system that recorded pedestrian behavior at the intersections. PATH systems record pedestrian activity at an intersection without interfering with pedestrians.

Upon review of the collected data, the research team decided to return to Salt Lake City and collect additional data. The data collection team returned in early May 2005 and collected data manually using field observers at the fourth intersection. Additional data also were collected at the three other study intersections.

Surveys

The project team did not survey pedestrians in Salt Lake City. The survey instrument was intended for use in an area where PCD signals were fairly novel and differed from pedestrian signals at surrounding intersections. In Salt Lake City, PCD signals were ubiquitous and had been in place for a number of years.

RESULTS

Walking Speeds

The walking speeds of 795 pedestrians were observed at the four intersections. This included 241 pedestrians estimated to be 65 or older based on visual observations. Pedestrian walking speeds were measured from when they left the curb to when they returned to the curb on the other side of the street. Pedestrians who left the influence area of the crosswalk (within 2 to 3 feet of the edge of the crosswalk) during their crossing were not included in the analysis. The mean (average), 50th-percentile (median), and 15th-percentile walking speeds were calculated for both groups of pedestrians. These values are presented in Table G-2 individually for each intersection's minor and major approach. The mean, median, and 15th percentile also are represented collectively for all four traditional crossings and all four countdown crossings.

Table G-2. Walking speeds for pedestrians at intersections in Salt Lake City, Utah.

Intersection	Crossing	Observed walking speeds (ft./sec.)							
		Younger pedestrians				Older pedestrians			
		Sample	Mean	Median (50th percentile)	15th percentile	Sample	Mean	Median (50th percentile)	15th percentile
State/ 3300 South (traditional)	Major	48	4.9	5.0	4.3	33	4.3	4.3	3.8
	Minor	69	4.9	4.7	4.2	31	4.7	4.6	4.2
State/ 2100 South (traditional)	Major	34	4.9	5.0	4.5	35	4.3	4.4	3.4
	Minor	32	5.1	5.2	4.7	34	3.7	3.7	3.0
Traditional approaches combined		**183**	**4.9**	**4.9**	**4.3**	**133**	**4.2**	**4.3**	**3.4**
State/ 200 South (countdown)	Major	71	5.2	5.1	4.6	30	3.8	3.8	3.4
	Minor	107	5.3	5.3	4.5	32	4.5	4.4	3.7
1300 East/ 500 South (countdown)	Major	89	5.3	5.3	4.7	28	4.5	4.6	3.7
	Minor	104	5.5	5.4	4.9	18	4.2	4.3	3.6
Countdown approaches combined		**371**	**5.3**	**5.3**	**4.7**	**108**	**4.3**	**4.3**	**3.5**

For younger pedestrians, the mean walking speed (MWS) was 4.90 feet/second (ft./sec.) at traditional intersections and 5.30 ft./sec. at intersections equipped with countdown signals. The 15th-percentile walking speed represents the slower pedestrians at the intersection. The 15th-percentile speed was 4.30 ft./sec. at traditional signals and 4.70 ft./sec. at countdown signals. A walking speed of 4.00 ft./sec. would accommodate the 15th-percentile pedestrian under 65 at any of these four intersections.

For older pedestrians, MWS was 4.20 ft./sec. at traditional intersections and 4.30 ft./sec. at intersections equipped with countdown signals. The 15th-percentile walking speed represents the slower pedestrians at the intersection. The 15th-percentile speed was 3.40 ft./sec. at traditional signals and 3.50 ft./sec. at countdown signals. A walking speed of 4.00 ft./sec. would not accommodate the 15th-percentile pedestrian 65 and older at any these intersections.

The significance testing for MWS is presented in Table G-3. There was a significant difference in MWS at the traditional and countdown intersections for younger pedestrians, but not for older pedestrians. For younger pedestrians, MWS was faster at countdown signals.

Table G-3. Significance testing of difference in mean walking speed at traditional and pedestrian countdown signals for two age groups.

Subjects	Intersection type	Mean	Standard deviation	T_{calc}	Outcome
Pedestrians under 65	Traditional	4.9	0.69	6.61	The difference between means **is** significant at 95 percent.
	Countdown	5.3	0.66		
Pedestrians 65 and older	Traditional	4.2	0.72	0.26	The difference between means **is** **not** significant at 95 percent.
	Countdown	4.3	0.77		

Table G-4 presents the results of significance testing of the difference in MWS for younger pedestrians and older pedestrians. As would be expected, the walking speed for older pedestrians was significantly slower than the walking speed for younger pedestrians, regardless of the type of pedestrian signal.

Table G-4. Significance testing of difference in mean walking speed for younger pedestrians and older pedestrians for two types of pedestrian signal.

Subjects	Intersection type	Mean	Standard deviation	T_{calc}	Outcome
Traditional	Younger pedestrians	4.9	0.69	10.02	The difference between means **is** significant at 95 percent.
	Older pedestrians	4.2	0.72		
Countdown	Younger pedestrians	5.3	0.66	14.66	The difference between means **is** significant at 95 percent.
	Older pedestrians	4.3	0.77		

Pedestrians with Impairments

Pedestrians with discernable mobility or visual impairments were recorded separately, regardless of their age. At the Salt Lake City intersections, 36 pedestrians with impairments were observed for walking speeds during the study periods. The walking speeds categorized by impairments are listed in Table G-5. These data are not stratified by age, location, or type of pedestrian signal because of the small sample size.

Table G-5. Walking speeds of pedestrians with impairments, regardless of age, in Salt Lake City, Utah.

Observed impairment	Pedestrians	MWS
Visually impaired	0	N/A
Mobility impaired (walked with a cane, crutch, or push cart)	24	3.6
Motorized wheelchair assisted	6	6.1
Standard wheelchair	6	5.0

No pedestrians with visual impairments were observed during the study periods. MWS for pedestrians with mobility impairments was only 3.60 ft./sec. This walking speed was similar to the 15th-percentile speed for older pedestrians at the intersections.

Start-Up Times

Pedestrians who approached the intersection during the steady DON’T WALK (DW) interval and waited for the WALK interval were observed to determine their start-up lost time. This is the time from when the WALK indication is displayed on the pedestrian signal until the pedestrian leaves the curb and starts his or her crossing. This start-up time is related to the pedestrian’s reaction to the signal timing. However, there could be other factors, such as turning vehicles still in the intersection, that may cause a pedestrian to delay their start across the intersection. No distinction was made between those who waited for turning vehicles and those who simply did not react to the signal as quickly. Only pedestrians who arrived prior to the onset of the WALK interval were included in this analysis.

Observations were recorded for pedestrians across the major leg of State Street and 200 South, which was equipped with a PCD signal. Based on a sample of 71 younger pedestrians, younger pedestrians had a start-up time of 1.70 sec. at this crossing. Based on a sample of 30 older pedestrians, older pedestrians had a start-up time of 2.30 sec. This is a difference of .50 sec.

Compliance

Pedestrians at each intersection were observed during two to three hours of peak vehicle and pedestrian activity by field observers. For each pedestrian, observers recorded the pedestrian signal indication (WALK, FDW, or DW) that was displayed when the pedestrian entered the intersection. Observations were recorded separately for younger pedestrians and those 65 and older. Observations were recorded during the hours of peak vehicle activity because vehicle volumes at intersections likely affect pedestrian compliance to the signal. This is related to the opportunity to cross. That is, at an intersection with low vehicle volume, pedestrians are more likely to violate the pedestrian signal because there are more available crossing gaps.

Younger Pedestrians

Table G-6 shows the frequency and percentage of younger pedestrians entering during each signal indication for the two intersections equipped with TPS.

Table G-6. Frequency and percentage of younger pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at traditional signals in Salt Lake City, Utah.

Intersection	Crossing	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
State/3300 South (traditional)	Major	24	71	7	21	3	9
	Minor	24	75	6	19	2	6
State/2100 South (traditional)	Major	46	94	2	4	1	2
	Minor	33	85	5	13	1	3
Total at traditional signals		**127**	**82**	**20**	**13**	**7**	**5**

The compliance for pedestrians under 65 at traditional signals was fairly consistent by site and approach, with 71 percent to 94 percent entering during the WALK indication. When the four intersection legs were considered together, 82 percent entered during the WALK interval.

Table G-7 shows the frequency and percentage of younger pedestrians entering during each signal indication for the two intersections equipped with PCD signals. As with the traditional intersections, the compliance varied by intersection and leg. The legs varied from 54 percent to 86 percent entering on WALK. When the four intersection legs were considered together, 73 percent entered during the WALK interval. This was lower compliance than at the traditional signals but is comparable.

Table G-7. Frequency and percentage of younger pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at pedestrian countdown signals in Salt Lake City, Utah.

Intersection	Crossing	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
State/200 South (countdown)	Major	155	63	53	22	37	15
	Minor	198	86	30	13	3	1
1300 East/500 South (countdown)	Major	22	73	4	13	4	13
	Minor	19	54	10	29	6	17
Total at countdown signals		**394**	**73**	**97**	**18**	**50**	**9**

Older Pedestrians

Table G-8 shows the frequency and percentage of older pedestrians entering during each signal indication for the two intersections equipped with TPS. The compliance for older pedestrians at traditional signals was fairly consistent by site and approach, with 67 percent to 89 percent of the pedestrians entering during the WALK indication. When the four intersection legs were considered together, 81 percent entered during the WALK. This was very close to the 82-percent compliance observed in the younger age group at traditional signals.

Table G-8. Frequency and percentage of older pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at traditional signals in Salt Lake City, Utah.

Intersection	Crossing	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
State/3300 South (traditional)	Major	22	67	4	12	7	21
	Minor	25	81	5	16	1	3
State/2100 South (traditional)	Major	31	89	1	3	3	9
	Minor	22	88	1	4	2	8
Total at traditional signals		**100**	**81**	**11**	**9**	**13**	**10**

Table G-9 shows the frequency and percentage of older pedestrians entering during each signal indication for the two intersections equipped with PCD signals. As with the traditional intersections, the compliance varied by intersection and leg. The legs varied from 79 percent to 96 percent entering on WALK. When the four intersection legs were considered together, 86 percent entered during the WALK interval. This was higher compliance than at TPS but is comparable. This also was a higher compliance than younger pedestrians at countdown signals.

Table G-9. Frequency and percentage of older pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at pedestrian countdown signals in Salt Lake City, Utah.

Intersection	Crossing	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
State/200 South (countdown)	Major	27	79	4	12	3	9
	Minor	22	96	1	4	0	0
1300 East/500 South (countdown)	Major	20	91	0	0	2	9
	Minor	12	80	2	13	1	7
Total at countdown signals		**81**	**86**	**7**	**7**	**6**	**6**

Pedestrians Left in Intersection

At the end of each FDW interval, the number of pedestrians remaining in the intersection was noted. Only pedestrians who entered during the WALK or FDW interval were included. Table G-10 displays the results of this data collection. The total number of pedestrians left in the intersection during the observation period is noted as a percentage of the number of pedestrians crossing at the intersection during the same period. The results are combined for traditional signals and for PCD signals. For younger pedestrians, 2 percent of the pedestrians crossing at the intersection were left in the intersection at TPS, compared to 5 percent at countdown signals. For older pedestrians, 2 percent of the pedestrians crossing at the intersection were left in the intersection at both TPS and PCD signals.

Table G-10. Pedestrians remaining in the intersection at the start of the DON'T WALK interval in Salt Lake City, Utah.

Intersection	Leg	Pedestrians under 65		Pedestrians 65 and older	
		Total pedestrians	Pedestrians left in intersection	Total pedestrians	Pedestrians left in intersection
State/3300 South (traditional)	Major	34	0 (0 percent)	33	2 (6 percent)
	Minor	32	1 (3 percent)	31	0 (0 percent)
State/2100 South (traditional)	Major	49	0 (0 percent)	35	0 (0 percent)
	Minor	39	2 (5 percent)	25	0 (0 percent)
Total at traditional signals		**154**	**3 (2 percent)**	**124**	**2 (2 percent)**
State/200 South (countdown)	Major	245	10 (4 percent)	34	0 (0 percent)
	Minor	231	8 (5 percent)	23	2 (9 percent)
1300 East/500 South (countdown)	Major	30	1 (3 percent)	22	0 (0 percent)
	Minor	35	2 (6 percent)	15	0 (0 percent)
Total at countdown signals		**541**	**21 (5 percent)**	**94**	**2 (2 percent)**

EFFECT OF CHANGING WALKING SPEEDS ON PEDESTRIAN CLEARANCE TIMES

Table G-11 displays the required pedestrian signal times for different walking speeds and the time available for that movement at each of the intersections studied. Table G-11 presents the ☒ symbol where the total pedestrian signal time exceeded the available minimum green time. Key findings related to pedestrian WALK clearance time durations for this case study intersections included:

- The pedestrian intervals exceeded the available green times for the 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec. scenarios in four of four crosswalks at the case study intersection.

Table G-11. Pedestrian WALK and clearance time durations for case study intersection in Salt Lake City, Utah.

Approach/ crosswalk	Length (ft.)	Clearance time (sec.)			Clearance time with 7-sec. WALK (sec.) [total WALK time]			Available green (sec.)
		3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	
Northbound/ south	103	34	29	26	41☒	36☒	33☒	31
Southbound/ north	112	37	32	28	44☒	39☒	35☒	31
Eastbound/ west	66	22	19	17	29☒	26☒	24☒	23
Westbound/ east	78	26	22	20	33☒	29☒	27☒	23

TRAFFIC OPERATIONS ANALYSIS

Table G-12 shows the intersection operational and geometric characteristics for the Salt Lake City case study intersection. Figure G-3 shows the overall average vehicle delay (AVD) and intersection level of service (LOS) under various peak-hour traffic volume and pedestrian walking speed scenarios (3.00, 3.50, 4.00 ft./sec. and base conditions).

Figures G-4, G-5, and G-6 show the major street and minor street approach AVD (in sec.) under walking speeds of 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec., respectively. Table G-13 shows the overall, major street approach, and minor street approach intersection LOS and AVD (in sec.) under various peak-hour traffic volume scenarios and under pedestrian walking speeds of 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec.

There was no change in the overall LOS (LOS C remained the same) when comparing the modeled decrease in volumes of -10 percent of existing volumes to a modeled increase of 15 percent above existing volumes. There was a maximum increase of 4 sec. in terms of average delay per vehicle (ADPV) under any of the volume or walking speed scenarios when comparing existing volume conditions to a modeled increase of 15 percent above existing volumes. The graph included in Figure G-3 shows there was a uniform increase in ADPV as peak-hour volumes increased.

For the major street approaches, there was no change in LOS (LOS C remained the same) for all volume groups and pedestrian walking speed scenarios analyzed. The increase in ADPV under existing volume conditions as compared to a modeled increase of 15 percent above existing volumes for the 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec. pedestrian walking speeds was 4, 3, and 2 sec., respectively. The lowest delay value modeled was 23 sec. and the highest delay value modeled was 29 sec.

For the minor street approaches, delays decreased as walking speeds decreased because the traffic along the minor street approaches required less green time than the pedestrian clearance time. LOS ranged from LOS B to LOS C for each of the volume and pedestrian walking speed scenarios analyzed. The range in ADPV under existing volume conditions as compared to a modeled increase of 15 percent above existing volumes irrespective of the walking speed assumption was 20 sec. to 24 sec.

Table G-12. Salt Lake City, Utah intersection characteristics: approach lane usage, peak-hour traffic volumes, and cycle length.

Approach	Number of approach lanes						Peak-hour traffic volumes (existing and modeled)					
	L	LT	T	TR	R	Total	-10 percent	Existing	+5 percent	+10 percent	+15 percent	Volume range
Northbound (MJ)	1	0	3	0	1	**5**	964	1,071	1,125	1,178	1,232	
Southbound (MJ)	1	0	3	0	1	**5**	428	476	500	524	547	
Eastbound (MN)	1	0	1	1	0	3	362	402	422	442	462	
Westbound (MN)	1	0	2	1	0	**4**	497	552	580	607	635	
MJ approach	2	0	6	0	2	**10**	1,392	1,547	1,624	1,702	1,779	1,392 – 1,779
MN approach	2	0	3	2	0	**7**	859	954	1,002	1,049	1,097	859 – 1,097
Total	4	0	9	2	2	**17**	2,251	2,501	2,626	2,751	2,876	2,251 – 2,876
Cycle length: 120 sec.												

* Note: L = left; LT = left-through; T = through; TR = through-right; R = right.

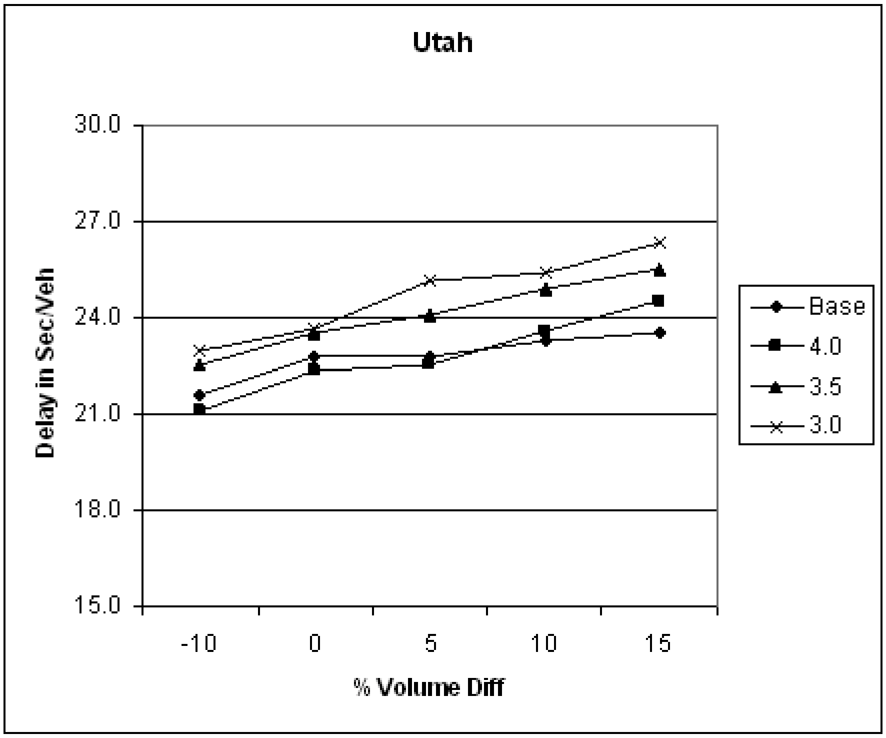

Figure G-3. Delay vs. volumes at case study intersections for walking speeds of 3.00, 3.50, 4.00 ft./sec. and base conditions.

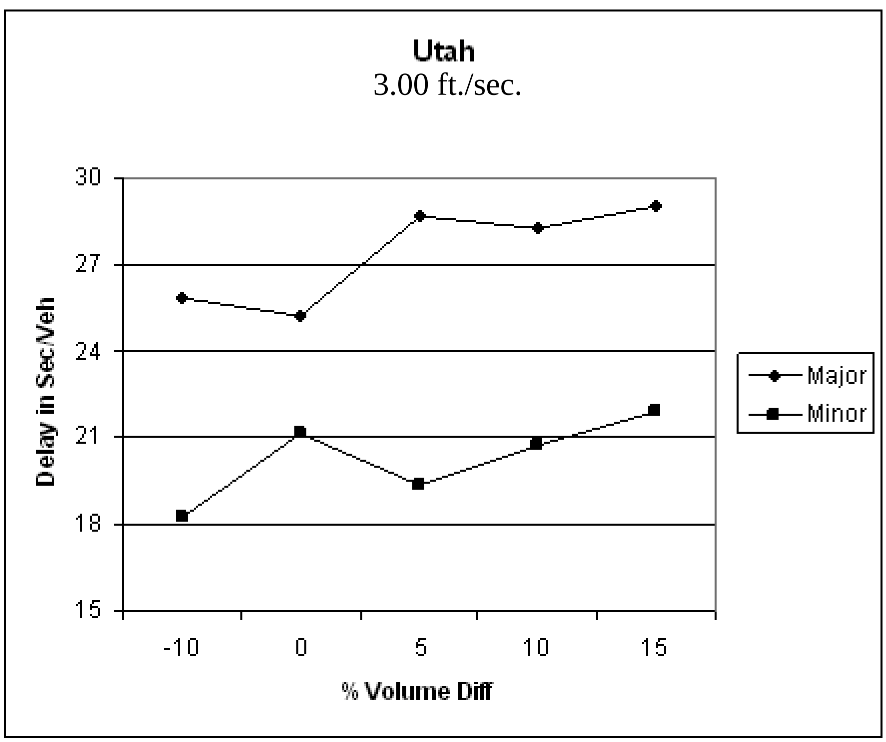

Figure G-4. Intersection delay for major and minor street approaches, 3.00 ft./sec. walking speed, Salt Lake City, Utah.

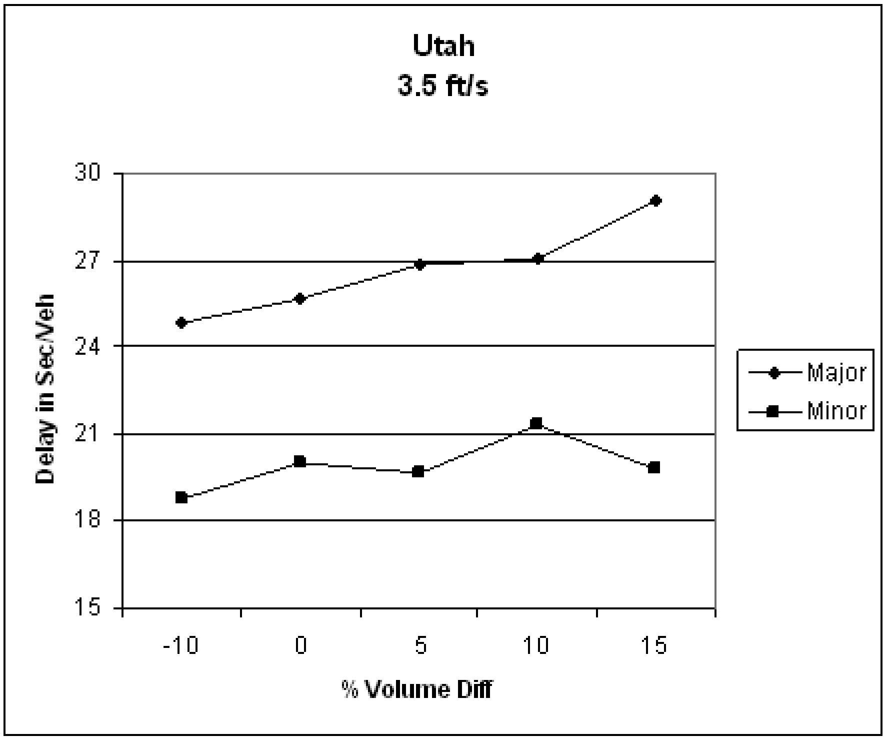

Figure G-5. Intersection delay for major and minor street approaches, 3.50 ft./sec. walking speed, Salt Lake City, Utah.

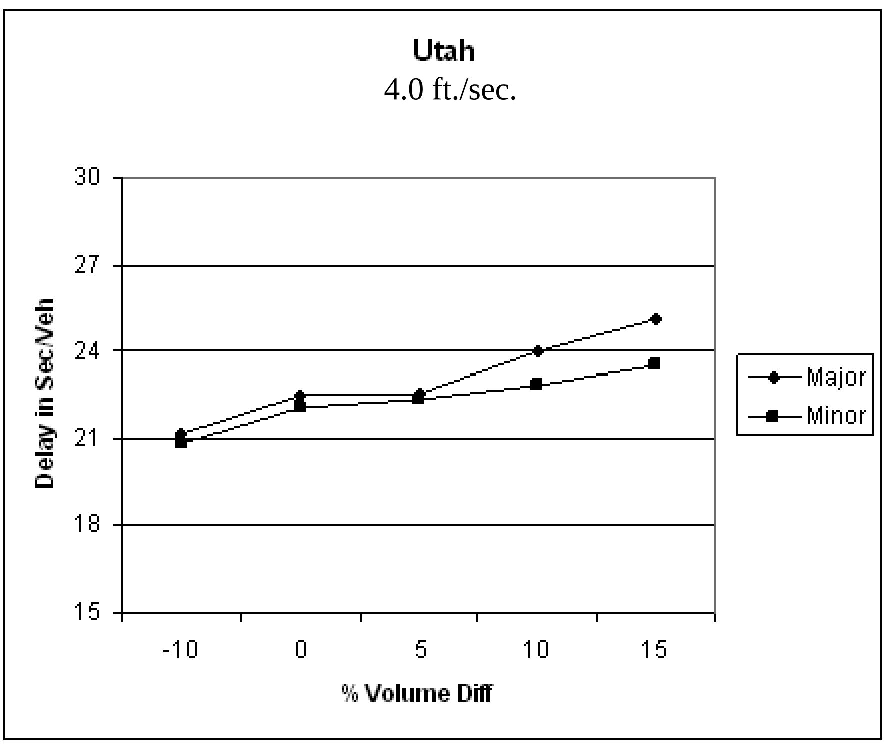

Figure G-6. Intersection delay for major and minor street approaches, 4.00 ft./sec. walking speed, Salt Lake City, Utah.

Table G-13. Salt Lake City, Utah intersection level of service under various peak-hour traffic volume and pedestrian walking speed scenarios.

Walking speed scenario	LOS (and average delay, in sec.)				
	-10 percent volume	Existing volume	+5 percent volume	+10 percent volume	+15 percent volume
3.00 ft./sec.	C (23)	C (24)	C (25)	C (22)	C (26)
3.50 ft./sec.	C (26)	C (24)	C (24)	C (25)	C (26)
4.00 ft./sec.	C (21)	C (22)	C (23)	C (24)	C (25)
Major street LOS (and average delay, in sec.)					
3.00 ft./sec.	C (26)	C (25)	C (29)	C (28)	C (29)
3.50 ft./sec.	C (25)	C (26)	C (27)	C (27)	C (29)
4.00 ft./sec.	C (21)	C (23)	C (23)	C (24)	C (25)
Minor street LOS (and average delay, in sec.)					
3.00 ft./sec.	B (18)	C (21)	B (19)	C (21)	C (22)
3.50 ft./sec.	B (19)	B (20)*	B (20)*	C (21)	B (20)*
4.00 ft./sec.	C (21)	C (22)	C (22)	C (23)	C (24)

SUMMARY

There were different environments between the two intersections with traditional signals and the two intersections with countdown signals, which may account for differences in observed pedestrian activity. With this caveat, the key results are as follows for Salt Lake City:

- MWS for younger pedestrians was 4.90 ft./sec. at the two TPS and 5.30 ft./sec. at the two PCD signals. This difference was statistically significant.
- MWS for older pedestrians was 4.20 ft./sec. at the two TPS and 4.30 ft./sec. at the two PCD signals. This difference was not statistically significant.
- MWS for older pedestrians was generally slower than for younger pedestrians by about 0.70 ft./sec. at traditional intersections and 1.00 ft./sec. at PCD intersections. The difference in walking speeds between the two age groups was significant at both PCD signals and traditional signals.
- Pedestrians with mobility impairments and without motorized or standard wheelchairs had appreciably slower walking speeds—their mean was 3.60 ft./sec. compared to about 4.20 ft./sec. for older pedestrians. A small sample size is recognized.
- Older pedestrians had a slower start-up time, but this will vary by intersection and leg of intersection.
- A higher level of compliance (entering crosswalk on WALK display) was found with TPS with younger pedestrians than with PCD signals. The reverse was true for older pedestrians.

- A slightly larger percentage of pedestrians were left in the intersection at PCD signals (5 percent versus 2 percent) for younger pedestrians. However, this was based on a very small sample size. There was no difference for older pedestrians.

- Operational analysis:

    - There was a relatively small, uniform increase in ADPV as peak-hour volumes increased.

    - There was no change in the overall LOS (LOS C remained the same) when comparing the modeled decrease in volumes of -10 percent of existing volumes to a modeled increase of 15 percent above existing volumes. There was a maximum increase of 4 sec. in terms of ADPV under any of the volume or walking speed scenarios when comparing existing volume conditions to a modeled increase of 15 percent above existing volumes.

APPENDIX H:

ORANGE COUNTY, CALIFORNIA CASE STUDY

LIST OF TABLES

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BACKGROUND

Orange County, California is located south of Los Angeles along the Pacific Coast, as shown in Figure H-1. The county grew from 2.4 million in 1990 to 2.8 million in 2000, an increase of 18 percent (California State University, Fullerton, Center for Demographic Research). This was 5 percent higher than the growth rate of the United States (13 percent) during the same time period. Of the 2.8 million residents in 2000, 8.7 percent were between the ages of 65 and 84 and 1.2 percent were 85 and older. This means that 9.9 percent of the population was 65 and older. This is slightly lower than both the state of California (10.4 percent) and the United States as a whole (12.4 percent), as shown in Table H-1.

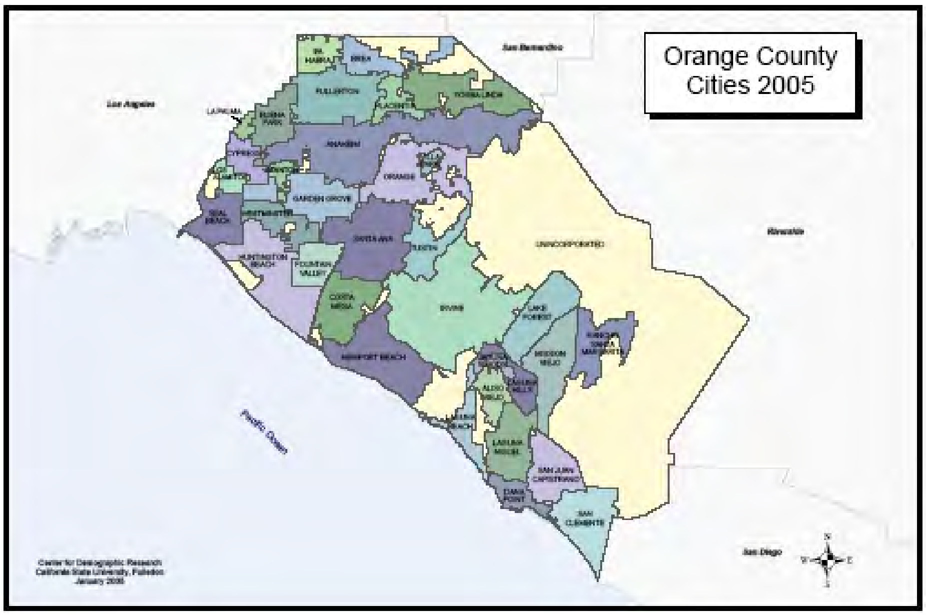

Figure H-1. Map of Orange County, California (California State University, Fullerton, Center for Demographic Research).

Table H-1. Orange County, California population distribution by age.

Age	Orange County		California		United States	
	Population	**Percent of total**	**Population**	**Percent of total**	**Population**	**Percent of total**
Under 18	768,419	27.0	9,249,829	27.3	72,293,812	25.7
18–34	734,505	25.8	8,595,092	25.4	67,035,178	23.8
35–54	838,028	29.4	9,816,976	29.0	82,826,479	29.4
55–64	224,574	7.9	2,614,093	7.7	24,274,684	8.6
65–84	*246,669*	*8.7*	*3,170,001*	*9.4*	*30,752,166*	*10.9*
85 and older	*34,094*	*1.2*	*425,657*	*1.3*	*4,239,587*	*1.5*
Total	**2,846,289**	**100**	**33,871,648**	**100**	**281,421,906**	**100**

SITE SELECTION

Pedestrian countdown (PCD) signals were used by various agencies in Orange County. However, the agencies that employed PCD signals used them almost exclusively at any intersection that had notable pedestrian volumes. Therefore, the project team worked with two municipalities in close proximity: one with PCD signals and one without.

A list of 10 intersections was provided for both jurisdictions. The traffic engineer in each jurisdiction selected the intersections for potential inclusion based on the pedestrian volume at the intersection and the likelihood of older pedestrians crossing at the intersection. The project engineer reviewed these 20 intersections for the following aspects:

- pedestrian volumes, particularly older pedestrian volumes;
- lack of any construction or other temporary impediments (such as street closures) that may affect pedestrian behavior;
- ability to sufficiently collect data;
- conventional intersection design;
- surrounding land use; and
- comparability in walking environment at intersections.

Based on field observations, discussions with the engineering staff at both jurisdictions, and the recommendations of the AAA representative, four intersections were selected for the study—referred to as intersections A, B, C, and D.

Intersections A and B were equipped with conventional pedestrian signals. Intersection A was located a few blocks from the beach. The area surrounding this intersection was predominantly commercial land use. Much of the pedestrian traffic was related to the beach or shopping near the beach. Intersection B was just more than 2 miles from intersection A. It was adjacent to a shopping plaza, a residential neighborhood, and a senior housing complex.

Intersections C and D were equipped with PCD signals and were approximately 5 miles from intersections A and B and 1 mile from each other. Both intersections were located adjacent to a park and residential neighborhoods. Most of the trips at these intersections were recreational trips surrounding the park.

The authors acknowledge that the land use and trip purposes were different at the two traditional intersections and the two PCD intersections. This may lead to different pedestrian characteristics, such as walking speed, at the two intersections. Although identifying intersections with comparable walking environments was one of the goals in the site selection, this goal had to be balanced with the other intersection aspects of interest, particularly, sufficient pedestrian volumes to collect a suitable sample size.

DATA COLLECTION METHODOLOGY

Pedestrian Behavior Data

Pedestrian behavior data were collected during the week of March 28, 2005. Due to concerns for liability, the data were not collected with Portable Archival Traffic History (PATH) systems. Instead, the data were collected manually in the field. Trained observers were stationed at each intersection, where they observed pedestrians crossing at the intersection and tallied information about each pedestrian on a data sheet. This reduced the amount of pedestrians that could be observed at each intersection because human data collectors were limited in the number of hours a day that they could observe pedestrian behavior.

Surveys

The project team developed a brief survey to be administered to pedestrians at the study intersections. The purpose of the survey was to gauge pedestrian understanding and preference for PCD signals and traditional pedestrian signals (TPS).

Survey administration took approximately 1 minute. Surveys were administered at two PCD intersections to pedestrians who had completed their crossing at the intersections. The targets of the survey were pedestrians over 18 years of age. The survey distribution was limited to two hours. Approximately 50 percent of the people who were approached regarding the survey declined to participate.

RESULTS

Walking Speeds

The walking speeds of 902 pedestrians were observed at the four intersections. This included 200 pedestrians estimated to be 65 or older based on visual observations. Pedestrian walking speeds were measured from when they left the curb to when they returned to the curb on the other side of the street. Pedestrians who left the influence area of the crosswalk (within 2 to 3 feet of the edge of the crosswalk) during their crossing were not included in the analysis. The mean (average), 50th-percentile (median), and 15th-percentile walking speeds were calculated for both groups of pedestrians. These values are presented in Table H-2 individually for each intersection's minor and major approach. The mean, median, and 15th percentile also are represented collectively for all four traditional crossings and all four countdown crossings.

Table H-2. Walking speeds for pedestrians at intersections in Orange County, California.

Intersection	Crossing	Observed walking speeds (ft./sec.)							
		Younger pedestrians				Older pedestrians			
		Sample	**Mean**	**Median (50th percentile)**	**15th percentile**	**Sample**	**Mean**	**Median (50th percentile)**	**15th percentile**
A	Major	55	4.7	4.6	4.1	25	4.2	4.1	3.7
	Minor	90	4.9	4.8	4.2	45	4.4	4.3	3.8
B	Major	43	4.7	4.7	4.2	34	4.2	4.3	3.6
	Minor	40	4.8	4.6	4.0	32	4.1	4.1	3.3
Traditional approaches combined		**454**	**4.8**	**4.7**	**4.1**	**136**	**4.2**	**4.2**	**3.6**
C	Major	30	5.5	5.5	4.9	31	5.3	5.4	4.7
	Minor	89	5.0	5.0	4.4	53	4.3	4.4	3.8
D	Major	31	5.6	5.7	4.9	32	5.1	5.1	4.4
	Minor	98	5.5	5.6	4.8	48	5.0	5.1	3.9
Countdown approaches combined		**248**	**5.3**	**5.4**	**4.7**	**164**	**4.8**	**4.9**	**4.0**

For younger pedestrians, the mean walking speed (MWS) was 4.80 feet/second (ft./sec.) at traditional intersections and 5.30 ft./sec. at intersections equipped with countdown signals. The 15th-percentile walking speed represents the slower pedestrians at the intersection. The 15th-percentile speed was 4.10 ft./sec. at traditional signals and 4.70 ft./sec. at PCD signals. A walking speed of 4.00 ft./sec. would accommodate the 15th-percentile younger pedestrian at any of these four intersections.

For older pedestrians, MWS was 4.20 ft./sec. at traditional intersections and 4.80 ft./sec. at intersections equipped with countdown signals. The 15th-percentile speed was 3.60 ft./sec. at traditional signals and 4.00 ft./sec. at PCD signals. A walking speed of 4.00 ft./sec. would accommodate the 15th-percentile older pedestrian at the PCD intersection but not at the traditional intersection.

The significance testing for MWS is presented in Table H-3. There was a significant difference in MWS at traditional and PCD intersections for both younger and older pedestrians.

Table H-3. Significance testing of difference in mean walking speed at traditional and pedestrian countdown signals for two age groups.

Subjects	Intersection type	Mean	Standard deviation	T_{calc}	Outcome
Pedestrians under 65	Traditional	4.8	0.73	9.66	The difference between means **is** significant at 95 percent.
	Countdown	5.3	0.73		
Pedestrians 65 and older	Traditional	4.2	0.71	6.84	The difference between means **is** significant at 95 percent.

Table H-4 presents the results of significance testing of the difference in MWS for younger pedestrians and older pedestrians. As would be expected, the walking speed for older pedestrians was significantly slower than the walking speed for younger pedestrians, regardless of the type of pedestrian signal.

Table H-4. Significance testing of difference in mean walking speed for younger pedestrians and older pedestrians for two types of pedestrian signal.

Intersection type	Subjects	Mean	Standard deviation	T_{calc}	Outcome
Traditional	Pedestrians under 65	4.8	0.73	7.83	The difference between means **is** significant at 95 percent.
	Pedestrians 65 and older	4.2	0.71		
Countdown	Pedestrians under 65	5.3	0.73	6.43	The difference between means **is** significant at 95 percent.
	Pedestrians 65 and older	4.8	0.81		

Pedestrians with Impairments

Pedestrians with discernable mobility or visual impairments were recorded separately, regardless of their age. At the Orange County intersections, 13 pedestrians with impairments were observed for walking speed during the study periods. The walking speeds categorized by impairments are listed in Table H-5. These data are not stratified by age, location, or by type of pedestrian signal because of the small sample size.

Table H-5. Walking speeds of pedestrians with impairments, regardless of age, in Orange County, California.

Observed impairment	Pedestrians	MWS
Cognitive impairment or other (including inebriation)	3	4.20
Mobility impaired (walked with a cane, crutch, limp, or push cart)	7	3.00
Motorized wheelchair assisted	3	6.70

MWS for pedestrians with mobility impairments was only 3.00 ft./sec. This walking speed was slower than the 15th-percentile speed for pedestrians 65 and older at any of the four intersections.

Start-Up Times

Pedestrians who approached the intersection during the steady DON'T WALK (DW) interval and waited for the WALK interval were observed to determine their start-up lost time. This is the time from when the WALK indication is displayed on the pedestrian signal until the pedestrian leaves the curb and starts his or her crossing. This start-up time is related to the pedestrian's reaction to the signal timing. However, there could be other factors, such as turning vehicles still in the intersection, that may cause a pedestrian to delay his or her start across the intersection. No distinction was made between those who waited for turning vehicles and those who simply did not react to the signal as quickly. Only pedestrians who arrived prior to the onset of the WALK interval were included in this analysis.

Observations were recorded for pedestrians across the major leg of intersection C (countdown). Based on a sample of 31 younger pedestrians, younger pedestrians had a start-up time of 1.20 sec. at this crossing. Based on a sample of 30 older pedestrians, older pedestrians had a start-up time of 1.60 sec. This is a difference of 0.40 sec., which is not statistically significant.

Compliance

Pedestrians at each intersection were observed during two to three hours of peak vehicle and pedestrian activity by field observers. For each pedestrian, observers recorded the pedestrian signal indication (WALK, FDW, or DW) that was displayed when the pedestrian entered the intersection. Observations were recorded separately for younger and older pedestrians. Observations were recorded during the hours of peak vehicle activity because vehicle volumes at intersections likely affect pedestrian compliance to the signal. This is related to the opportunity to cross. That is, at an intersection with low vehicle volume, pedestrians are more likely to violate the pedestrian signal because there are more available crossing gaps.

Younger Pedestrians

Table H-6 shows the frequency and percentage of younger pedestrians entering during each signal indication for the two intersections equipped with TPS.

Table H-6. Frequency and percentage of younger pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at traditional signals in Orange County, California.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Intersection A	Major	48	67	6	8	18	25
	Minor	57	76	7	9	11	15
Intersection B	Major	27	69	3	8	9	23
	Minor	35	71	4	8	10	20
Total at traditional signals		**167**	**71**	**20**	**9**	**48**	**20**

The compliance for younger pedestrians at traditional signals was fairly consistent by site and approach, with 67 percent to 76 percent of pedestrians entering during the WALK indication. When the four intersection legs were considered together, 71 percent entered during the WALK.

Table H-7 shows the frequency and percentage of younger pedestrians entering during each signal indication for the two intersections equipped with PCD signals. As with the traditional intersections, the compliance varied by intersection and leg. However, when the four approaches were considered together, only 46 percent of the pedestrians entered during the WALK indication and 41 percent entered during the DW indication. This was lower compliance than at the traditional signals. This may be due to a difference in the availability of gaps during the DW interval at the countdown intersection. Additionally, both intersections were pedestrian actuated. Pedestrian-actuated intersections generally have a lower compliance rate than intersections with dedicated pedestrian intervals. Intersection D had lower vehicle volumes than intersection C. Therefore, pedestrians may have found it easier to cross against the signal instead of activating the pedestrian pushbutton and waiting for the pedestrian interval. This finding will be compared to other cities.

Table H-7. Frequency and percentage of younger pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at pedestrian countdown signals in Orange County, California.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Intersection C	Major	16	84	0	0	3	16
	Minor	35	64	9	16	11	20
Intersection D	Major	21	37	9	16	27	47
	Minor	23	30	10	13	44	57
Total at countdown signals		**95**	**46**	**28**	**13**	**85**	**41**

Older Pedestrians

Table H-8 shows the frequency and percentage of older pedestrians entering during each signal indication for the two intersections equipped with TPS. During the peak hours of vehicle activity, 102 older pedestrians were observed crossing at these intersections. When all four traditional legs were considered together, 79 percent of the older pedestrians entered the intersection during the WALK indication.

Table H-8. Frequency and percentage of older pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at traditional signals in Orange County, California.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Intersection A	Major	23	72	4	13	5	16
	Minor	32	82	3	8	4	10
Intersection B	Major	22	81	0	0	5	19
	Minor	25	81	2	6	4	13
Total at traditional signals		**102**	**79**	**9**	**7**	**18**	**14**

Table H-9 shows the frequency and percentage of older pedestrians entering during each signal indication for the two intersections equipped with PCD signals. During the three hours of peak vehicle activity, 80 older pedestrians were observed crossing at these intersections. As with the traditional signals, the compliance varied by intersection leg. When all four pedestrian countdown legs were considered together, 73 percent of older pedestrians entered the intersection during the WALK indication. This was similar to, although lower than, the compliance at traditional signals. As with their younger counterparts, this difference in compliance may have been due to a difference in the availability of gaps during the DW interval at the countdown intersection. This finding will be compared to other cities.

Table H-9. Frequency and percentage of older pedestrians entering during the WALK, flashing DON'T WALK, or DON'T WALK indication at pedestrian countdown signals in Orange County, California.

Intersection	Leg	WALK		FDW		DW	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Intersection C	Major	26	100	0	0	0	0
	Minor	26	76	1	3	7	21
Intersection D	Major	14	74	1	5	4	21
	Minor	14	45	5	16	12	39
Total at countdown signals		**80**	**73**	**7**	**6**	**23**	**21**

Pedestrians Left in Intersection

At the end of each FDW interval, the number of pedestrians remaining in the intersection was noted. Only pedestrians who entered during the WALK or FDW interval were included. Table H-10 displays the results of this data collection. The total number of pedestrians left in the intersection during the observation period is noted as a percentage of the number of pedestrians crossing at the intersection during the same period. The results are combined for traditional signals and PCD signals. For younger pedestrians, 1 percent of the pedestrians crossing at the intersection were left in the intersection at traditional signals, compared to 6 percent at countdown signals. For older pedestrians, 1 percent of the pedestrians crossing at the intersection were left in the intersection at TPS, compared to 2 percent at PCD. However, these percentages are based on very small samples. Very few pedestrians entered the intersections during the FDW interval.

Table H-10. Pedestrians remaining in the intersection at the start of the DON'T WALK interval in Orange County, California.

Intersection	Leg	Younger pedestrians		Older pedestrians	
		Total Pedestrians	Pedestrians left in intersection	Total pedestrians	Pedestrians left in intersection
Intersection A	Major	72	1 (1 percent)	32	0 (0 percent)
	Minor	75	1 (1 percent)	39	1 (3 percent)
Intersection B	Major	39	1 (3 percent)	27	0 (0 percent)
	Minor	49	0 (0 percent)	31	0 (0 percent)
Total at traditional signals		**235**	**3 (1 percent)**	**129**	**1 (1 percent)**
Intersection C	Major	19	1 (5 percent)	26	0 (0 percent)
	Minor	55	0 (0 percent)	34	0 (0 percent)
Intersection D	Major	57	2 (4 percent)	19	0 (0 percent)
	Minor	77	3 (13 percent)	31	2 (7 percent)
Total at countdown signals		**208**	**13 (6 percent)**	**110**	**2 (2 percent)**

SURVEY RESULTS

A total of 30 pedestrians were surveyed in Orange County, including six older pedestrians. Approximately 50 percent of those approached declined to be surveyed. Pedestrians were intercepted after they completed their crossing at countdown-equipped intersections and asked if they would like to participate in a brief survey on pedestrian safety. Pedestrians were asked if they noticed anything different about crossing at this intersection than at similar intersections in Orange County. A follow-up question confirmed that the difference noted was the countdown signal. Twenty-three (approximately 80 percent) of the pedestrians noticed the PCD signals.

All surveyed pedestrians were asked to explain the meaning of the PCD indication. All of the pedestrians provided a satisfactory explanation of the countdown indication—either that the countdown was the time remaining to cross or the time until the light turns red. Twenty-three of the pedestrians had a preference regarding the use of TPS or PCD signals, all of whom preferred PCD signals. Similarly, all but one of the surveyed pedestrians indicated that the PCD signal was helpful in crossing the street safely.

EFFECT OF CHANGING WALKING SPEEDS ON PEDESTRIAN CLEARANCE TIMES

Table H-11 displays the required pedestrian clearance time and the pedestrian clearance time plus a 7-sec. WALK time. For the case study intersection in Orange County, the available green time was not provided by the agencies and, therefore, analysis of the adequacy of the pedestrian interval could not be undertaken.

Table H-11. Pedestrian WALK and clearance time durations for case study intersection in Orange County, California.

Approach/ crosswalk	Length (ft.)	Clearance time (sec.)			Clearance time with 7-sec. WALK (sec.) [total WALK time]			Available green (sec.)
		3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	3.00 ft./sec.	3.50 ft./sec.	4.00 ft./sec.	
Northbound/ south	115	38	33	29	45	40	36	N/A*
Southbound/ north	110	37	31	28	44	38	35	N/A*
Eastbound/ west	71	24	20	18	31	27	25	N/A*
Westbound/ east	58	19	17	15	26	24	22	N/A*

* Note: Available green time not provided.

TRAFFIC OPERATIONS ANALYSIS

Table H-12 shows the intersection operational and geometric characteristics for the Orange County case study intersection. Because volume data were not available from the jurisdiction, existing volumes were estimated based on the operational and geometric characteristics of the intersection. Total intersection volume was estimated at 6,500 peak-hour vehicles, with 2,000 vehicles and 1,250 vehicles on the major and minor street approaches, respectively. This approach produced more of a saturated/lower level of service (LOS) condition at a “base” level scenario similar to the base condition LOS at the Montgomery County, Maryland case study intersection.

The modeled peak-hour volumes at the Orange County case study intersection ranged from a decrease of 10 percent to an increase of 15 percent of existing (modeled) peak-hour volumes. Comparatively, as the White Plains, New York case study intersection had the lowest total intersection traffic volume range analyzed (1,611 to 2,059 peak-hour vehicles), the Orange County case study intersection had the greatest total intersection traffic volume range analyzed (5,850 to 7,475 peak-hour vehicles).

Figure H-2 shows the overall average vehicle delay (AVD) and intersection LOS under various peak-hour traffic volume and pedestrian walking speed scenarios (3.00, 3.50, 4.00 ft./sec. and base conditions).

Figures H-3, H-4, and H-5 show the major street and minor street approach AVD (in sec.) under walking speeds of 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec., respectively. Table H-13 shows the overall, major street approach, and minor street approach intersection LOS and AVD (in sec.) under various peak-hour traffic volume scenarios and under pedestrian walking speeds of 3.00 ft./sec., 3.50 ft./sec., and 4.00 ft./sec.

Table H-13 shows there was a uniform increase in average delay per vehicle (ADPV) for the volume scenario that was 5 percent above existing volumes. There was a greater vehicular delay at pedestrian walking speeds of 4.00 ft./sec., 3.50 ft./sec., and 3.00 ft./sec. (in that order). The ADPV was 72 sec., 68 sec., and 55 sec., respectively. This trend remained the same for volume scenarios to 10 percent and 15 percent above existing volumes.

The total intersection LOS decreased from LOS D to LOS F under the 3.00 ft./sec. walking speed scenario when existing volume conditions were compared to the modeled increase of 10 percent above existing volume conditions. Concomitantly, there was a corresponding increase in ADPV of 75 sec.

An incremental increase of another 5 percent of peak-hour volume (to 15 percent above existing volumes) at the 3.00 ft./sec. pedestrian walking speed added 47 sec. to the ADPV. Thus, from existing volume conditions to a modeled increase of 15 percent over existing volumes, there was a reduction of two LOS designations (from LOS D to LOS F) and a corresponding increase in 122 sec. for ADPV.

Under the 3.50 ft./sec. pedestrian walking speed scenario, the delay increased at a greater rate than at the 3.00 ft./sec. scenario until traffic volumes were increased between 5 and 10 percent. This occurred because the 3.00 ft./sec. scenario provided more green time for the minor street due to the increase in the pedestrian clearance interval for the parallel pedestrian movement. Under the 3.50 ft./sec. pedestrian walking speed scenario and under a scenario that increased existing volumes by 15 percent, the total intersection LOS decreased from LOS D to LOS F and there was a corresponding increase in 108 sec. for ADPV.

At the 4.00 ft./sec. pedestrian walking speed scenario, a large increase in ADPV occurred at the existing level to 5 percent above existing volume conditions (17 sec.), followed by smaller increases exhibited in the volume level modeled 5 to 10 percent above existing conditions (4 sec.) and in the volume level modeled 10 to 15 percent above existing conditions (6 sec.). The total increase in average intersection delay per vehicle from the existing volume condition level to 15 percent above the existing volume condition level was 28 sec. and there was a reduction of one LOS designation from LOS E to LOS F. Note that the difference in the ADPV between 15 percent above the existing volume and the existing volume condition at the 3.00 ft./sec. and 3.50 ft./sec. pedestrian walking speed scenarios was 94 sec. and 80 sec., respectively.

Major Street Approaches

The range in ADPV under existing volume conditions as compared to a modeled increase of 15 percent above existing volumes for the 3.00 ft./sec. walking speed assumption was 47 sec. to 219 sec. (this represented an increase in average delay of 172 sec.). LOS was reduced from LOS D under existing volume conditions to LOS F when the volumes were increased to 15 percent above existing volumes.

Very similar results and trends were evident at the 3.50 ft./sec. walking speed for the same volume range comparison. The range in ADPV was 40 sec. to 169 sec. (this represented an increase in average delay of 129.0 sec.). LOS also was reduced from LOS D to LOS F. There were only minor increases in AVD at the 4.00 ft./sec. walking speed under existing volume conditions as compared to a modeled increase of 15 percent above existing volumes. The range in ADPV was 33 sec. to 43 sec. (this represented an increase in average delay of 10 sec.). LOS was reduced from LOS C to LOS D.

Minor Street Approaches

Delays were shown to be higher with a 4.00 ft./sec. walking speed than with 3.50 ft./sec. and 3.00 ft./sec. walking speeds. This is because the minor street traffic was getting lesser green time based on 4.00 ft./sec. walking speed as compared to 3.50 ft./sec. and 3.00 ft./sec. walking speeds. The additional green time needed for the minor street traffic movement was acquired from the major street green time and thereby increased the delays on the major street approaches.

The range in ADPV under existing volume conditions as compared to a modeled increase of 15 percent above existing volumes for the 3.00 ft./sec. walking speed assumption was 25 sec. to 68 sec. (this represented an increase in average delay of 43 sec.). LOS was reduced from LOS C under existing volume conditions to LOS E. Similar trends (but more extensive differences) were evident at the 3.50 ft./sec. walking speed for the same volume range comparison. The range in ADPV was 35 sec. to 109 sec. (this represented an increase in average delay of 74 sec.). At a walking speed of 4.00 ft./sec., LOS remained the same (LOS F). The range in ADPV was 91 sec. to 147 sec. (this represented an increase in average delay of 56 sec.).

Table H-12. Orange County, California intersection characteristics: approach lane usage, peak-hour traffic volumes, and cycle length.

Approach	Number of approach lanes						Peak-hour traffic volumes (existing and modeled)					
	L	LT	T	TR	R	Total	-10-percent volume	Existing volume	+5-percent volume	+10-percent volume	+15-percent volume	Volume range
Northbound (MJ)	1	0	2	1	0	**4**	1,800	2,000	2,100	2,200	2,300	
Southbound (MJ)	1	0	2	1	0	**4**	1,800	2,000	2,100	2,200	2,300	
Eastbound (MN)	1	0	1	1	0	3	1,125	1,250	1,313	1,375	1,438	
Westbound (MN)	1	0	2	1	0	**4**	1,125	1,250	1,313	1,375	1,438	
MJ approach	2	0	4	2	0	**8**	3,600	4,000	4,200	4,400	4,600	
MN approach	2	0	2	2	0	**6**	2,250	2,500	2,625	2,750	2,875	2,250 – 2,875
Total	4	0	6	4	0	**14**	5,850	6,500	6,825	7,150	7,475	5,850 – 7,475
Cycle length: 100 sec.												

* Note: l = left; LT = left-through; T = through; TR = through-right; R = right.

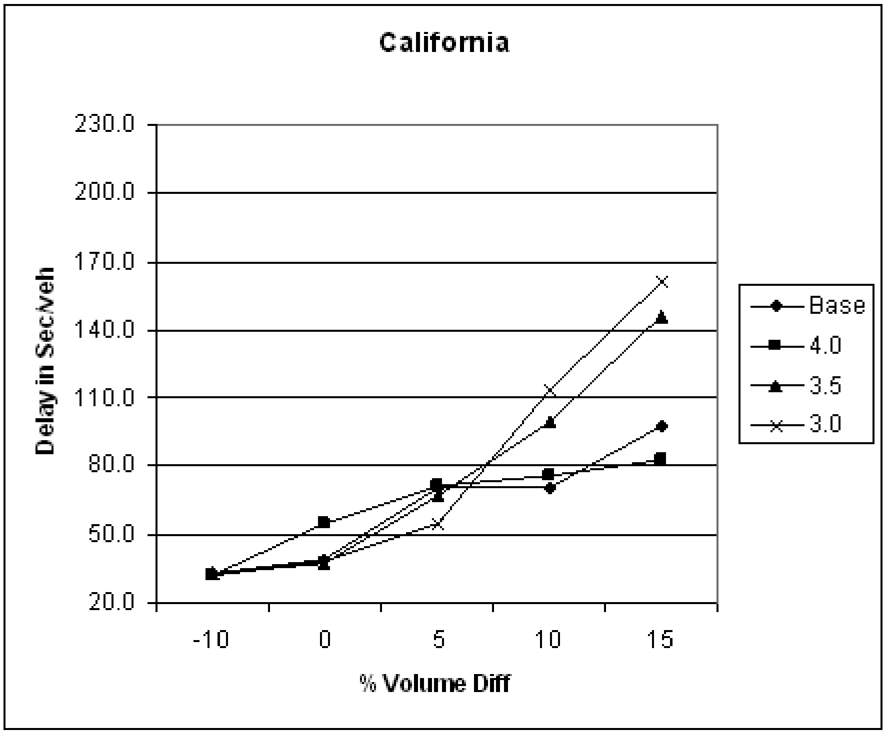

Figure H-2. Delay vs. volumes at case study intersection for walking speeds of 3.00, 3.50, 4.00 ft./sec. and base conditions.

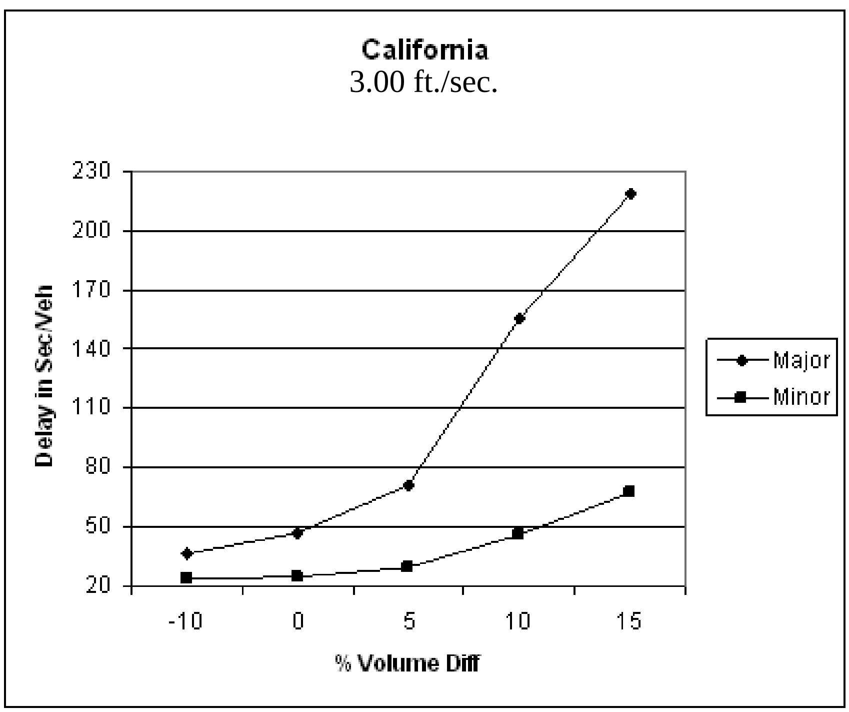

Figure H-3. Intersection delay for major and minor street approaches, 3.00 ft./sec. walking speed, Orange County, California.

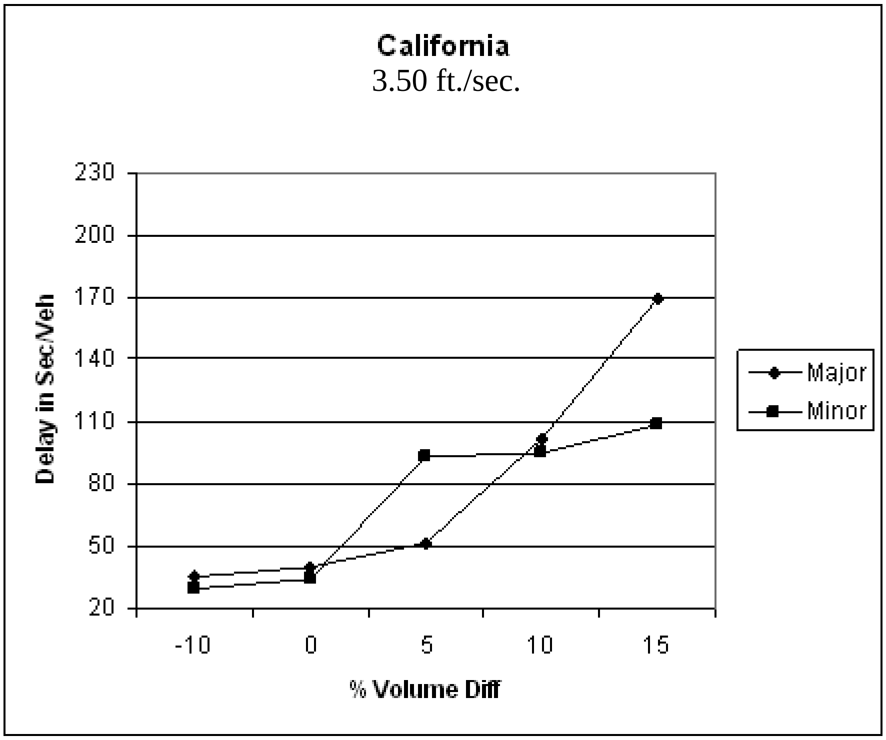

Figure H-4. Intersection delay for major and minor street approaches, 3.50 ft./sec. walking speed, Orange County, California.

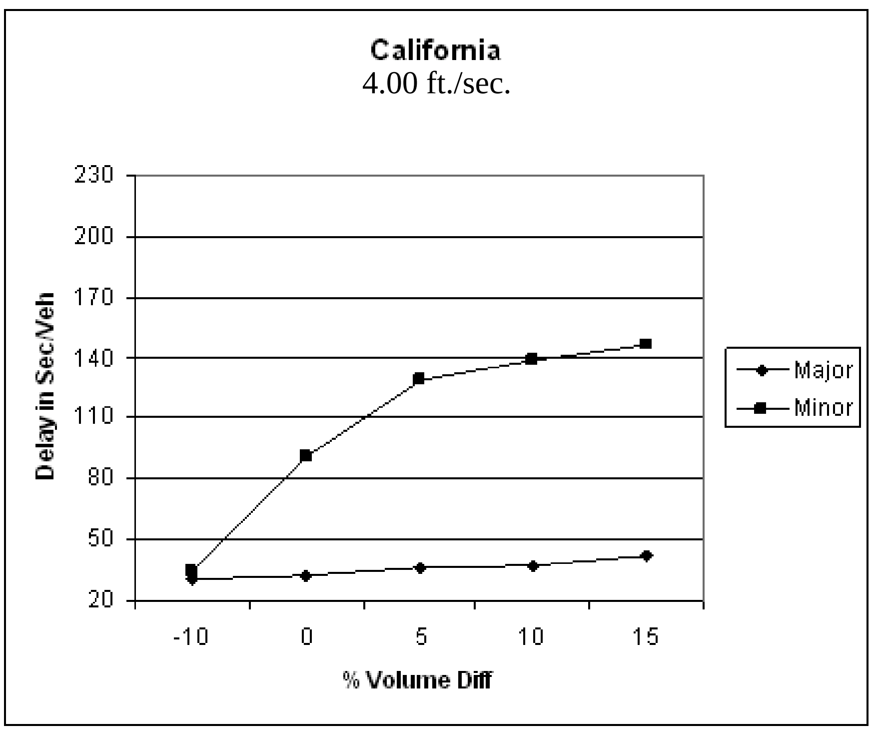

Figure H-5. Intersection delay for major and minor street approaches, 4.00 ft./sec. walking speed, Orange County, California.

Table H-13. Orange County, California: intersection level of service under various peak-hour traffic volume and pedestrian walking speed scenarios.

Walking speed scenario	LOS (and average delay, in sec.)				
	-10-percent volume	Existing volume	+5-percent volume	+10-percent volume	+15-percent volume
3.00 ft/sec.	C (32)	D (39)	E (55)	F (114)	F (161)
3.50 ft/sec.	C (33)	D (38)	E (68)	F (99)	F (146)
4.00 ft/sec.	C (32)	E (55)	E (72)	E (76)	F (83)
Major street LOS (and average delay, in sec.)					
3.00 ft/sec.	D (37)	D (47)	E (71)	F (156)	F (219)
3.50 ft/sec.	C (35)	D (40)	D (52)	F (102)	F (169)
4.00 ft/sec.	C (31)	C (33)	D (37)	D (38)	D (43)
Minor street LOS (and average delay, in sec.)					
3.00 ft/sec.	C (24)	C (25)	C (30)	D (46)	E (68)
3.50 ft/sec.	C (30)	C (35)	F (93)	F (95)	F (109)
4.00 ft/sec.	D (35)	F (91)	F (129)	F (138	F (147)

SUMMARY

There were different environments between the two intersections with traditional signals and the two intersections with countdown signals, which may account for the differences in observed pedestrian activity. With this caveat, the key results are as follows for Orange County:

- MWS for younger pedestrians was 4.80 ft./sec. at the two TPS and 5.30 ft./sec. at the two countdown signals. This difference was statistically significant.
- MWS for older pedestrians was 4.20 ft./sec. at the two TPS and 4.80 ft./sec. at the two countdown signals. This difference was statistically significant.
- MWS for older pedestrians was generally slower than for pedestrians under 65 by about 0.60 ft./sec. The difference in walking speeds between the two age groups was significant at both countdown signals and traditional signals.
- Pedestrians with mobility impairments and without motorized wheelchairs had appreciably slower walking speeds—their mean was 3.00 ft./sec. compared to about 4.20 ft./sec. for older pedestrians and 4.80 ft./sec. for younger pedestrians. A small sample size is recognized.
- Older pedestrians had a slower start-up time, but this will vary by intersection and leg of intersection.
- A higher level of compliance (entering crosswalk on WALK display) was found with the TPS with both age groups.

- There was a slightly larger percentage of pedestrians left in the intersection at PCD signals for younger pedestrians. However, this was based on a very small sample size.

- Surveyed pedestrians generally preferred the PCD signal to traditional signals, with 90 percent of pedestrians understanding the indication.

- Operational analysis:

    - Total intersection volume was estimated at 6,500 peak-hour vehicles, with 2,000 vehicles and 1,250 vehicles on the major and minor street approaches, respectively. This approach produced more of a saturated/lower LOS condition at a “base” level scenario similar to the base condition LOS at the Montgomery County, Maryland case study intersection.

    - Under the 3.00 ft./sec. walking speed scenario when existing volume conditions were compared to the modeled increase of 15 percent above existing volume conditions, there was a reduction of two LOS designations (from LOS D to LOS F) and a corresponding increase in 122 sec. for ADPV. A similar result occurred under the 3.50 ft./sec. walking speed scenario, where the total intersection LOS decreased from LOS D to LOS F and there was a corresponding increase in 108 sec. in ADPV.

    - At the 4.00 ft./sec. pedestrian walking speed scenario, the total increase in average intersection delay per vehicle from the existing volume condition level to the 15 percent above existing volume condition level was 28 sec. and there was a reduction of one LOS designation, from LOS E to LOS F. Note that the difference in the ADPV between the 15 percent above existing volume condition and the existing volume condition at the 3.00 ft./sec. and 3.50 ft./sec. pedestrian walking speed scenarios was 94 sec. and 80 sec., respectively.

    - The total intersection traffic volume range modeled in White Plains, New York was the lowest compared to the six case study intersections (approximately 1,600 to 2,100 peak-hour vehicles). The highest total intersection traffic volume modeled was in Orange County, California, where the case study intersection exhibited a range of approximately 5,900 to 7,600 peak-hour vehicles.

APPENDIX I:

MONROE COUNTY, NEW YORK CRITERIA FOR DEPLOYMENT OF COUNTDOWN PEDESTRIAN DEVICES

COUNTY OF MONROE

DEPARTMENT OF TRANSPORTATION

TELEPHONE: 760-7700 FAX: 760-7730

MEMORANDUM

To: Terry Rice

From: Jim Pond

RE: COUNTDOWN PEDESTRIAN SIGNAL DEVICES

A device called the "countdown pedestrian signal" has been developed which displays to pedestrians the number of seconds remaining on the flashing "DON'T WALK" interval. The device is intended to notify pedestrians how long it will be before the flashing "DON'T WALK" time has expired. This expiration is the point in time where they should have completed their crossing. This information in turn may guide them in their decision-making process as they either initiate or complete a crossing of the street.

The current NYSDOT MUTCD does not address these devices. The Federal MUTCD describes them as an optional device, but does not offer specific guidance on when it is appropriate to use them. NYSDOT Region 4 is using them on new projects at intersections for crosswalks across the primary street, and does not use them across side streets. They do not have any other criteria for their deployment.

Cost is a significant issue with these devices. In addition to the cost of purchasing and installing them, there is a very significant energy cost to operate them. There is also the potential for both mechanical failure (based on experience by NYSDOT signals) and erroneous information being displayed on the device (as per the caution in the Federal MUTCD guidance). Therefore, this device should be used selectively where it would provide the most benefit to pedestrians.

Typically, the crossing time is set with an assumed walking speed of 4.0 feet per second so that the pedestrian can reach the vicinity of the far curb when the crossing time has expired. Many pedestrians walk at speeds higher than this rate. According to ITE's *Toolbox on Intersection Safety and Design*, walking speeds range up to 6.0 feet per second. Table 1 illustrates the difference in crossing times at these various speeds. The table assumes 12-foot lanes and adds 12 feet to each situation to allow for the extra distance introduced by the curb radii typically found at an intersection. It also assumes there is no significant skew angle in the crosswalk.

MONROE COUNTY

COUNTDOWN PEDESTRIAN SIGNAL DEVICES

Table 1

Typical Pedestrian Crossing Times at 4.0 feet per second and 6.0 feet per second

	Number of Lanes To Cross (12 foot lanes plus 12 feet for corner radii)			
	2 Lanes To Cross	3 Lanes To Cross	4 Lanes To Cross	5 Lanes To Cross
Typical Distance	36 feet	48 feet	60 feet	72 feet
Time @ 4.0 ft/sec	9 seconds	12 seconds	15 seconds	18 seconds
Time @ 6.0 ft/sec	6 seconds	8 seconds	10 seconds	12 seconds
Time Difference	3 seconds	4 seconds	5 seconds	6 seconds

The time difference reflects extra time that a fast-walking person theoretically has to work with. The table demonstrates the increased usefulness of the device as the crosswalk distance gets longer, especially in cases of extreme length. The longest crosswalks that we operate (NYSDOT crosswalks across West Ridge Road at Hoover Drive and Buckman Road) have a clearance time of 30 seconds, can be walked in 20 seconds at 6.0 feet/second, and have a time difference of 10 seconds. They have countdown pedestrian signals in place, and the value of them is apparent.

Another consideration is the influence of conflicting vehicles that could delay a pedestrian briefly during the flashing “DON’T WALK” interval. Locations with heavier right- and left-turning vehicle volumes have a higher potential to delay a pedestrian’s crossing. The time-remaining information would be helpful in this situation to reassure a pedestrian that there is still adequate crossing time available for the completion of the crossing.

The following guidelines are recommended for the placement of countdown pedestrian signals.

1. PCD devices are recommended for the longer crossing lengths where crossing time variance is greatest. A suggested threshold is at least 60 feet of crossing distance.

2. PCD devices are recommended where the right-turning and left-turning volumes that conflict with the crosswalk are high. A suggested threshold is a combined 400 vehicles per hour (adding the conflicting right and left turning vehicle volumes together).

   In considering whether to install the devices, I would suggest that the location meet at least one and preferably two of the above thresholds.

   Although the devices could also be considered where the pedestrian volumes are high, the better adjustment for this situation is to add more “walk” start up time. Therefore, the primary need for the devices should be based on the two criteria listed above.

APPENDIX J:

NATIONAL COMMITTEE ON UNIFORM TRAFFIC CONTROL DEVICES REVISIONS TO WALKING SPEEDS SECTION 4.E.10

NATIONAL COMMITTEE ON UNIFORM TRAFFIC CONTROL DEVICES

General Session—Friday, January 20, 2006—Arlington, Virginia

Moved by Friedman, seconded by Pusey to approve the proposed revisions to Section 4.E.10 as recommended by the Signals Committee (Attachment No. 1).

Moved by Hawkins, seconded by Sparks to change the proposed new Standard paragraph number 5 in Section 4.E.10 relating to pedestrian clearance time to Guidance and change the word “shall” to “should”. Motion passed 31-1-2.

Vote on the original motion to approve Section 4.E.10 as amended (Attachment No. 1) passed unanimously.

Revisions to walking speeds in Section 4.E.10

The Pedestrian Task Force of the Signals Technical Committee proposed revised text for Section 4.E.10 to address two different issues:

1. Concern raised by the Public Rights-of-Way Access Advisory Committee that the pedestrian walking speed of 4 ft./sec. in the 2003 MUTCD (and preceding editions) did not appropriately address the needs of the disabled community as they relate to safe crossing of streets at signalized intersections.

2. Concern raised by various organizations (including ITE and AAA) that the pedestrian walking speed of 4 ft./sec. in the 2003 MUTCD (and preceding editions) did not appropriately address the needs of senior citizens as they relate to safe crossing of streets at signalized intersections.

The information presented at the January 2005 meeting by the Texas Transportation Institute (TTI) concerning pedestrian crossing technologies provided a reasonably large sample size and good analysis relating to the speed of pedestrians and was used as the basis of setting the pedestrian walking speed at 3.5 ft./sec., which is approximately a 15th-percentile walking speed. The same TTI research also concluded that 3.0 ft./sec. was the 15th-percentile walking speed for senior citizens.

The Signals Technical Committee discussed pedestrian walking speed issues at length. It was felt that changes to the current MUTCD guidance were appropriate to address the above-cited concerns and to address operational alternatives available through current technology.

The Signals Technical Committee took the following four actions related to this topic:

1. Modify the walking speed used to calculate the pedestrian clearance time and include it as a Standard rather than Guidance as in the current MUTCD.

2. Delete the existing Guidance statement that is being upgraded to a Standard in Item 1. Also, for consistency with the walking speed included in the prior recommendation, change the existing Guidance statement to note that a walking speed of less than 3.5 ft./sec. (rather than 4 ft./sec.) should be used to determine the pedestrian clearance time at locations where pedestrians who walk slower than normal or pedestrians who use wheelchairs routinely use the crosswalk.

3. Add a new Guidance statement recommending that the total crossing time provided be calculated using a walking speed of 3 ft./sec. and be based on the pedestrian crossing from the location of the pedestrian detector or, if none, from a point 6 ft. from the curb face. The total crossing time includes the walk interval and the pedestrian clearance time.

   If the total crossing time calculated using the 3 ft./sec. Guidance is longer than the sum of the PCI (as calculated using the 3.5 ft./sec. Standard) and the walk interval, the walk interval should be increased. It was noted that, for most applications on streets that are less than 100 ft. wide, the walk time plus the pedestrian clearance time (as calculated using the 3.5 ft./sec. Standard) will meet or exceed the recommended total crossing time, especially when the pedestrian detectors are located near the ramp and curb.

4. Delete an existing Option statement and replace it with a new Option statement noting that a walking speed of 1.2 m (4 ft.) per sec. may continue to be used to calculate the pedestrian clearance time at locations where equipment is installed to permit pedestrians to request and receive a longer pedestrian clearance time.

These actions address the walking speed concerns of the Public Rights-of-Way Access Advisory Committee, ITE, and AAA. They also recognize that equipment is available to permit pedestrians to select longer walking times on an as needed or as desired basis.

These actions were approved by the Council of the NCUTCD at the General Session on January 20, 2006. The resulting text was as follows (added text shown as underlined and deleted text shown as strike-through):

Section 4.E.10 <u>Pedestrian Intervals and Signal Phases</u>

Standard:

When pedestrian signal heads are used, a WALKING PERSON (symbolizing WALK) signal indication shall be displayed only when pedestrians are permitted to leave the curb or shoulder.

A pedestrian clearance time shall begin immediately following the WALKING PERSON (symbolizing WALK) signal indication. The first portion of the pedestrian clearance time shall consist of a pedestrian change interval during which a flashing UPRAISED HAND (symbolizing DON'T WALK) signal indication shall be displayed. The second portion, if used, shall consist of the yellow change interval during which a steady UPRAISED HAND (symbolizing DON'T WALK) signal indication shall be displayed. The third portion, if used, shall consist of the red clearance interval (prior to a conflicting green being displayed), during which a steady UPRAISED HAND (symbolizing DON'T WALK) signal indication shall be displayed.

If countdown pedestrian signals are used, a steady UPRAISED HAND (symbolizing DON'T WALK) signal indication shall be displayed during the yellow change interval and any red clearance interval (prior to a conflicting green being displayed) (see Section 4.E.07).

At intersections equipped with pedestrian signal heads, the pedestrian signal indications shall be displayed except when the vehicular traffic control signal is being operated in the flashing mode. At those times, the pedestrian signal lenses shall not be illuminated.

Guidance:

Except as noted in the Option immediately below, the pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder ~~during~~ at the end of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of ~~1.2~~ 1.1 m (~~4~~ 3.5 ft.) per second, to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. [Note – this paragraph has been relocated]

Option:

~~Passive pedestrian detection equipment, which can detect pedestrians who need more time to complete their crossing and can extend the length of the pedestrian clearance time for that particular cycle, may be used in order to avoid using a lower walking speed to determine the pedestrian clearance time.~~ A walking speed of up to 1.2 m (4 ft.) per second may be used to evaluate the sufficiency of the pedestrian clearance time at locations where equipment such as an extended pushbutton press or passive pedestrian detection has been installed to provide slower pedestrians an opportunity to request and receive a longer pedestrian clearance time. [Note – this paragraph has been relocated]

Guidance:

Where pedestrians who walk slower than ~~1.2~~ 1.1 m (~~4~~ 3.5 ft.) per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than ~~1.2~~ 1.1 m (~~4~~ 3.5 ft.) per second should be considered in determining the pedestrian clearance time. [Note – this paragraph has been relocated]

Except as noted in the Option below, the walk interval should be at least 7 seconds in length so that pedestrians will have adequate opportunity to leave the curb or shoulder before the pedestrian clearance time begins. *[No change from 2003 MUTCD]*

Option:

If pedestrian volumes and characteristics do not require a 7-second walk interval, walk intervals as short as 4 seconds may be used. *[No change from 2003 MUTCD]*

Support:

The walk interval itself need not equal or exceed the pedestrian clearance time calculated for the roadway width, because many pedestrians will complete their crossing during the pedestrian clearance time. *[No change from 2003 MUTCD]*

Guidance:

The total of the walk interval and pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the pedestrian detector (or, if no pedestrian detector is present, a location 1.8 m (6 ft.) back from the face of the curb or from the edge of the pavement) at the beginning of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 0.9 m (3 ft.) per second to the far side of the traveled way being crossed. Any additional time that is required to satisfy the conditions of this paragraph should be added to the walk interval.

~~Guidance:~~

Where the pedestrian clearance time is sufficient only for crossing from the curb or shoulder to a median of sufficient width for pedestrians to wait, additional measures should be considered, such as median-mounted pedestrian signals or additional signing. *[No change from 2003 MUTCD]*

Option:

The pedestrian clearance time may be entirely contained within the vehicular green interval, or may be entirely contained within the vehicular green and yellow change intervals. *[No change from 2003 MUTCD]*

On a street with a median of sufficient width for pedestrians to wait, a pedestrian clearance time that allows the pedestrian to cross only from the curb or shoulder to the median may be provided. *[No change from 2003 MUTCD]*

During the transition into preemption, the walk interval and the pedestrian change interval may be shortened or omitted as described in Section 4.D.13. *[No change from 2003 MUTCD]*

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