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Accessible Pedestrian Signals: Synthesis and Guide to Best Practice

This digest announces an interim product from NCHRP Project 3-62, "Guidelines for Accessible Pedestrian Signals," which is being carried out under a contract with the University of North Carolina Highway Safety Research Center under the direction of David L. Harkey (Principal Investigator). The digest summarizes the publication "Accessible Pedestrian Signals: Synthesis and Guide to Best Practice," prepared by J.M. Barlow, B.L. Bentzen, and L. Tabor of Accessible Design for the Blind. The complete report is available on the web at www.walkinginfo.org/aps.

INTRODUCTION

The Transportation Equity Act for the 21st Century directs that pedestrian safety considerations, including installation of audible traffic signals and signs at street crossings, be included, where appropriate, in transportation plans and projects. However, the type of audible signals most commonly used in the United States does not adequately indicate to blind pedestrians which crosswalks at an intersection have the Walk signal, does not provide adequate directional guidance where it is needed, and does not meet the needs of people with both visual and hearing impairments. The engineering profession is looking for a standard approach to the selection of locations for, and the installation and operation of, accessible pedestrian signals (APS).

The results of this NCHRP project will be the basis for more precise and well-supported guidance on APS for consideration in future editions of the *Manual on Uniform Traffic Control Devices* (*MUTCD*) and in the *Public Rights-of-Way Accessibility Guidelines*. The project will also provide extensive guidance on selection and installation of APS to provide maximally useful information to pedestrians who are visually impaired, while minimizing the impact on the surrounding community.

BACKGROUND

APS and Travel by Pedestrians Who Are Blind or Visually Impaired

An APS is a device that communicates information about pedestrian timing in nonvisual formats such as audible tones, verbal messages, and/or vibrating surfaces (*MUTCD*, Section 4A.01) (*1*). APS can provide information to pedestrians about the existence and location of the pushbutton; the onset of the walk interval; the direction of the crosswalk and location of the destination curb; the clearance interval; intersection geometry through maps, diagrams, or speech; intersection street names in Braille, raised print, or speech; and intersection signalization.

Although audible crossing indicators have been available for over 25 years, they have not been commonly installed in the United States. This is probably attributable to two factors: (1) noise pollution and consequent community opposition; and (2) disagreement among blind people on the need for, and effectiveness of, APS. More recently, changes in intersection design and signalization have affected the traditional street crossing techniques used by blind pedestrians, making the pedestrian phase harder to recognize without seeing the

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visual pedestrian signal. In addition, it has become essential to cross during the pedestrian phase at many intersections.

Visual Impairment

Vision correctable to 20/20 with at least 180-degree field is considered "normal" vision. Visual impairment is a functional limitation in seeing even when wearing glasses or contact lenses, including "nonsevere" limitation (difficulty seeing words and letters) and "severe" limitation (unable to see words and letters). Legal blindness is a level of visual impairment that has been defined by law to determine eligibility for benefits. It refers to central visual acuity of 20/200 or less in the better eye with the best possible correction, or a visual field of 20 degrees or less. A person who is legally blind sees at approximately 20 ft what a person with 20/20 vision sees at 200 ft, or is able to see no more than a 20-degree field without scanning. Some degree of vision impairment affects 8.3 million (3.1%) Americans of all ages (*2*). By 2010, projections are that there will be 20 million visually impaired persons over 45.

Street Crossing Tasks and Typical Techniques

At any given time, people who are blind or visually impaired can travel using a human guide, a long white cane to identify and avoid obstacles, a dog guide, special optical or electronic aids, or no additional aid. Many visually impaired pedestrians have received orientation and mobility training provided by an Orientation and Mobility (O&M) specialist. O&M specialists usually have an undergraduate or graduate degree in teaching travel skills to persons who have visual impairments. The goal of most O&M training is to prepare a person who is visually impaired to travel in a variety of environments and to assess new intersections and travel new routes. Orientation is not provided to people who are blind or visually impaired for every route they need to travel. Individuals who are blind or visually impaired often travel to unfamiliar areas and intersections and gather information from available sources.

The first question that pedestrians who are blind need to answer is "Have I arrived at a street?" People who are blind or visually impaired use a combination of cues, including the curb or slope of the ramp, traffic sounds and detectable warnings, to recognize the street edge.

For decision-making at unfamiliar intersections, the next question asked is "Which street is this?" This information is only occasionally provided in any accessible format, so pedestrians who are visually impaired develop a mental map and keep track of where they are within that map, usually by counting blocks and street crossings. Assistance may be sought from other pedestrians.

Next, information is needed about the geometry of the intersection. To obtain it, people ask such questions as the following: Is my destination curb straight in front of me, or must I angle to the left or right to reach it? How many streets intersect here? How wide is this street? Should I expect to encounter any islands or medians as I cross this street? Am I standing within the crosswalk? It may not be possible for pedestrians who are blind to determine this information by listening to traffic patterns.

Pedestrians with visual impairments also need to identify the type of traffic control system at an intersection. This may be determined by listening to traffic patterns through several light cycles or searching the sidewalk area for poles with pushbuttons. However, it has become difficult or impossible to determine the type of traffic control at many intersections by listening. The inability to determine the type of traffic control may result in failure to use pedestrian push buttons and crossing at times other than the pedestrian phase.

After determining the geometry of the intersection, aligning to face toward the destination curb, determining that the intersection is signalized and having pushed a button, where necessary, pedestrians who are blind ask, "When does the Walk interval begin?" In the most common technique utilized for crossing at signalized intersections, pedestrians who are blind begin to cross the street when there is a surge of traffic going straight ahead on the street parallel to their direction of travel.

Once the pedestrian who is blind has begun to cross the street, the next question is, "Am I headed straight toward my destination curb?" Turning traffic can make it difficult to hear and align with the traffic traveling straight through the intersection. In the absence of traffic on the parallel street, pedestrians who are blind are more likely to veer toward or away from the intersection.

Effect of Changes in Intersection Geometry and Signalization

The above techniques may be sufficient to determine the onset of the walk interval and the direction of the crosswalk at some types of intersections. However, in the past 20 years, significant changes in intersection geometry, signalization, driver behavior, and the technology of automobiles have affected the ability of blind travelers in the United States to use the above-mentioned techniques.

Intersection signalization and geometry have become more complex. Pedestrian actuation requires blind pedestrians to locate and push a pushbutton, then cross on the next pedestrian phase, to be assured of having enough time. Blind pedestrians have three types of problems at these locations. First, they have traditionally waited through a light cycle to assess and refine their heading by listening to vehicular trajectories, before crossing at the next pedestrian phase. At a pedestrian-actuated intersection, that is not possible because blind pedestrians then have to locate and push the button again (and re-establish their heading). Second, at a location with little vehicular traffic, even if pedestrians who are blind know there is a pushbutton and use it, they may not be able to detect the onset of the Walk interval if there is not a vehicle traveling straight ahead on the street parallel to

their crossing. Third, blind pedestrians may not be aware that there is a pushbutton or they may be unable to locate the pushbutton. In addition, some locations do not include a pedestrian phase, and, at times when vehicular volume is low, there may not be enough time to cross the street.

U.S. RULES AND REGULATIONS RELATED TO APS

The Rehabilitation Act (1973) requires nondiscrimination in all federally assisted programs, services, and activities. This means that they are to be available and usable to people with disabilities (Section 504). The Americans with Disabilities Act (ADA) requirements for Federal, state, and local governments extend and increase the existing requirements in Section 504 of the Rehabilitation Act. The ADA requirements are more stringent and require public facilities to be accessible regardless of the funding source.

Title II of the ADA requires municipalities and states to make their 'programs' accessible. Pedestrian circulation is considered a program, and APS may be necessary to provide access to certain types of intersections. Some municipalities have considered the addition of APS at intersections as part of their ADA transition plan.

The ADA is a civil rights law guaranteeing nondiscrimination in the provision of public programs and facilities. It requires effective communication with persons with disabilities and, in order to meet this requirement, cities must respond to requests for APS from pedestrians who are blind by providing access to the information provided to sighted pedestrians by visual pedestrian signals if such signals are present.

The *Americans with Disabilities Act Accessibility Guidelines* (*3*) gives minimum guidelines that must be applied to new construction or reconstruction and to alterations, renovations, or additions. Currently, these guidelines do not specifically address public rights-of-way or APS. However, the lack of guidelines or technical specifications does not alter the obligation to make pedestrian signal information accessible to persons who are unable to see existing pedestrian signals.

Draft Public Rights-of-Way Accessibility Guidelines (*4*) were published on June 17, 2002 for comment. These Draft Guidelines require APS at all newly constructed or reconstructed intersections where visual pedestrian signals are installed. A Notice of Proposed Rulemaking on Public Rights-of-Way, based on the draft, is expected to be published by the Access Board in 2003.

Manual on Uniform Traffic Control Devices (MUTCD)

The *MUTCD*, Revision 1, 23 CFR 655 Subpart F, contains two sections on Accessible Pedestrian Signals: Part 4E.06, Accessible Pedestrian Signals, and Part 4E.08, Accessible Pedestrian Signal Detectors (*1*). The following paragraphs describe the requirements in the *MUTCD*.

Where Required

Engineering studies to decide whether an APS is needed should be based on potential demand for APS; a request for APS; traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turn-on-red volumes; complexity of traffic signal phasing; and complexity of intersection geometry. APS shall operate day and night.

Walk Indications

APS installations and technology must clearly indicate which pedestrian crossing is served by each device. If APS have tones, they shall have a tone for the Walk interval. Walk tones shall have a faster repetition rate than an associated pushbutton locator tone. If used, the speech message for a Walk signal shall be the term "Walk sign" which may be followed by the name of the street to be crossed. "Vibrotactile devices, where used, shall indicate that the Walk interval is in effect, and for which direction it applies, through the use of a vibrating directional arrow or some other means." Vibrotactile pedestrian devices "should be located next to, and on the same pole as, the pedestrian pushbutton, if any, and adjacent to the intended crosswalk."

Volume

Audible tones must be audible from the beginning of the associated crosswalk, but no louder than the locator tone except when there is optional activation to provide a louder signal tone for a single pedestrian phase. Walk signals and locator tones should respond to ambient sound, be no more than 5dB louder than ambient sound, and be 89 dB maximum. Locator tones should be audible 6 to 12 ft from the pushbutton or to the building line, whichever is less.

Pushbuttons

Pushbuttons must activate both the Walk interval and the APS. They should contrast with the housing. They may have locator tones which shall repeat at 1-s intervals and shall have a duration of 0.15 s maximum. Pushbuttons should be located adjacent to a level all-weather surface; on an accessible route to the curb ramp; within 5 ft (1.5 m) of the crosswalk extended; and within 10 ft (3 m) of the edge of the curb, shoulder, or pavement. Where two APS pushbuttons are located on the same corner, the pushbuttons should be separated by a distance of at least 10 ft (3 m).

Tactile arrows on pushbuttons should be oriented parallel to the associated crosswalk and should have high visual contrast. The name of the street may be provided in Braille.

Audible Beaconing

The audible tones may be made louder for the subsequent pedestrian phase, up to a maximum of 89 dB, by holding down the pushbutton for a minimum of 3 s. They may also alternate back and forth across the crosswalk to provide optimal beaconing.

Other

If the pedestrian clearance time is sufficient only to cross from the curb to a median (of sufficient width for pedestrians to wait) and accessible pedestrian detectors are used, an additional accessible pedestrian detector should be provided in the median.

Draft Public Rights-of-Way Accessibility Guidelines

The U.S. Access Board published *Draft Public Rights-of-Way Accessibility Guidelines* on June 17, 2002 (*4*). This is the second step in a rule-making process that began with meetings of a Public Rights-of-Way Access Advisory Committee (PROWAAC) that was chartered by the Access Board in 1999 to develop recommendations on guidelines for accessible public rights-of-way. The report of that committee was titled *Building a True Community: Final Report, Public Rights-of-Way Access Advisory Committee* (*5*).

Guidelines will apply to new construction and alterations. Provisions in the Draft Guidelines, which are subject to public comment, revisions, and review by the Office of Management and Budget, require that "Each crosswalk with pedestrian signal indications shall have a signal device which includes audible and vibrotactile indications of the Walk interval (*4*)."

Walk Indications

The Walk indication shall be both audible and vibrotactile. The audible indication shall be by voice or by tone; and, where tones are used, they shall consist of multiple frequencies with dominant component at 880 Hz; duration of 0.15 s, repeated at intervals of 0.15 s.

Volume

APS shall be responsive to ambient noise level changes. The tone or voice volume, measured at 36 in. from the APS, shall be 2 dB minimum and 5 dB maximum above the ambient noise level.

Pushbuttons

Pedestrian pushbuttons shall be integral with the APS device; have locator tones which operate during the flashing and steady Don't Walk intervals; have locator tones that repeat at 1-s intervals for a duration of 0.15 s max; be operable with one hand; and not require grasping, twisting, or pinching. They shall be installed with the control face facing the intersection and parallel to the direction of the crosswalk it serves, be 2 in. minimum across, contrast visually with the housing, and require 5 lbf (pound-force) maximum force.

Pushbuttons shall be located at a level landing connected to the pedestrian access route, 60 in. maximum from the crosswalk line extended, 120 in. maximum and 30 in. minimum from the curb line, and 120 in. minimum from other pedestrian signal devices at the crossing.

Pushbutton Signage

Tactile and visual signs on the face of the device or its housing or mounting shall indicate crosswalk direction and the name of the street containing the crosswalk served by the pedestrian signal. Signage shall comply with ADA Accessibility Guidelines 703.2 specifications for Braille and raised print (*3*), and shall include a tactile arrow aligned parallel to the crosswalk direction and adhere to specifications for arrow size. The arrow shall contrast with the background. Where provided, graphic indication of the crosswalk shall be tactile, and characters shall contrast with the background.

Other

An extended button press is permitted to activate additional features. Buttons of devices with additional features shall be marked with a symbol comprising three Braille dots forming an equilateral triangle.

INTERNATIONAL PRACTICE

Two of the authors, Barlow and Bentzen, visited four countries whose use of APS has been long term, extensive, systematic, and positively accepted by pedestrians who are blind or visually impaired and by transportation professionals. During trips to Japan, Sweden, Australia, and Denmark, the authors met with transportation professionals, O&M specialists, APS manufacturers, and representatives of consumer groups to discuss APS. Installations were observed and photographed. Summaries of information on the use of APS in each of the four countries are available on the web site at www.walkinginfo.org/aps. While many other countries have a long history of using APS, there was no attempt to review all international experience.

APS TECHNOLOGIES AND FEATURES

Types of APS

A number of devices are available which provide Walk and Don't Walk information. All products produce a sound, vibration, or both, during the Walk interval. Currently avail-

able products are of four design types and can be categorized by the location and type of Walk indication provided.

- Pedhead-mounted—Speakers mounted in, on, or near the visible pedestrian signal head.
- Pushbutton-integrated—Audible tones, speech, or vibrating hardware integrated into the pedestrian pushbutton.
- Vibrotactile-only—Walk information only provided by vibrotactile indication at the pushbutton location.
- Receiver-based—Infrared transmitters mounted in or on pedestrian signal heads that provide speech messages at personal receivers, or LED pedestrian signal heads that pulse to transmit a code to call up a speech or vibrotactile message at personal receivers.

The matrix in Figure 1 shows the types of APS currently produced by 11 different manufacturers and available in the United States. The walk indications provided and other features available for the products are also shown in the matrix. An interactive product selection tool, as well as contact information for each manufacturer, is available on the web site at www.walkinginfo.org/aps.

Pedhead-mounted

The type of APS that has been most commonly installed in the United States has a speaker mounted inside or in the vicinity of the pedestrian signal head (see Figure 2). The APS emits a sound such as a bell, buzz, birdcall (typically a chirp or cuckoo), speech message, or some other tone during the Walk interval of the signal only. The sound is *directly audible*, that is, it is heard by everyone in the vicinity; users do not require receivers to hear the sound. Typical equipment of this type has no locator tone or vibrotactile indicator, but it may be responsive to ambient sound.

As typically installed in the United States, pedhead-mounted devices are intended to act as a beacon across the street, are relatively loud as a consequence, and sound from both ends of the crosswalk simultaneously. They may be irritating to other persons in the vicinity and may mask traffic sounds that provide critical safety information for blind pedestrians. Signals of the pedhead-mounted type, with tones currently used, have not proven to be localizable and do not provide directional information that many people hope for (*6*). Speakers must be carefully located so that they are above the end of the crosswalk they signal, otherwise they provide ambiguous information about which crosswalk has the Walk interval.

Pushbutton-integrated

Pushbutton-integrated systems are common in Europe and Australia and are now being installed in the United States (see Figure 3). They have loudspeakers integrated into the pushbutton housing. They have locator tones plus a Walk indication that may be a different tone, a rapid repetition of the locator tone, or a speech message. Locator tones used in the United States vary, but the repetition rate is standardized at 1 per s. The duration of the tone is 0.15 s maximum, so that it is not mistakable for a vehicle back-up tone that usually sounds during approximately half of its cycle length. A tactile arrow is aligned with the crosswalk to show its direction; either the arrow, or the pushbutton, may vibrate rapidly during the Walk interval. The *Draft Public Rights-of-Way Accessibility Guidelines* (*4*) require that all signals provide both vibrotactile and audible indications. Vibrotactile information is useful in combination with audible information when the APS is well located, for confirmation at particularly noisy intersections, and for persons who are hearing impaired. When pushbutton-integrated APS are consistently mounted on poles at the ends of crosswalks and near the crosswalk line furthest from the center of the intersection, they provide unambiguous information about which crosswalk has the Walk signal. Pushbutton-integrated APS, in their typical mode of operation and installation, are intended to be loud enough to be heard only at the beginning of the crosswalk, although the locator tone on the opposite curb becomes audible as the pedestrian approaches it.

Vibrotactile-only

APS that are vibrotactile-only have been installed in some locations in the United States in response to concerns about noise and misleading information provided by some pedhead-mounted devices. This type of APS has an arrow or button that vibrates rapidly during the walk interval (see Figure 4). There is no audible indication. Vibrotactile-only APS must be installed close enough to the crossing departure location so that blind or deaf-blind pedestrians can stand with a hand on the device while they are aligned and ready to begin crossing. Devices of this type are useful to blind pedestrians only when they know the pushbuttons exist and know where to find them.

Receiver-based

Receiver-based APS have been installed for street crossing use in a few U.S. locations. Users scan with receivers, as shown in Figure 5, for pedestrian signal information as they approach the street and after they stop at the street edge. When receivers are oriented in the direction of pedestrian signals, a prerecorded message corresponding to the status of the signal is received. Receiver-based systems can provide clear, unambiguous information and directional guidance at atypical intersections where there are more than four crosswalks and when direct signals, such as tones, may overlap and therefore be unclear or misleading. Information is available only to individuals who have the receivers; it is not audible to others. Receiver-based systems, at this time, may best be used to supplement APS having directly audible and vibrotactile information.

Matrix of Accessible Pedestrian Signal Functions	Campbell	Georgetown	Mallory	Novax	Panich	Polara	Prisma	Relume	Talking Signs	U.S. Traffic	Wilcox
TYPE											
Pedhead mounted	O		X	X			O			X	X
Pushbutton integrated	X	X		O	X	X	X				
Vibrotactile		X									
Receiver based								X	X		
WALK INDICATIONS											
Tones	X	X	X	X	X	X	X			X	X
Speech messages	X			O	O	X	X	X	X		
Vibrating surface	O	X		O	X	X	O	O			
Message to receiver								X	X		
Audible beaconing	O			X		X	O				
OTHER FEATURES											
Pushbutton locator tone	X	X		O	X	X	X				
Tactile arrow	O	X		O	X	X	X				
Pushbutton information message	X			O		O	O				
Automatic volume adjustment	X			X	X	X	X			X	
Alert tone	O				X						
Actuation indicator	X			O	O	X	X				
Tactile map							X				
Braille & raised print information	O				O						
Extended button press	O			O	O	X					
Passive sensor circuit	X										
Clearance interval tones	O			X		O					

Notes: X = Standard feature; O = Optional feature.
Some manufacturers produce multiple APS products; features indicated may represent more than one product.
An interactive product selection tool, as well as contact information for each manufacturer, is available on the web site at www.walkinginfo.org/aps.

Figure 1. Matrix of APS features by manufacturer.

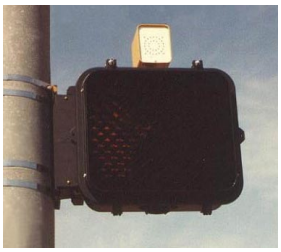

Figure 2. APS unit mounted on top of pedhead.

Figure 3. Pushbutton-integrated APS.

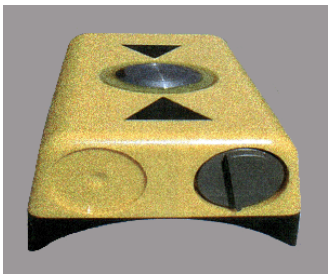

Figure 4. Bottom view of a vibrotactile APS showing a raised arrow that vibrates.

Figure 5. A receiver-based system provides information to a receiver carried by the user.

APS Walk Indications

The indication of the Walk interval is the most important information provided by APS; it is critical. There are a number of APS available, and different devices and Walk indications may be needed for different situations.
APS indication of the Walk interval

- Must be unambiguous with regard to which street has the walk interval;
- Must be audible from the beginning of the associated crosswalk;
- Should be no louder than the associated quiet locator tone unless a louder beaconing feature is actuated for a single pedestrian phase;
- Should have a much faster repetition rate than the locator tone when tones are used to indicate the walk interval;
- Should be readily detectable in the presence of ambient vehicular sound;
- Should be highly localizable;
- Should be uniquely recognizable as a Walk signal; and
- Should be unambiguous with regard to which crosswalk has the Walk interval.

These criteria are based on the *MUTCD* (*1*) and the *Draft Public Rights-of-Way Accessibility Guidelines* (*4*). At this time there are a number of APS available that meet the above criteria.

High detectability of the Walk indication under all ambient sound conditions is essential for APS usability. However, while the signal needs to be detectable, it is desirable to have a sound that is not irritating to individuals in the area of the signal. Because vehicular sounds are concentrated in the lower frequencies, the most detectable signals are those that are concentrated in higher frequencies. Signal detection is aided by multiple, sharp onsets, and a large frequency component at about 880 Hz. The large proportion of pedestrians with visual impairments who have age-related upper frequency hearing loss may have difficulty hearing signals having a fundamental frequency above 1 kHz. Both the commonly used cuckoo and chirp are less detectable than more rapidly repeating tones in the 880-Hz range.

It is critical that pedestrians recognize which street is being signaled and begin their crossings within the Walk interval. Unfortunately, the most common solution used in the United States is ambiguous. Surveys of pedestrians who are blind and the authors' evaluation of typical overhead pedhead-mounted signals have revealed that they frequently provide ambiguous information about the crosswalk being signaled. When the APS sound for both streets comes from the same general location, it is difficult to discriminate which street the tone or speech message applies to. The pedestrian who is blind waits to cross while standing approximately at the curb line, and may be 10 to 15 ft or more from the device speaker. The mounting of speakers does not provide clear

indications of which street is being signaled, unless the speakers are separated and aligned with the crosswalk they signal. The use of different tones for each direction requires pedestrians to know their direction of travel and to know which tone is associated with which travel direction *in a particular jurisdiction*. While traffic movements also help clarify the signal status in many situations, beginning to cross with the wrong signal can be a fatal mistake.

Ambiguity can be addressed by careful location of signal sounds. The best solution is location of the speakers precisely beside or above the end of associated crosswalks and at least 3 m (10 ft) from another APS on the same corner, so it is clear from the source of the sound which crosswalk is being signaled. Figure 6 illustrates two poles with APS located in this manner.

If the APS must be located with two pushbuttons on the same pole or in locations that are not separated by at least 3 m (10 ft), one alternative recommended by PROWAAC is to use speech messages, in which the APS provides speech crosswalk identification information when the button is pushed, as well as a speech message which includes the name of the street being signaled at the onset of the walk interval.

Walk Indications Provided by Tones

Some audible pedestrian signals utilize two different tones that are associated with two different crossing directions. The most common tones used are the bird sounds like "cuckoo" and "chirp." The repeating cuckoo sound is normally used for north/south crosswalks, and the repeating chirp is normally used for east/west crosswalks. This has been the recommended signal in California and Canada. The use of two tones for crossings in two different directions has been assumed to provide unambiguous information about which crosswalk has the Walk signal. However, research since 1988 has documented that such a system is often ambiguous.

For two different sounds to be useful, users must remember which sound goes with which direction and know their direction of travel. At intersections that are not aligned according to the primary compass coordinates, installers may be inconsistent in how signals are installed and information from paired audible tones may be ambiguous, except to frequent users of those intersections. In areas where the street system is curvilinear or otherwise irregular, it may not be apparent to a pedestrian who is blind that a heading has changed. Pedestrians may not know the compass orientation of a route of travel.

Several surveys (*6–8*) have documented that blind pedestrians are often unsure which crosswalk is being signaled by a cuckoo or a chirp. *MUTCD* 4E.06 points out that the provision of different sounds for nonconcurrent pedestrian phases has been found to provide ambiguous information (*1*). Some APS products have the capability of

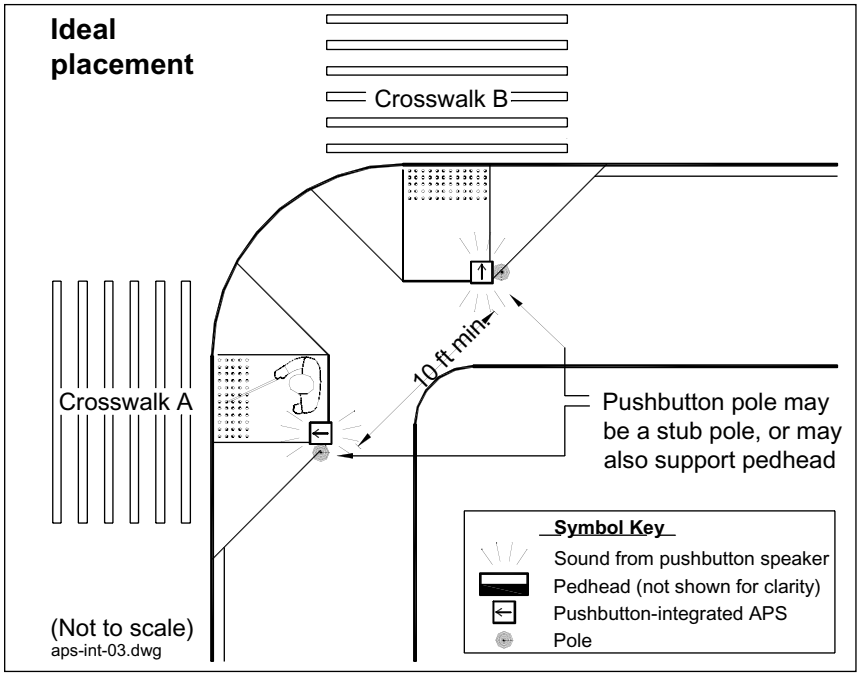

Figure 6. Ideal placement for pushbutton-integrated APS in new construction. This drawing illustrates two poles with pushbutton-integrated APS located beside the level landing and near the crosswalk line that is farthest from the intersection. Pedhead-mounted APS also benefit from placement in these locations.

producing more than two different tones to accommodate intersections having more than two intersecting streets. It is difficult to interpret the use of additional tones without specific instruction and unfamiliar or nonstandard tones are not useful to pedestrians who are not familiar with a given intersection.

In Europe and Australia, tones are used successfully to indicate the walk interval from pushbutton-integrated APS. There is some variability in the tones used. Typically, the tone for Walk is the same tone as the locator tone, repeated at a faster repetition rate, usually 5 to 10 times faster. The same tone is used for all crossing directions. The standardized location of the pushbutton in relation to the crosswalk makes it obvious to users which crosswalk has the walk interval. In all locations, pedestrians are beside the appropriate APS when they are waiting to cross, normally within arm's reach of that APS and at some distance from the APS for another crosswalk.

Walk Indications Provided by Speech Messages

Some APS systems have the capability of utilizing directly audible speech messages to provide information about the status of the signal cycle. The speech Walk message must be detectable, localizable, and recognizable. For use as a Walk indication, a speech message must also be correctly understood by all users.

Speech messages from pushbutton-integrated APS seem very user-friendly and have become popular in the U.S. market. Such messages can communicate to all pedestrians which street has the Walk interval. However, the words and their meaning must be correctly understood by all users in the context of the street environment where they are used. Use of speech messages will not automatically solve all ambiguity problems. Pedestrians have to know the names of streets they are crossing in order for speech Walk messages to be unambiguous. In getting directions to travel to a new location, travelers do not always get the name of each street to be crossed. They may only know that they have to cross four streets before looking for their destination. Therefore, the APS has to give the user the name of the street controlled by the pushbutton. This can be done by means of a pushbutton information message during the flashing or steady Don't Walk intervals.

Most APS that can provide speech Walk messages can also provide a pushbutton that clarifies which street the pushbutton and signal controls. In addition, they may have the option of Braille labels. Users must combine the information from the pushbutton message or Braille label, the tactile arrow, and the speech Walk message, in order to correctly respond to the Walk messages, particularly if there are two pushbuttons on a pole. All may be necessary to correctly identify the street and crossing time at an unfamiliar intersection. This complex process is much more cognitively demanding and liable to result in errors than the simple system adopted decades ago in Australia and several European countries in which the source of a Walk tone is in the immediate vicinity of where pedestrians are standing to initiate the crossing associated with that tone.

Speech messages need to provide accurate information in a clear, concise, and standardized manner, so pedestrians will know what to expect from the messages and be more likely to understand them. Messages should not be worded in a way that seems to provide a command to the pedestrian. For example, "Cross Howard Street now" would not be an appropriate message. Messages should also not tell users that it is "safe to cross." It is always the pedestrian's responsibility to check actual traffic conditions.

The term "Walk sign" has been established as the most appropriate message to inform the pedestrian of the Walk indication. Model speech Walk messages were recommended in the report titled *Determining Recommended Language for Speech Messages Used by Accessible Pedestrian Signals* (*9*), which is available at www.ite.org/library/APS_speech.doc. The model message for the walk interval, applicable to most intersections, is "Howard. Walk sign is on to cross Howard." Additional messages are contained in the full report. Speech messages for the Walk interval of directly audible APS should follow these model messages. Word order should not be changed. Where complete sentences are used in the models, they should be used in actual messages for the same situations. In the model messages, such words as street, avenue, and road are not used. However, in some locations they may be needed to avoid ambiguity. The recommendations are available at www.walkinginfo.org/aps.

Walk Indications Provided by Vibrating Surfaces

On vibrotactile APS, the pushbutton or a raised arrow on the housing vibrates during the Walk interval. The vibration may be synchronous with the pulsing of the audible signal (slow during Don't Walk, and faster during Walk), or may be present only during the Walk interval. Indication of the Walk interval with a vibrating surface is commonly provided on pushbutton-integrated signals, in addition to the audible indication.

Walk Indications Provided by Receiver-based Systems

Walk indications of receiver-based systems can be provided by speech messages or by vibration of the handheld receiver. The pedestrian who is blind must have a receiver and point it at the pedhead to receive the verbal or vibratory message. There are currently two technologies that provide messages to personal receivers. Remote infrared audible signage (RIAS) is a system in which unique messages that are recorded in a transmitter are transmitted by infrared light to receivers. LED pedestrian signals provide a system that can be pulsed to call up a limited selection of speech or vibratory messages that are recorded in receivers.

Volume

Loud overhead audible signals have been problematic to neighbors of APS installations. In addition, the sound of the signal may prevent pedestrians who are visually impaired from hearing critical traffic sounds used for alignment, determining that cars have stopped, hearing cars that may be turning across their path, or localizing on the signal source. The Walk indication should normally be audible only from the beginning of the crosswalk, not across the intersection. This is a change from the expectations regarding setting the volume typical of previous installation of APS in the United States.

Many APS have volume control that is automatically responsive to ambient (background) sound. A louder signal is produced when vehicle and other noise at an intersection is high, as during rush hour or construction; a quieter sound is produced when traffic volume is lower, such as during night-time hours. Most signals with automatic volume control have a minimum limit placed at about 30 dB and a maximum limit at about 90 dB. A signal that is 2 to 5 dB above ambient sound, as perceived at the departure curb, is loud enough to inform pedestrians who are blind that the walk interval has begun. The automatic volume adjustment minimizes noise pollution and decreases the possibility that pedestrians with visual impairments will not be able to hear critical traffic sounds in addition to the sound of the signal.

The pushbutton locator tone and Walk indication should normally be between 2 to 5 dB above ambient noise levels and should respond to ambient sound. The system is to be adjusted so the sound is audible no more than 6 to 12 ft from the sound source, or at the building line, whichever is less. However, louder pedestrian phase signals may be actuated by an extended button press, subject to a maximum volume of 89 dBA (absolute sound level measured on the A-weighted scale) (*1*). The volume should be individually adjusted at each APS installation for satisfactory performance.

Audible Beaconing

A minority of crosswalks require audible beaconing, in which the sound source provides directional orientation. Where audible beaconing is required, an extended button press is the preferred method of actuating beaconing for the subsequent pedestrian phase. Beaconing can be provided in several ways: (1) the volume of the Walk tone and the subsequent locator tone for one signal cycle may be increased; (2) the audible Walk signal may be alternated back and forth from one end of the crosswalk to the other; or (3) the signal may come from the far end of the crosswalk only.

Audible beacon speakers must be oriented in line with the relevant crosswalk. If the speaker is not carefully oriented, the signal may give ambiguous information about which street has the Walk interval and ambiguous information for traveling straight across the street. Beaconing is enhanced by the presence of a locator tone that users can home in on as they approach the destination corner, island or median having an accessible pushbutton.

Not all crosswalks at an intersection may need beaconing; beaconing may actually cause confusion if used at all crosswalks at some intersections. Audible beaconing may be needed at intersections having skewed crosswalks or irregular geometry such as multiple legs, crosswalks longer than 70 ft—unless they are divided by a median that has another APS with a locator tone—and at crosswalks where APS are requested by individuals with severe veering problems. Audible beaconing is not appropriate at locations with free right turns or split phasing, because of the possibility of confusion.

Other APS Features

APS may include the following features in addition to the Walk indication: a pushbutton locator tone, a tactile arrow, a pushbutton information message, automatic volume adjustment, an alert tone at the onset of the Walk interval, an actuation indicator, a tactile map of the crosswalk, Braille and raised print information, an extended button press to actuate special features, passive pedestrian detection, remote activation, and clearance interval tones.

Pushbutton Locator Tone

A pushbutton locator tone is "A repeating sound that informs approaching pedestrians that they are required to push a button to actuate pedestrian timing and that enables pedestrians who have visual disabilities to locate the pushbutton. (*1*)"

Pushbutton locator tones typically sound during the flashing and steady Don't Walk intervals. A slowly repeating tone or ticking sound is adjusted to be heard no more than 6 to 12 ft (2 to 4 m) from the pushbutton or to the building line, whichever is less. The locator tone informs pedestrians of the need to push a button and provides an audible cue to the location of the pushbutton and the destination corner. A sample pushbutton locator tone is available on the web site at www.walkinginfo.org/aps.

Tactile Arrow

Most APS devices that are integrated into the pushbutton incorporate a raised (tactile) arrow that helps users know which crosswalk is actuated by the pushbutton. The arrow must be oriented in the direction of travel on the crosswalk. Misalignment of the arrow by a few degrees can direct a blind pedestrian into the center of the intersection. The arrow may be part of the pushbutton, above the pushbutton, or on top of the device. On some devices, this arrow also vibrates during the Walk interval. (See Figure 4.)

For arrows on the face of the device, the alignment is determined by the installation of the pushbutton on the pole. Arrows on the top of the pushbutton-integrated APS are

typically glued into place after the pushbutton is installed and their alignment can be adjusted separately from the APS itself. Arrows should have good visual contrast with their background so that all users, including those having low vision, will see them readily.

Pushbutton Information Message

A pushbutton information message is a speech message that provides additional information when the pedestrian pushbutton is pushed. This message may provide the name of the street that the pushbutton controls, as well as other intersection geometry or signalization information. The pushbutton information message is provided from a speaker located at the pushbutton, during the flashing and steady Don't Walk intervals only. The message is intended to be audible when standing at the pushbutton location. Pedestrians may be required to press the pushbutton for approximately 3 s (see extended button press) to call up this additional speech message.

Pushbutton information messages should be developed according to models recommended (*9*). For a typical intersection, the model pushbutton information message would be, "Wait to cross Howard at Grand." Model pushbutton information messages appropriate to other situations and signalization can also be found on the web site at www.walkinginfo.org/aps.

Alert Tone

A very brief burst of high frequency sound, rapidly decaying to a 500 Hz Walk tone, is used by one manufacturer to alert pedestrians to the exact onset of the Walk interval. This may be particularly useful if the Walk tone is not easily audible in some traffic conditions. As used in Australia, the alert tone is 14 dB above the ambient sound level. Australian engineers believe the alert tone encourages faster initiation of crossing, decreasing the likelihood of conflict between pedestrians and turning vehicles. A sample alert tone is available on the web site at www.walkinginfo.org/aps.

Actuation Indicator

Either a light, a tone, a voice message, or both audible and visual indicators may indicate to pedestrians that the button press has been accepted. Several APS devices emit an audible click or beep when the pushbutton is pushed. One provides a speech confirmation message. If there is a light, it is at or near the pushbutton and remains illuminated until the Walk indication is illuminated. A light is helpful to persons with low vision (see Figure 7), but persons who are blind require a tone.

Figure 7. APS with actuation indicator light illuminated. Light remains illuminated until the call is serviced.

Tactile Map

One manufacturer's pushbutton-integrated signal can incorporate a raised schematic map showing what will be encountered as the pedestrian negotiates the crosswalk controlled by that push button (see Figure 8). This map is made up of changeable 'slugs' inserted in the side of the pushbutton housing. It must be set up for each crosswalk of the intersection. The map shows just the crosswalk controlled by that signal, not the entire intersection. It is read from the bottom to top showing lanes as pedestrians would reach them. Symbols used are not standardized in the United

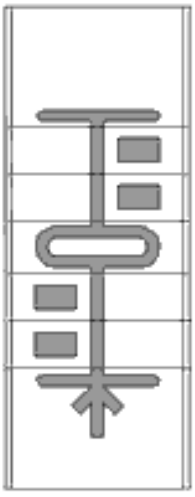

Figure 8. This example shows (from the bottom) "START," 2 vehicle lanes (traffic from the left), 1 median, 2 vehicle lanes (traffic from the right), and then "END."

States, but one manufacturer has developed a standard set that is used in other countries.

Map information includes the number of lanes to be crossed, whether these are vehicular or bicycle lanes or trolley tracks, which direction traffic will be coming from in each lane, and whether there is a median.

Braille and Raised Print Information

Some manufacturers will provide the name of the associated street in Braille above the pushbutton as an option (see Figure 9). Braille information or raised print information in combination with the tactile arrow can help pedestrians learn or confirm the street name which is controlled by the pushbutton and can help pedestrians choose which of two pushbuttons to press to cross the desired street.

Although this may be helpful to some pedestrians who are blind, many would not be able to locate the Braille because of the lack of a standardized location for such information. Many individuals who are blind do not read Braille. However, those who do would prefer Braille information to confirm which street is controlled by the pushbutton. Some individuals who do not read Braille may be able to read large print or raised print.

The street name on a device should be the name of the street whose crosswalk is controlled by the pushbutton. PROWAAC suggested that providing intersection identification information in an audible format may be useful to the greatest number of users.

Extended Button Press

Extended button press is an option on many APS that actuates additional accessibility features. Most require the pushbutton to be pressed for between 1 s and 3 s to activate the features. Locations that use such a system should provide educational materials and information to individuals in the community who are blind or visually impaired to assure that they can take advantage of the features. Any or all of the following features may be actuated by pressing and holding the same button that is used by all pedestrians.

Figure 9. Braille label is located on the face of the APS device, just below the street name in large print.

- The accessible Walk indication.
- A pushbutton message identifying the intersection and the crosswalk, available during the Don't Walk or flashing Don't Walk.
- A pushbutton message with intersection signalization and geometry information, available during the Don't Walk or flashing Don't Walk.
- Audible beaconing by increasing the volume of the Walk tone and the associated locator tone for one signal cycle, so a blind pedestrian might be able to use the sound from the opposite side of the street to provide directional guidance.
- Audible beaconing by alternating the audible Walk signal back and forth from one end of the crosswalk to the other.
- Audible beaconing by providing the Walk signal from the far side of the street only, at an elevated volume for one signal cycle.
- Extended crossing time.

Passive Pedestrian Detection

Passive pedestrian detection is available to call the Walk indication and it can also extend the clearance interval. The authors are not aware of U.S. installations that include audible signals as well as visual signals, but this technology is known to be in use in the United Kingdom, Australia, New Zealand, and the Netherlands. In Adelaide, Australia, the installation of passive pedestrian detection in the crosswalk, for extending crossing time, is now standard at intersections where there is a newly installed APS.

While passive detection of pedestrians for activating the locator tone may be helpful in reducing noise near the intersections, pedestrians who are blind may not be approaching the crosswalk or intersection within the detection zone.

Remote Activation

At least one manufacturer offers the option of a handheld pushbutton that sends a message to the APS to call the pedestrian phase. It operates on a limited range radio frequency within 100 ft. The manufacturer's information does not clarify how the device would differentiate between locations at the intersection or whether using the device would place a pedestrian call for all crossings of the intersection.

Remote activation can make it possible for pedestrians to place a pedestrian call as they approach the intersection, without having to travel to the pushbutton location. This

would make it unnecessary to deviate from the travel path and may be particularly advantageous for wheelchair users.

Clearance Interval Tones

Clearance interval information is sometimes provided by APS in Japan and Canada. Clearance interval tones let pedestrians who are visually impaired who have begun to cross the street know that the clearance interval prevails, that is, that they do not yet have to fear the onset of perpendicular traffic. However, the sound is relatively loud, possibly masking the sound of critical traffic movement, and the clearance interval sound might be mistaken for the Walk signal. It is particularly important that pedestrians who are blind not mistake a clearance interval signal for a Walk signal, as they could begin crossing late in the clearance interval when they would not have enough time to complete crossing before the onset of perpendicular traffic. This feature is not currently used in the United States and is not recommended due to the potential confusion of the Walk interval with the clearance interval.

Developing Features

The increasing use of personal pagers, cellular telephones, and other mobile digital communication devices that could potentially receive transmitted pedestrian signal messages suggests that there may be other technologies and methods to provide information to pedestrians and for pedestrians to call the Walk interval in the future. Development is ongoing on an integrated handheld computer-type device to provide geographic, GPS, intersection layout, and real-time signal information to pedestrians who are blind as they travel. Communication of a pedestrian call is also being investigated. However, such technology is in the very early development stages.

WHERE TO INSTALL APS

Where Are APS Needed?

Section 4E.06 of the *MUTCD* recommends, "The installation of accessible pedestrian signals at signalized intersections should be based on an engineering study, which should consider the following factors: potential demand for accessible pedestrian signals; a request for accessible pedestrian signals; traffic volumes during times when pedestrians might be present; including periods of low traffic volumes or high turn-on-red volumes; the complexity of traffic signal phasing; and the complexity of intersection geometry. (*1*)"

Too little traffic is as great a problem for pedestrians who are blind as is too much traffic. In the absence of APS, blind pedestrians must be able to hear a surge of traffic parallel to their direction of travel in order to know when the walk interval begins. Locations that may need APS include those with vehicular and/or pedestrian actuation; very wide crossings; major streets at intersections with minor streets having very little traffic, where APS may be needed to cross the arterial; T-shaped intersections; nonrectangular or skewed crossings; high volumes of turning vehicles; split phase signal timing; exclusive pedestrian phasing, especially where right-on-red is permitted; and leading pedestrian intervals. Where these conditions occur, it may be impossible for pedestrians who are visually impaired or blind to determine the onset of the Walk interval by listening for the onset of parallel traffic or to obtain usable orientation and directional information about the crossing from the cues that are available.

Prioritizing Locations for APS

Prioritization may be desirable either to determine the order in which locations will be equipped with APS in response to individual requests, or in updating ADA transition plans. Prioritization schemes should place only limited emphasis on factors related to frequency or likelihood of use by blind pedestrians. The information provided by APS may be necessary at any time and along any route to residents, occasional travelers, and visitors. Intersections having high pedestrian volumes are likely to have pedestrians whose vision is sufficiently impaired that they have difficulty using conventional pedestrian signals. Of greater importance are factors related to determining whether sufficient acoustic information exists—at all times—to permit safe crossing at a particular intersection.

Several rating scales have been developed, some of which have been utilized for over 20 years. These rating scales are used in different ways in different cities. Generally, points are assigned to specific intersection features, as well as proximity to services for all pedestrians, such as transit, government offices, or shopping. San Diego; Los Angeles; Portland, Oregon; and the Maryland Department of Transportation use point rating scales as part of their process. These scales are included on the web site at www.walkinginfo.org/aps.

Systems for determining the priority of APS installations usually involve participation of one or more representatives of three groups of experts: traffic engineers, O&M specialists, and pedestrians who are blind. Intersections with the highest number of points are generally considered highest priority. However, the date of the request, plans for other construction at the intersection in question, and other issues may affect priority of the installation.

In most schemes, each crosswalk of the intersection is evaluated separately. Items and point values assigned differ on the rating scales, but most include items related to pedestrian usage, intersection and traffic conditions, and a number of special conditions. A rating scale used in developing a transition plan may be slightly different than one used to determine responses to individual requests. A rating scale will be developed and validated as part of this NCHRP project.

DESIGNING INSTALLATIONS

Installation Decisions

Each installation requires engineering judgment, according to the following general principles.

- Provide information to pedestrians about the presence and location of pushbuttons if pressing a button is required to actuate pedestrian timing.
- Provide unambiguous information about the Walk indication and which crossing is being signaled.
- Use audible beaconing only where necessary.

In many cases, a municipality or state will wish to purchase one type of APS device for all installations. However, there are engineering and design decisions in the installation of APS as well as in the choice of equipment. When retrofitting intersections with APS, it may be necessary to utilize either different types of APS or different options on the same type of device in order to provide unambiguous information at different intersections. In new construction or reconstruction, where the APS can be located consistently, it is possible to use a standardized device and mounting location.

Device locations are critical to the proper function of the APS and need to be planned. The APS may provide ambiguous information if located incorrectly, just as pedestrian or vehicular signal heads can provide ambiguous, or even dangerous, information if located incorrectly. Pedestrians who are blind or visually impaired must be able to perceive quickly and accurately which crosswalk is being signaled by an audible Walk indication. Unless the sound sources are separated by at least 10 ft and located appropriately in relation to the crosswalk, they are difficult to distinguish. At pedestrian-actuated crossings, the pushbutton should be located in close proximity to the level landing of the curb ramp serving that crossing, for the convenience of all pedestrians using the pushbutton.

Audible Beaconing

The need for audible beaconing may affect the type of device to be installed and the installation location. Not all manufacturers' devices are capable of providing audible beaconing. A minority of crossings is likely to require beaconing and not all crosswalks at an intersection may need beaconing. Beaconing may actually cause confusion at some locations. Beaconing should typically be provided in response to a long button-press. It may consist of a louder Walk signal followed by a loud locator tone for one pedestrian phase, signals that alternate from one end of the crosswalk to the other, or a far-side-only Walk signal. Where beaconing is provided, location of all speaker components of the APS within the width of the crosswalk is essential, as users will direct their travel toward the source of the sound.

Signal Phasing Considerations

Some types of signalization schemes, such as exclusive pedestrian phasing and split phasing, need careful adjustment and consideration to avoid confusing pedestrians who are blind. It is critical that the Walk indication be audible only from the ends of the crosswalk being signaled so pedestrians do not begin to cross at a time when vehicles are turning across their path in a protected vehicular movement. This can be accomplished by locating the APS very close to the crossing location so that a very quiet signal is nonetheless audible to pedestrians waiting to cross. Careful adjustment of the APS volume at all times of the day and night is critical, as well as careful aiming of the speakers.

Exclusive pedestrian phasing, sometimes referred to as scramble phasing, makes it difficult for pedestrians who are blind or visually impaired to recognize the onset of the Walk interval, particularly at locations where right on red is permitted. In addition, there is no vehicular flow to aid in crossing straight to the destination corner. Ongoing research is evaluating strategies for APS installation at intersections with exclusive pedestrian phasing.

At locations where the pedestrian signal to cross the minor street rests-in-Walk, the Walk indication would sound constantly for that crossing. In many locations, that might prove to be irritating to neighbors. Some APS manufacturers provide a limit switch that limits the length of the audible Walk indication to 7 or 8 s, but recalls the audible and vibrotactile indications of the Walk if the button is pressed when there is adequate clearance time remaining. The availability of that feature should be investigated in the installation planning.

Intersection Geometry Considerations

Geometries, such as unsignalized and signalized right-turn lanes, and medians are recognized as situations of concern in the *MUTCD* (*1*). An unsignalized right-turn lane can pose a problem if the APS for crossing the center of the intersection is too loud. Pedestrians who are unaware of the existence of an unsignalized right-turn lane may reach the curb, hear the APS sounding, and cross the unsignalized lane, thinking that it is signalized.

Where crosswalks from corners to splitter islands are signalized, the signals to cross to the island may not be concurrent with parallel traffic movements. Pedestrians waiting on the island must not confuse the Walk indication for the turn lane with the Walk indication for the through lanes of the intersection.

In these situations, the APS must be adjusted so it is only heard from the location where the pedestrian is waiting to cross and only audible for the crosswalk being signaled. It is generally not appropriate to use audible beaconing where there are splitter islands because the volume cannot be controlled precisely enough.

If the pedestrian clearance time is sufficient only to

cross to a median having an additional pushbutton, it is very important that the pushbutton on that median be an APS with a locator tone. This will indicate to pedestrians who are visually impaired that a second button press is needed to complete the crossing, and will aid in location of the median and the pushbutton.

NEW CONSTRUCTION OR RECONSTRUCTION INSTALLATION

Device Requirements in New Construction and Reconstruction

As previously noted, the *Draft Public Rights-of-Way Accessibility Guidelines* (*4*) were published on June 17, 2002. While the Guidelines have not been published as a final rule, they provide the most comprehensive guidance available at this time. The Draft Guidelines require APS to have the following characteristics:

- APS devices shall be integral with the pushbutton;
- The Walk interval shall have audible and vibrotactile indications;
- The Walk indication shall be by tone or voice (speech message);
- There shall be a pushbutton locator tone where there are pushbuttons;
- There shall be tactile and visual signs on the face of the device or its housing; and
- The APS shall include a tactile arrow indicating the crosswalk direction and the name of the street to be crossed.

Location Requirements in New Construction and Reconstruction

The Draft Guidelines specify that APS devices shall be located as follows (*4*):

- At a level landing connected to the pedestrian access route;
- 60 in. maximum from the crosswalk line extended (see Figure 10);
- 120 in. maximum and 30 in. minimum from the curb line (see Figure 11); and
- 120 in. minimum from other pedestrian signal devices at the crossing with an exception to that distance for devices installed on medians (see Figure 12).

The control face of the device is to be installed to face the intersection, parallel to the direction of the crosswalk it serves. *MUTCD*-recommended locations are substantially the same as required in new construction and reconstruction by the *Draft Public Rights-of-Way Accessibility Guidelines*.

Figure 10. Pushbuttons should be a maximum of 5 ft from the crosswalk line extended.

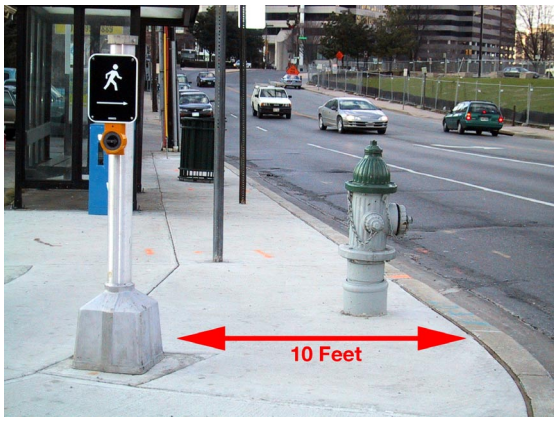

Figure 11. Pushbuttons should be a maximum of 10 ft from the curb line.

Figure 12. Well-located pedestrian signal poles provide APS audible indications from the optimal location, close to the pedestrian waiting area.

RETROFITTING AN INTERSECTION WITH AN APS

Addition of APS to an Intersection with Existing Pedestrian Signals

In retrofit situations, the ADA requires that new construction guidelines be followed to the maximum extent feasible, where compliance with new construction guidelines is technically infeasible. The determination of technical infeasibility will vary depending on the scope of the project and the existing situation.

The goal of the new construction location requirements and guidelines is to provide unambiguous information about which crosswalk has the Walk indication and to make pushbuttons accessible to, and usable by, all pedestrians, including those with visual and mobility impairments. Poor location and installation can render APS unusable by a pedestrian who is blind or mobility impaired; they can also lead to the APS's providing dangerous or incorrect information.

When the only change is addition of an APS, existing pole location at the intersection often restricts the location of APS components, such as pushbuttons, speakers, and tactile arrows, which can affect the device features needed. Location of two APS on one pole requires either speech walk indications or additional mast arms or other provisions to separate the sounds (see Figure 13). APS loudspeakers may be located at the pushbutton location or on the pedhead. The location of these speakers can be critical.

If there are no poles at the recommended locations, options to consider in retrofit situations, in order of decreasing desirability (from the standpoint of ambiguity), include the following: repositioning of pedestrian signals and poles, or the addition of stub pole(s) and associated conduit and wiring (see Figure 14); use of pedhead-mounted speakers, possibly with mast arms or other provision to locate the Walk tone speakers as near to the associated crosswalk as possible; and two APS on a pole with speech messages.

Repositioning poles may be considered a major change in some renovation projects but may be less difficult when the addition of the APS is part of the upgrading of the curb ramp. The optimal choice is positioning speakers and pushbuttons on poles that are located in the appropriate location, and ways to accomplish this should be strongly considered before other options are explored.

In some locations, the addition of stub poles may be fairly simple. The wires to pushbuttons are low voltage wires and it may be possible to run the wires in a sawcut to a pushbutton pole installed with bolts. Looking at the wiring and the use of stub poles in unconventional ways may provide solutions to the problems.

SPECIFICATIONS FOR INSTALLATION OF APS COMPONENTS

APS devices may include some or all of the following components: controller boards and wiring; pushbuttons, tac-

Figure 13. Speech walk messages and pushbutton information messages needed when two pushbuttons must be installed on the same pole. This should be last choice, if APS cannot be separated by 10 ft.

Figure 14. APS are positioned appropriately at this intersection by the addition of a stub pole for one crosswalk. The stub pole holding the APS for the crosswalk at right is simply bolted in. The other APS is mounted on the pole that supports the pedhead.

tile arrows, vibrating surfaces and signs; and speakers and microphones. All components may be integrated into one unit or separate components may need to be sited and installed. The following section briefly reviews some of the installation specifications. The web site at www.walkinginfo.org/aps provides a more extensive discussion.

Wiring and Controller Boards

All APS currently on the market are wired to the pedestrian signal indications. The addition of APS does not change the signal timing. Pushbutton-integrated devices generally require an extra set of wires to the pushbutton to power the audible indications. APS with actuation indicators may need to receive an actual signal from the controller that the call has been accepted. If conduit is not adequate for extra wiring, plans for installation may require conduit and wiring replacement.

APS devices work with current controllers used in the United States. In the past year, some controller conflicts have been reported, mainly related to a change in voltage that leads to the MMU (controller conflict monitors/malfunction management units) override. These have been addressed by the manufacturers and seem to be solved.

Two manufacturers are developing APS that can be adjusted by engineering staff using pocket computers or PDA-type devices. These involve simpler wiring, and post-installation adjustment can be done from the sidewalk, with no need to open the APS or controller.

Some APS have a controller board that is completely contained within the device. Other pushbutton-integrated APS require a separate controller board that is mounted in the pedhead. The controller board often includes voice or sound chips and switches to control volume, microphone response, and other features.

Locations of Pushbuttons, Tactile Arrows, Vibrating Surfaces, and Signs

Engineering drawings for installations should include location of pushbuttons, tactile arrows, vibrating surfaces, and signs of the APS devices. The locations and orientation of these features affect the safety and usability of the devices. More guidance is available on the web site at www.walkinginfo.org/aps on the location of the tactile arrow, orientation of the tactile arrow, height of pushbuttons, shape and type of mounting poles, mounting on wooden poles, and use of stub poles.

Location of Speakers and Microphones

Engineering drawings and specifications should include the location and orientation of all microphone and speaker components. The microphones are measuring the sound levels to adjust the volume at the waiting location. If the microphone is mounted too far from the intersection, it will not adequately sample and adjust the volume levels. The Walk indication is likely to be too quiet for a pedestrian who is waiting at the curb to hear above the sound of traffic.

Speakers for APS may be pedhead-mounted or pushbutton-integrated. There are different issues to be considered, depending on the speaker location. Figure 15 shows ideal placement of pushbutton integrated APS speakers, while Figures 16 and 17 illustrate unacceptable installations.

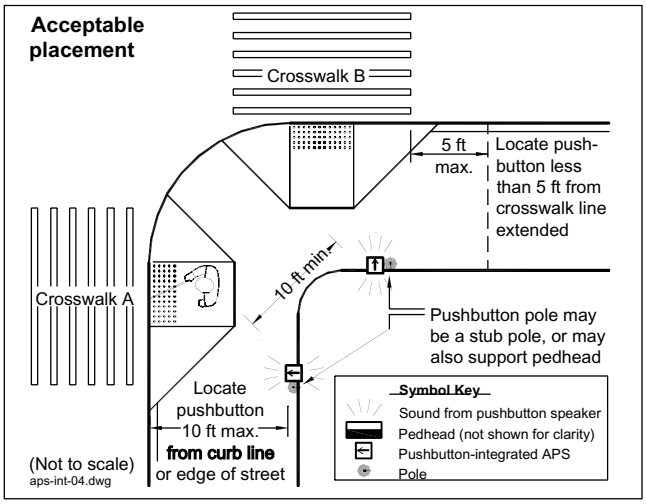

Figure 15. Acceptable placement of pushbutton-integrated devices. If it is not possible to locate the speakers closer to the curb, the locations shown here are acceptable. Pushbuttons should be within 10 ft of the curb.

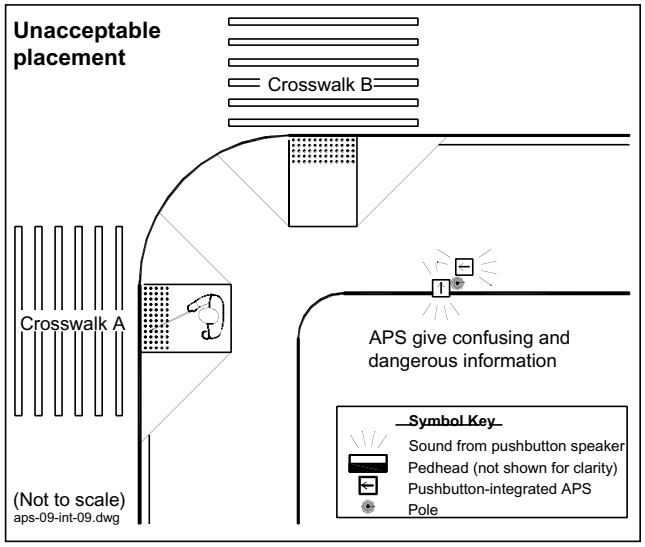

Figure 16. Unacceptable placement for pushbutton-integrated APS (gives ambiguous information).

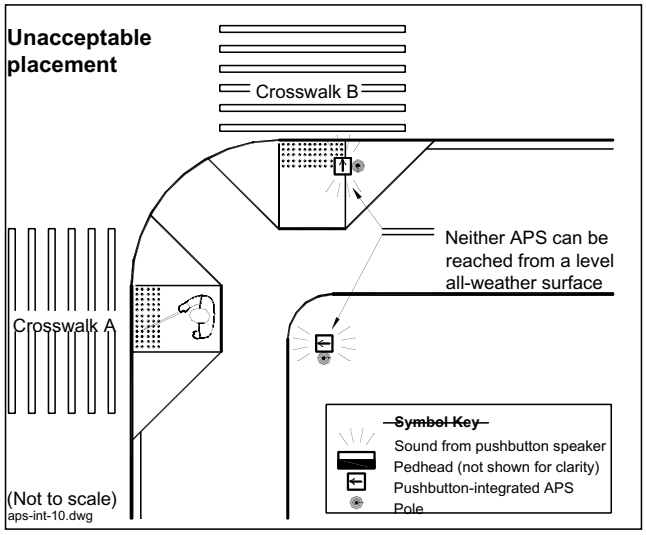

Figure 17. Unacceptable placement for pushbutton-integrated APS (not reachable from level all-weather surface).

If APS cannot be separated, Figure 18 shows a possible solution using speech messages. The messages must clarify which signal is sounding by use of a street name and should include a pushbutton information message to provide the street name to travelers unfamiliar with the intersection.

The authors have observed that it is common for overhead speakers that are attached to pedheads to provide ambiguous information. The drawings and discussion on the web site at www.walkinginfo.org/aps illustrate some typical speaker and pedhead placements, including a commonly

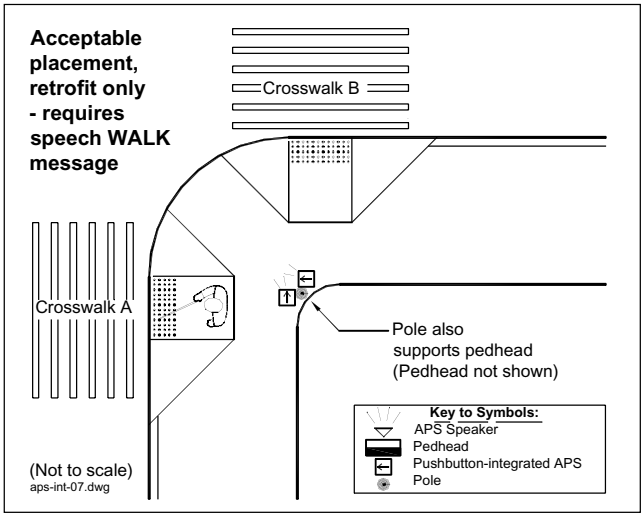

Figure 18. Acceptable placement for pushbutton-integrated APS, retrofit only. If APS cannot be separated, need speech pushbutton message and speech WALK message to prevent ambiguity.

observed mounting which provides ambiguous information to pedestrians with visual impairments. Refer to the web site if planning an installation with pedhead-mounted speakers.

Field Adjustments

Devices should be carefully adjusted in the field and evaluated after installation to be sure they are working properly from an engineering perspective and from the perspective of pedestrians who are visually impaired. If the APS has been added in response to a request from a pedestrian who is blind or visually impaired, that individual should also be involved in evaluation after installation.

Because installers may be unfamiliar with new types of APS devices, extra supervision and attention will be required during the first few installations by any crew or contractor. Even when carefully specified, installations sometimes do not match the specifications because installers do not understand that failure to exactly follow specifications may lead to an installation that cannot be accessed by pedestrians who use wheelchairs or could cause a pedestrian who is blind to push the wrong pushbutton, veer into the center of the intersection, or mistake which crosswalk has the Walk interval and start crossing at an unsafe time. The sound level of the speakers must be carefully set and evaluated at the time of installation, and then checked at a time with different traffic volume to assure that settings are correct.

Setting and Evaluating Sound Levels

In general, installers have a tendency to set volume levels of devices too loud. The Walk indicator must be audible

from the beginning of the crosswalk, according to the *MUTCD* 4E.06 Standard (*1*). *MUTCD* 4E.06 and 4E.08 Guidance states that the locator tone and walk tone of an APS should be at the same volume (except by special actuation, providing a louder tone for a single pedestrian phase) and specifies that the locator tone should be audible 6 to 12 ft from the pushbutton, or to the building line, whichever is *less* (*1*).

Most devices require setting microphone sensitivity or automatic gain control (AGC) sensitivity, volume of the pushbutton locator tone, and volume of the Walk indication.

The microphone sensitivity or AGC controls how the other tones or message volumes respond to ambient noise levels. The correct setting will vary depending on whether there are buildings close to the APS and the presence of split phasing or of slip lanes. When buildings are close to the APS, the sound reflected from the buildings will make the sound seem louder. The reflected sound may also influence the microphone and AGC such that the APS will sound louder for the same setting than if the APS were in an open area. At intersections having split phasing, APS at parallel crosswalks must not be audible across the street (at the other crosswalk) or users may begin crossing with the wrong Walk signal. This should be checked at times of low ambient sound as well as at times with normal sound.

Sound levels should be between 30 dB minimum and 89 dB maximum. At no time should the sound level be more than 5 dB above ambient sound (except by special actuation for audible beaconing). The *Draft Public Rights-of-Way Accessibility Guidelines* (*4*) specify that the sound level should be between 2 and 5 dBA above ambient sound, measured 36 in. from the pole. Manufacturers typically set a maximum and minimum output level on APS devices. The maximum should be 89 dBA, as required by Occupational Safety and Health Administration (OSHA) regulations. Preset automatic gain controls cannot assure that the volume meets the criterion for distance at which the APS should be audible. Similar automatic volume adjustment settings on APS by different manufacturers may seem to provide quite different loudness, as judged by listeners. Automatic volume adjustment technology used by different manufacturers varies in the rate of sampling of ambient sound and in the speed with which output adjusts to changes in ambient sound. Some APS and some installations will be more subject to responding to their own noise than others. For example, as the Walk signal continues throughout the walk interval, the signal may get louder and louder in response to its own noise. Different tones or speech will seem louder or quieter depending on their frequency content, although they may measure the same on the dBA scale. The setting of the microphone sensitivity must be adjusted by the installer to provide output at one of a number of ranges between the maximum and minimum. The number and width of ranges varies by manufacturer.

Because of the short duration of pushbutton locator tone and Walk tone pulses, conventional analog or digital sound level meters are not able, in the crosswalk environment, to accurately measure dBA of APS tones or the sound level of APS tones relative to ambient sound. At present, setting and evaluation of APS sound level is typically done by ear. It is critical for the Walk indication to be audible at the crosswalk waiting location.

At crosswalks where audible beaconing is needed, the decibels should be evaluated from the middle of the street when the loud Walk indication has been called, to be sure beaconing will be provided throughout the crossing. However, OSHA limits the maximum output of APS to 89 dB, and most manufacturers preset this maximum. Therefore, at exceptionally wide crossings and when and where there is high ambient sound, there may be a distance in the middle of the crosswalk where the beaconing is not readily heard.

Microphones for pedhead-type APS are typically in or on the pedhead, incorporated into the APS. Pushbutton-integrated devices may have microphones at the pedhead or the microphones may be incorporated into the pushbutton housing. An APS microphone should be mounted as close as possible to the position of the pedestrian who is waiting to cross the associated crosswalk, because sound pressure is halved for each doubling of the distance from the sound source in a free field.

Installation of Speakers and Microphones

Speaker location and orientation need to be checked against the specifications. Installers should make no change in speaker location or orientation without checking with the responsible signal engineer. Poorly located speakers can result in ambiguous information about which crosswalk has the Walk interval, failure of blind pedestrians to begin or end crossings within the crosswalk, and veering of blind pedestrians outside the crosswalk, possibly into conflicting traffic.

Incorrect speaker location can make a difference in the ability of pedestrians who are visually impaired or blind to discern which APS is sounding. Each APS speaker at a corner must always be closest to the crosswalk it signals. For pedhead-mounted APS, speakers should not be automatically located on the pedhead that signals the same crosswalk. The pedhead closest to one crosswalk may signal the perpendicular crosswalk. In this case, speakers must be mounted on the pedhead for the perpendicular crosswalk.

The speakers should be adjusted so the pushbutton locator tone can be heard by a pedestrian approaching the corner from both the sidewalk side and the street. However, it is critical that the APS Walk indication can be heard at the beginning of the crosswalk.

Specifications for installations should include speaker orientation. Precise orientation of the APS speaker is especially critical at locations with audible beaconing. If a speaker or transmitter is oriented even a few degrees out of alignment with the associated crosswalk, pedestrians may inadvertently travel out of the crosswalk, perhaps into the path of vehicular traffic.

Installation of Pushbuttons, Vibrating Surfaces, Signage, and Tactile Arrows

Pushbuttons must be within accessible reach range of a level landing for use from a wheelchair and no higher than 42 in. measured from the landing. They should be within 5 ft of the crosswalk lines extended and within 10 ft of the curb. Vibrotactile Walk information should be provided during the associated Walk interval by each APS equipped with a vibrating surface. If two pushbutton-integrated APS with vibrating surfaces are installed on the same pole, they may both vibrate during both Walk intervals if they are not properly insulated from the pole and spaced apart from each other.

The tactile arrow must be oriented parallel to the direction of the crosswalk controlled by the pushbutton. The installer should check that the arrow direction and pushbutton information message agree. APS have accidentally been installed with the message providing notification about the wrong street. When sound chips with the recorded speech message are part of the device or its control board, the installer must take care to install the proper device and control board in each location.

Follow Up on Installations

After an installation is complete, at each corner for each device, the installer should evaluate and adjust the locator tone volume, evaluate and adjust the Walk indication volume, and evaluate and set the sensitivity level of the automatic volume adjustment.

SUMMARY

The entire *Synthesis* is available in html and pdf formats at www.walkinginfo.org/aps, a website maintained by the Pedestrian and Bicycle Information Center. It includes a multitude of illustrations, detailed information on products currently available, and an extensive summary of past and current research. The html version includes sample APS sounds and an interactive matrix of the selection of APS devices by features.

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