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Older Pedestrian Characteristics for Use in Highway Design

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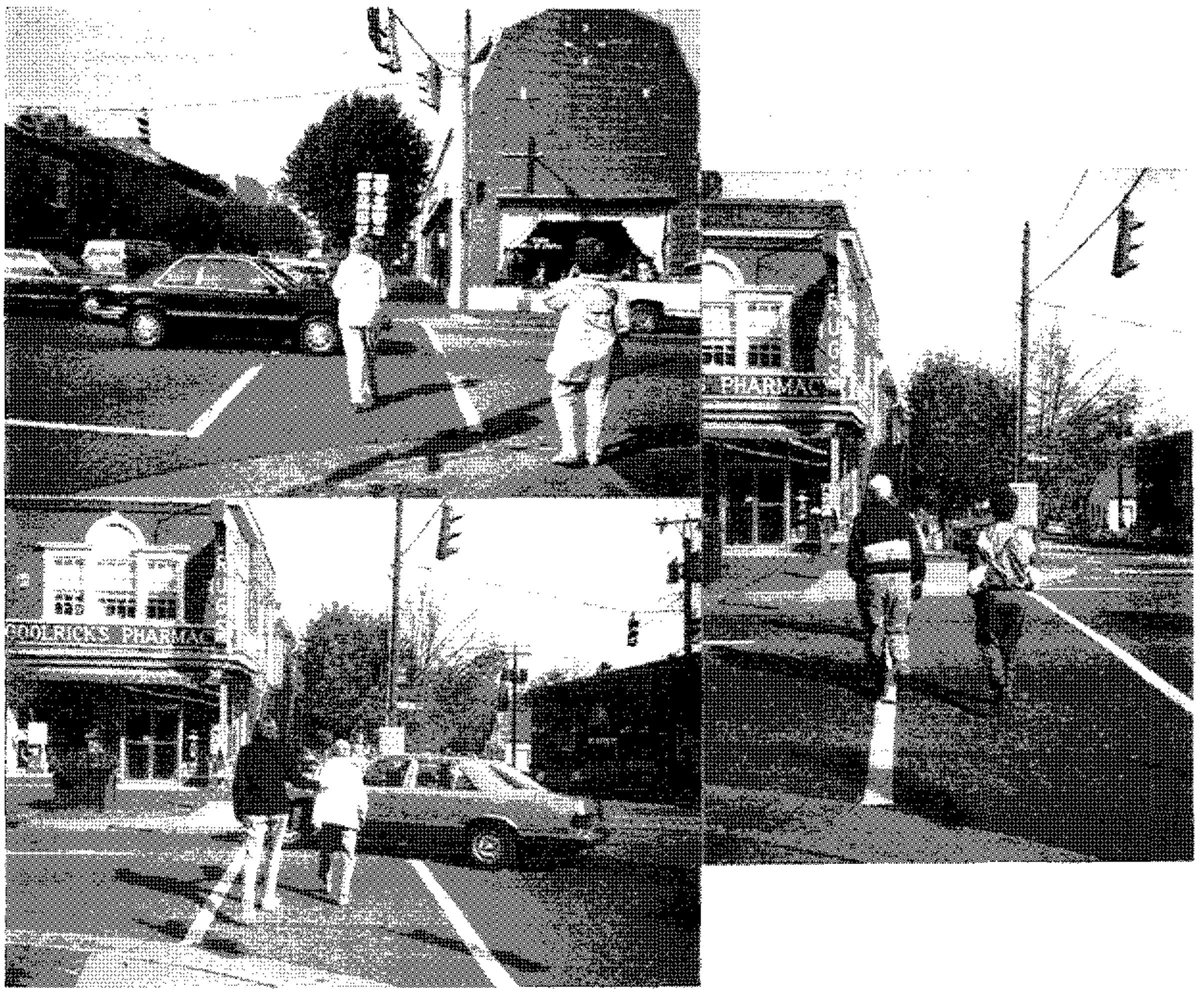

U.S. Department of Transportation

Federal Highway Administration

Research and Development
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22010-2296

FOREWORD

The proportion of those over age 65 in the North American population is increasing and will continue to increase dramatically. The majority of research on older road users focusses specifically on the older driver. However, today's traffic environment also is not well adapted to the needs of the older pedestrian. Unfortunately, older pedestrians have the highest pedestrian fatality rate of any age group, and little is known about the characteristics and behavior of older pedestrians.

The research documented in this report reviewed existing information on the mental and physical capabilities necessary for pedestrian activities by older persons. The research also identified gaps in the information pertinent to the functions essential for pedestrian movement by older persons. The results of the review and various other study activities were used to develop recommended changes to design standards and operational procedures to accommodate older pedestrians within the highway system.

The information contained in this report should be of interest to design engineers, transportation planners, and transportation engineers involved in the design, construction, and/or reconstruction of facilities within the highway system.

Sufficient copies of this report are being distributed to provide a minimum of one copy to each Region and two copies to each Division office and State Transportation Agency. Additional copies for the public are available from the National Technical Information Service (NTIS), Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161. A small charge will be imposed by NTIS.

Lyle Saxton, Director
Office of Safety and Traffic
Operations Research and Development

NOTICE

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16. Abstract
The objective of this project was to develop traffic planning and engineering guidelines for the design of pedestrian facilities that are sensitive to the needs of older pedestrians. A detailed task analysis and literature review were conducted to identify the aspects of the pedestrian's taks that are difficult for older persons, including motor, sensory, perceptual, cognitive, and behavioral factors. Several activities were undertaken to identify specific problems experienced by older pedestrians that could be addressed by changes in design stndards and operational practices. These activities included analysis of accident exposure data, a survey of older pedestrians, focus group discussions, and a survey of practitioners. It was determined that older pedestrians experience difficulties at signalized intersections and often do not have sufficient time to cross.

A field study was conducted to determine the walking speed, startup time, and stride length of older pedestrians. More than 7,000 pedestrians in 4 cities were observed in order to measure these parameters. Specific recommendations for changes to highway design and opertional practices are described.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

NOTE: Volumes greater than 1000 l shall be shown in m^3.

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

(Revised September 1993)

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- Martin Nizlek, Chairperson, and members of ITE Committee 5P-3—Pedestrian Characteristics for sharing the Committee's data base of pedestrian walking speeds. Comparison tables of the ITE data and the data collected during this project are presented in this report.

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INTRODUCTION

This report describes the work performed under the contract Older Pedestrian Characteristics for Use in Highway Design. The objectives and scope of the contract were as follows:

OBJECTIVE

To develop guidelines for the design of pedestrian facilities for older persons to be utilized by traffic planners and engineers.

SCOPE

A determination of the mental and physical capabilities required for pedestrian activities by older persons shall be made. Information on the actual capabilities of older persons shall be reviewed. Gaps in existing information on the mental and physical functions that are essential for pedestrian movement by older persons shall be identified and additional studies shall be designed and conducted to fill the identified gaps. Recommendations for changes in appropriate design standards and operational procedures to accommodate older pedestrians within the highway system shall be made.

The first project activity involved conducting a detailed analysis of the tasks of the older pedestrian and reviewing relevant literature on various aspects of the pedestrian task—motor, sensory, perceptual, cognitive, and behavioral factors. The purpose of this activity was to identify the kinds of problems older pedestrians are likely to experience in today's traffic environment.

The second project activity involved efforts to define more specifically the problems of older pedestrians identified in the task analysis, particularly those that could be addressed by changes in design standards and operational practices. Five activities were undertaken:

- Identification of Older Pedestrian Accident Characteristics and Exposure Data.
- American Association of Retired Persons (AARP) Survey.
- *Walking* Magazine Survey.
- Focus Group Discussions.
- Survey of Practitioners.

The problem identification studies, like the task analysis/literature review, found that older pedestrians experience a variety of difficulties. The most frequently identified problem that could be effectively addressed by changes in design standards was that older pedestrians have great difficulty at signalized intersections. Because of age-related changes in perception, response time, and motor abilities, they have difficulties crossing such intersections before the signal changes and traffic starts flowing again. What is not known is whether these problems are the result of older pedestrians not responding quickly to a signal change, or slower walking speeds, or a combination of these two factors. A field study was undertaken to quantify the walking speed and signal startup time of older pedestrians.

This field study provided quantitative information on the walking speed, startup time, and stride length of older pedestrians. This information was used to develop specific recommended changes to highway design and operational practices that are described in the last chapter of this report.

1. AN ANALYSIS OF THE OLDER PEDESTRIAN'S TASK AND RELATED MOTOR, SENSORY, PERCEPTUAL, COGNITIVE, AND BEHAVIORAL FACTORS

INTRODUCTION

The older road user has received plenty of attention over the past decade, and with good reason. The proportion of those over age 65 in the North American population is increasing and will continue to increase dramatically. Research papers and funding for related research have also increased. In 1992 FHWA sponsored eight ongoing major research projects on older road users. The nature of these projects indicates that older drivers, rather than older pedestrians, receive the majority of attention. Today's traffic environment is not well adapted to the needs of the older pedestrian. Unfortunately, except in the case of children, little is known about the characteristics and behavior of pedestrians. Older pedestrians have the highest pedestrian fatality rate of any age group. This cannot be explained by their exposure to risk. Older people are less likely to be pedestrians than are those in other age groups.[1]

Even though the driver's task is very different from the pedestrian's task, it is likely that most of the characteristics of older people that relate to driving also relate to safe pedestrian behavior, and that the sensory, perceptual, and cognitive limitations that disadvantage drivers also present problems for older pedestrians. No effort is made to present a thorough review of the relevant literature on older driver character-istics, as such reviews are already available through other FHWA contracts.[2,3] In addition, recent issues of the journal *Human Factors* have addressed the aging driver.[4] The essentials of this work are summarized here to incorporate the material on those characteristics of older people that is most relevant to the task of the older pedestrian.

This section presents related task analysis research that has addressed the pedestrian task.[5,6] A detailed task analysis based on this work is presented. Relevant research concerning key aspects of the pedestrian task—motor, sensory, perceptual cognitive, and behavioral factors—is also discussed. The following topics are addressed:

- The Pedestrian's Task.
- Visual Perception.
- Auditory Processing.
- Motor Abilities/Mobility Disabilities.
- Cognition.
- Behavioral Factors.
- Conclusions.

THE PEDESTRIAN'S TASK

In examining human performance in any activity, it is appropriate to first conduct a task analysis to identify the main components of the task. Task analyses are a means of developing and linking detailed data about personal capabilities and environmental demands in analyses of performance problems in daily activities (and Faletti provides a thorough introduction to the process).[7] The essential goal of task analysis is to define systematically the relevant points of transaction between the human operator and the environment in ways that specify what is being accomplished and what purpose it serves.

Although no such analysis appears to have been conducted for older pedestrians, the task analysis for child pedestrians by van der Molen et al., which identified 26 tasks, appears to apply to elderly pedestrians as well.[5] Behavioral requirements were first determined. Psychological processes such as recognition, identification, detection, and decision required for this behavior are discussed. Various types of factors are considered—environment (road type, intersections, surfaces, lighting, regulations), traffic (flow, moving and stationary vehicles, communication), personal (physical, personal characteristics, motivation, experience, psychological state), weather (rain, snow, ice), and social (presence of others, purpose of journey, play).

The van der Molen model provides a useful point of departure. However, recent studies suggest additional strategies that can be incorporated to break his analysis down to a microanalytical level. Hale and Glendon have suggested a model in which a person's abilities to operate successfully in a dangerous situation is dependent on three levels of abstraction of behavior.[8] At the *skill-based level*, incoming information produces an automatic response. We encounter a curb and descend it without much thought. We are usually skilled at using curbs. If the traffic signal is red, however, our behavior changes to a *rule-based level* and we wait. If there is no signal, no rules, then a *knowledge-based level* leads us to think briefly about the solution—wait for a gap in the traffic, hurry across, or abort the move.

The Hale and Glendon model was developed for occupational safety, as a way of understanding danger in routine tasks, for hazard detection, for danger labeling and assessment, and for developing safer behavior and designs. It is a system model that forms a matrix. The Y axis of the matrix consists of the knowledge, rules, and skill-based levels of functioning of people. The X axis sets out the classic system modes—input, processing, and output. The model uses these cells as points at which decisions about a danger are made at the levels of functioning within the system. For pedestrians, the Hale/Glendon model can be amplified by analyzing the perception and behavior by process.

The use of a sidewalk, street, or some other pedestrian area by one representative individual in a stream of pedestrians consists of several actions. Some of these take place sequentially and some concurrently. Templer discusses a behavioral task analysis, and then applies it to stair users.[9] Some actions entail deliberate decision making that affects the way the environment is used. The process is applicable to many environmental conditions and can be summed up as follows:

- Expectation (about the pedestrian environment).
- Perception (through scans of the environment).
- Detection (of information, hazards or obstacles).
- Cognition (understanding what has been perceived).
- Selection (of a route, and behavior).
- Action.
- Reaction (to any missteps, hazards, or obstacles).

The Conceptual Scan

In the conceptual scan phase, we scan and sample the parts of the visual array in succession.[10] We note fixed and variable factors to the best of our available perceptual skills. The fixed environmental components include the pedestrian element's disposition in space and its vicinity, approach and exit directional options, shape and layout configuration, obvious obstructions or potential hazards, and numerous minor details.

Beside these fixed factors, effective scans will encompass available information on the ambient conditions. Is the surface wet or slippery? How much light is available? Is there obstructive litter in the way? And, finally, what motion is taking place? For the latter, the scan provides information on whether people or vehicles are approaching, at what speeds, taking what routes, their numbers, sizes and ages, behavior, and whether they have affective characteristics.

Much of the information gathered in the conceptual scan is not immediately significant, but the human information system is skillful at layering impressions according to their current importance. Environmental details may be seen, but relegated to a level below consciousness, or selectively kept in the forefront of concern. For example, many directional signs are displayed in the subway system, and a stranger may selectively exaggerate their role in the visual field. To a native, though, the signs would no longer be consciously apparent, unless they were repainted or otherwise given some new significance. This is the same mechanism that selectively tunes out unwanted background noise and tunes in a particular conversation. The products of the *conceptual scan* allow us to form a *cognitive model* of the pedestrian environment.

Expectation and the Cognitive Model

During the conceptual scan and the subsequent location, and monitoring scans, the area is surveyed visually with *appropriate thoroughness*. This thoroughness is related to our *expectations*. Our expectations are compared to the newly formed *cognitive model*. If the two do not appear to match in some way, we are likely to abort the whole trip if the area looks dangerous. At least, we are likely to scrutinize the area more thoroughly. For example, we would examine an obviously muddy or icy surface with much greater care than a walkway stair inside a heavily used public building. On a wilderness trail, on the other hand, we know that the ground may be uneven, rocky or soft, with tree roots to trip on. So we scan the path more thoroughly than we would the corridor in an office building. Any violation of our expectations may turn out to be hazardous.

It is often a failure of expectations that causes falls on sidewalks that have surface irregularities. The scans fail to detect the dimensional differences. Expectation should not be confused with memory. Little of our experience is committed to memory for any length of time. It is not only the visual memory that is operational. All the senses play a part. For those with severe visual impairments, the auditory-sensory store may be even more significant than the visual memory. Thus, we would do better to refer to modality-specific sensory memories. Some sensory memories may be moved into short-term or working memory where information processing occurs. However, short-term memory capacity is not great; it can process or retain only a small quantity of information at a time. Also, if the information is not "rehearsed" because it is significant for some reason, it will be displaced rapidly by other incoming information.

If the results of the mapping process meet our expectations, we begin the *selection of appropriate behavior*—route and speed selection and so on. If our expectations are not met, if the walkway looks icy for example, we move to a knowledge-based level and consider whether to proceed or abort the trip. A decision to proceed again leads us to the selection of appropriate behavior. This is the equivalent of solving an equation containing several terms. This may be conducted at the skill, rule, or knowledge level depending on the circumstances. The scanning will have provided values for some of these factors—the fixed and variable conditions extant on the stair. However, powerful regulatory, motivational, and physiological pressures will be controlling factors.

Conforming to cultural norms is an example of a controlling pressure—avoiding physical contact with others in a crosswalk or obeying traffic rules, for example. Another factor might be trip urgency, which would govern speed, overtaking, and the choice of an appropriately short route. Distractions in the field of vision could also have an effect—trying to maintain visual contact with the subway train at the foot of the stairs, for example, to see if the doors are still open.

Personal, physical, and psychological factors could be influential. Weariness or wearing high-heeled shoes might dictate a route with a handrail, and so might timidity, infirmity, personal preference, or icy conditions. And, finally, the route selected might be affected by the direction from which a pedestrian approaches the crosswalk, and likewise by the eventual destination. These controlling factors are discussed in greater detail later.

Meanwhile, movement continues. Just before we take the first step down a curb, for example, we scan further. This first *step scan* is a close-up fixation looking down at the curb to locate it accurately in space. Frequently at this point there is a noticeable hesitation in forward movement before we take the step down. This is accentuated by the inevitable change of horizontal speed that must occur. Locating the curb accurately and placing the foot is a matter of some care, particularly for the elderly, the very young, and the physically handicapped.

After this rather deliberate step, the gait relaxes into the normal rhythmic pace, followed by a series of *monitoring scans*. These scans are simply a continuation of the conceptual scans, used to detect new information as it becomes available—as new areas enter the visual field, and as changes occur in the fixed and variable conditions, particularly changes in the movement of people and vehicles.

During the monitoring scans, we search the crosswalk for obstacles to travel, such as vehicles, people, objects on the surface, or ice. Any obvious impediments cause us to regress to make the appropriate behavioral choice. If there are no obstacles, we continue to advance until the trip is completed. During the whole advancing process, we constantly monitor ambulation. If gait continues to be normal, we continue to advance. However, if we detect a loss of balance, a trip, a slip, or any other event that may cause a loss of balance, we trigger gait modification and fall avoidance reactions.

Information about the crosswalk or the place through which we are walking is gathered during eye scans of the area ahead, as is anything that catches our interest. These scans are coupled with regular glances down at the surface on which we are walking. The frequency and duration of these glances is related to how regular, even, and generally safe the surface appears to be. Walking on a concrete sidewalk that is clean, dry, and in good condition may promote a relaxed awareness with few glances at the ground.

Route modification may then take place as conditions change, as new factors concerning the fixed and variable conditions are understood and as personal motivations alter. Route modifications will involve interpersonal transactions with regard to territoriality. These are resolved usually through normative behavior.

If a loss of balance occurs for some reason, a series of involuntary, and then voluntary, actions will be triggered. These may be successful, leading to some behavioral and gait modification. If there is not enough time for an appropriate reaction, or if the reaction is not successful, a loss of balance or a fall may ensue.

The appendix of the van der Molen paper details the elements of the task—purpose of trip, route selection to minimize the number of street crossings, preparation for trip. In starting across the street, pedestrians should consider the following: selecting a place with a good view of traffic, a straight road, away from parked cars, with a traffic island available to stop, where other pedestrians are crossing, and where there is good street lighting at night. It is also essential to try to communicate their intentions to drivers. Pedestrians should not assume traffic will stop at crosswalks where pedestrians have priority.

Van der Molen's analysis specifically addresses the task of child pedestrians. It also addresses many of the issues facing older pedestrians. Van der Molen's original listing of 26 child pedestrian tasks has been modified to 24 tasks more specifically targeted to the older pedestrian. This modified task description is presented as appendix A of this report.

VISUAL PERCEPTION

As with driving, the information essential for safe pedestrian behavior comes almost entirely from vision. Upon approaching the curb, pedestrians may begin to assess their chances of crossing safely before reaching the roadway to be crossed. An estimate of when oncoming traffic will reach their crossing area or when the traffic signal will change in their favor will help determine whether they should pick up the pace to cross at the earliest possible time or take their time, as they will reach the crossing point before it is safe to cross.

Upon reaching the crossing point, pedestrians must either wait for the signal to change at a signalized intersection, or decide when a gap in the traffic is sufficient to cross safely. Information on the former comes mainly from looking at the signal, or (for the blind) listening to traffic noise or auditory signals at the rare intersection that has such signals. Where the traffic is not controlled, the decision becomes much more difficult, unless traffic is light, and the information processing and judgment skills required are more sophisticated.

The main information processing skills required to make safe judgments about when to cross the street at a signalized intersection are visual acuity (to read pedestrian walk signals), and color perception (to discriminate red and green traffic signals). The latter may be of little importance, as the condition of the signal can be determined by the direction of traffic flow at any specific time. At uncontrolled intersections, correct perception of the distance and speed of vehicles is essential. Peripheral vision may also be important if pedestrians do not take the time to scan the roadway environment properly for traffic—a turning vehicle may be detected only at the last second as the pedestrian enters the roadway. Whatever the roadway configuration, there are potential problems for pedestrians and drivers alike under poor visibility conditions such as darkness, snow, or fog. Visual information processing becomes even more difficult at night when the streets are wet, due to glare off the road surface from vehicle headlights and street lights. This problem is worse for older road users.

There are five main dimensions of visual function:

1. Visual processing speed (reading).
2. Light sensitivity (seeing in low illumination).
3. Dynamic vision (seeing things in motion).
4. Near vision (reading small print).
5. Visual search (locating targets).

Numbers 2, 3, and 5 are relevant to the pedestrian's task of crossing the roadway.

Many biological changes in the normal aging process influence vision. The largest factor in visual aging deterioration is increased absorption and scattering of light in the crystalline lens. Changes in spectral absorption of blue light are such that elders have trouble seeing blue light as less of it gets through to the retina.

Reduced visual abilities can be assumed for nearly all elderly pedestrians, and these difficulties need to be considered in determining how best to communicate visually with these road users. The normal aging process results in the following reductions in visual abilities:

- Decrease in visual acuity begins at age 40.
- Less light gets into the eye as pupil size decreases and the lens yellows with age.
- Glare sensitivity increases and recovery takes longer.
- Contrast sensitivity is reduced.
- Size of the visual field is reduced.
- Visual acuity and contrast sensitivity are reduced under low light conditions.
- More time is required to change focus.
- Eye movements are slower and scanning is less efficient.

A number of eye diseases are more prevalent among older road users. The most important ones are macular degeneration, glaucoma, cataracts, and diabetic retinopathy.(11) Cataracts are four times as common among 75- to 85-year-olds as for 52- to 64-year-olds (21 vs 80 percent), while age-related maculopathy is doubled. The extent to which this affects older pedestrians is difficult to say, but may play a part in their ability to take in essential visual information under some circumstances.

Shinar and Schieber have summarized the main visual requirements for older drivers.(12) They report a reduction in three "simple visual tasks"—photopic visual acuity, mesopic static acuity, and static acuity in the presence of glare—for older drivers. However, age-related deterioration is much more significant for three "complex visual tasks"—dynamic visual acuity (ability to see clearly objects that are in motion), central angular movement (accurate perception of objects moving across the line of vision), and central movement in depth (the ability to perceive changes in the size of the visual image of an object as it approaches us). This last variable is an important cue in judging the speed of an approaching vehicle and has been correlated with traffic accidents in drivers over age 50.[13] Deterioration begins in the late fifties for all three of these visual abilities. Training in visual skills has produced some success in improving dynamic visual acuity, central angular movement, and visual search.[12] Perhaps it should be attempted with older pedestrians.

Sensory deficits of drivers generally do not correlate well with traffic accidents.[13] However, mesopic acuity and dynamic visual acuity are reasonable predictors of accidents among the elderly. This is understandable, as drivers have more difficulty finding and interpreting roadway information under night driving conditions than during the day, and most relevant information is dynamic in nature, as drivers and other vehicles are almost always on the move. Judgment of speed and distance of moving objects is central to the driving task. Many of these observations can also apply to the older pedestrian.

Visual Acuity

Visual acuity not only deteriorates with age, but is found in a variety of vision problems in the general population. At age 70 only about 25 percent of people have 20/20 vision. Frequently their vision cannot achieve this level even with corrective lenses, and many people have glasses with prescriptions that are out of date. It has been shown, for example, that between 5 and 10 percent of drivers 60 to 65 years old have corrected visual acuity worse than 20/40.[14] Acuity declines gradually with age, then more rapidly after age 60. One study showed that 10 percent of adults between the ages of 65 and 74 and 30 percent of those over age 70 had acuity worse than 20/30.

Accommodation

With age there is a loss in the amplitude of accommodation (i.e., presbyopia). The lens thickens and is less able to contract and focus near objects so that by the age of 60 almost no accommodative capacity remains. Eventually people need reading glasses. In addition, there is a slowing of the accommodation to nearer objects. This is unlikely to affect the task of the pedestrian unless there is a need to read small print on a sign. This problem is worse in low light levels. Under degraded conditions, including reduced ambient illumination, the accommodation time of older people is many times greater than that of younger ones.

Conspicuity and Contrast

Several factors determine whether visual information will be easily noticed. The most obvious is size. The color of an object and its contrast with the background are also very important. Light colored targets are generally more conspicuous, but conspicuity depends mainly on the degree of contrast with the surrounding background. In terms of sign legibility and conspicuity, Yee found that 25 percent of elderly drivers experienced problems reading traffic signs.[16] Of these, 42 percent reported problems with sign placement, size, clarity of lettering, clarity of message, and difficulty more often in and around cities. However, the problem is based not only on visual impairment but also on reaction time, decision making, and problem solving. Scene complexity is also a significant determinant in sign detection. Older drivers require more contrast between the message and the background of a sign than younger drivers. Legibility losses with age are greater at lower levels of background luminance.

An important visual function that has received attention only in the last 3 decades is contrast sensitivity or the ability to discriminate objects from their background. It has been found to be a more appropriate measure of a person's spatial abilities than acuity. Reductions in contrast sensitivity occur for older people mainly with small- and medium-size objects.[16] A 60-year-old needs about 2.5 times the contrast as a 23-year-old. This is a real disadvantage at night for older pedestrians.

Difficulty seeing a vehicle against a street background may occur with vehicles of certain colors; those that blend in with the surroundings are less likely to be noticed. This is less of a problem at night, with headlights readily visible, except in complex urban areas where many other lights distract and confuse some pedestrians. Another nighttime factor that can make some vehicles difficult to see is the combination of certain types of street lighting and specific vehicle colors. The problem of poor vehicle conspicuity should gradually disappear in those countries that require daytime running lights. It should be noted that pedestrians typically believe they can be seen by motorists at a greater distance than they can actually be seen by drivers.

Visual Fields

Absolute loss of the visual field occurs with age. Johnson and Keltner report that visual field loss is more significant after age 60.[17] Another significant change is senile miosis, in which the size of the pupil decreases so that at about age 60 there is one-third the light reaching the retina as at age 20. This reduction in peripheral vision can disadvantage older pedestrians. Drivers with a significant binocular visual field loss have been found to have traffic accident and conviction rates twice as high as that of drivers with normal fields.

Night Vision

At night, pedestrians often move under conditions where some degree of illumination is present. However, many pedestrian fatalities occur on rural roads where the only light may be from headlights. It has been clearly demonstrated that visual sensitivity declines significantly as stimulus luminance decreases from daytime to low photopic and/or mesopic levels, especially for older people. Older subjects perform worse than younger subjects on legibility tasks because of vision deficits rather than deficits in information processing.

With age comes elevation of both cone and rod thresholds. Thus, it takes old eyes longer to adapt to darkness and to recover from glare. As a result, peripheral stimuli need to be much brighter to be detected or to capture the pedestrian's attention.

Glare and Glare Recovery

Glare is a significant source of visual interference. Older pedestrians sometimes see a shiny floor (from highly polished surfaces or from streaks of sunlight) as slippery, and hesitate to walk on it. On the roadway, glare is aggravated by wet roads and specular reflection, headlights, and stray light sources. Water reduces the contrast of pavement markings because the roadway is only 1/5 to 1/10 as bright when wet as when dry.

Glare occurs in three main situations: (1) when stray light is distributed across the retina, reducing contrast (veiling glare), (2) when details to be seen are presented in an overly bright visual display (dazzling glare), and (3) during the extended recovery period after exposure to an intense light source (scotomatic glare). Susceptibility to glare of all three types appears to increase in older adults.[(18)]

A study by Burg on age differences in illumination thresholds for form recognition found that recognition in glare, as well as recovery time from glare, were markedly greater among older observers.[(19)] Glare recovery times were 3.9, 5.6, and 6.8 s for people aged 20 to 24, 40 to 44, and 75 to 79, respectively.

Wolf examined age differences in target identification with and without veiling glare.[(20)] Even without glare, the illumination required to identify targets increased with age. Under glare conditions, age differences increased, especially past age 45.

Reductions in contrast sensitivity may account for the glare differences seen with age.[(16)] Schieber and Williams report that age-related reductions in contrast sensitivity under nighttime glare conditions may be greater for the low spatial frequency components (larger details) than for high frequency components.[(21)] This has important implications for the visibility of pedestrians at intersections at night.

Field Dependence

Field dependence is a cognitive style that involves modes of perceiving, remembering, thinking, storing, and using information. Older people are more field dependent; that is, they have more difficulty ignoring irrelevant information in the visual scene and are more easily distracted. Field-dependent people also need more time to process visual information and are less effective with the road visual search behavior. They also restrict visual fixations and are slower at visual search.

Visual Search

There are age-related deficits in ability to scan or search the environment. Older people are slower and make more errors in visual search tasks where they are to decide whether or not a target is present. Reducing attentional demands improves their speed of visual search. Visual search behavior of drivers has been found to be less efficient after age 50.

A recent concept in information processing is the useful field of view, an attention measure in which the subject must locate and identify peripherally presented complex visual stimuli. This ability has been found to decline markedly with age.[22,23] Evidence also suggests that this measure is a better estimate of the difficulties that older persons have with peripherally located real-world targets than are traditional field size measurements that assess only the presence of very simple stimuli.[24]

Attention

Research on older drivers indicates that safe driving is not well correlated with basic sensory functions such as static acuity, depth and color perception, or visual field, the measures typically made for driver licensing. Rather, the most important factor appears to be driver attention. Work by Treat et al. indicates that approximately 40 percent of traffic accidents that involve human error have some aspect of information processing as a contributing factor (e.g., improper lookout, inattention, internal distraction).[25] It is difficult to say whether these factors play a comparable role in pedestrian accidents, but it is reasonable to assume they are important.

As a significant proportion of pedestrians have some limitations in their range of movement, difficulties can arise in scanning the roadway environment for vehicles. The elderly may take less care to look properly down the road and will often be slower in their search behavior.

Environmental Factors

Wet conditions at night create a significant glare problem from street lights and head-lights reflecting off the road surface. One study asked drivers to describe conditions under which their driving ability was "worse than it was 5 years ago."[26] Results indicated the main problems to be: headlight glare (25 percent), night driving (25 percent), rain and/or fog (19 percent), rush hour driving (19 percent), long distance driving (18 percent) and snow, sleet, or slush (14 percent). Such conditions will also present problems for older pedestrians.

Visually Impaired Pedestrians

Visually impaired pedestrians have special difficulties crossing the street and walking in the traffic environment. Not only are they unable to see traffic hazards, their walking speed is also affected. A study by Clark-Carter et al. found that the blind prefer to walk at a speed close to that of sighted people, if allowed to set the pace when accompanied by a sighted person.(27) However, when walking alone they adopt a slower pace than their preferred walking speed. The authors introduce a new concept— "Percentage of Preferred Walking Speed" or PPWS—that they consider to be an index of confidence and physiological stress. Their study showed that the PPWS was less (about 72 percent) for complex, as compared with simple (93 percent) or medium complexity (90 percent), routes. PPWS was greatest when using a guide dog (100 percent), but was also high (90 percent) when using a long cane.

In another study of walking speed in the visually impaired, Beggs had pedestrians make a short (100 m [328 ft]) journey in a suburban street with a number of obstacles and then complete a mood checklist.(28) He concluded that PPWS was related to distress—lack of confidence and cognitive anxiety. Visual factors such as acuity were not related to walking speed.

AUDITORY PROCESSING

It is obvious that the visual sense provides the greatest amount of information required by the pedestrian, unless that person has a visual deficit. The visually impaired must rely on other senses, especially hearing. They often rely on hearing traffic noise to evaluate the distance and speed of traffic, and the direction of traffic flow.

Older people have a number of potential auditory problems, including higher thresholds for sounds, especially high frequency ones (> 3000 Hz), and decreased ability to filter out background noise.(29) Thus, it is more difficult for them to hear in noisy environments.

The most prevalent source of disruption of auditory communication is ambient noise from traffic. One of the best sources on the effects of noise is Kryter.(30) Noise is a particular problem for older pedestrians who have decreased ability to filter out background noise, and more difficulty hearing in noisy environments than younger people with similar hearing ability. The extent of masking depends on the intensity and frequency of the sounds. In the case of relatively pure tones (as might be used for a warning), the masking is greater if the frequency of the noise is similar to that of the tone. Therefore, warning signals should be very different from the dominant frequencies of the environmental noise. There are four aspects of a warning signal:

1 Detection—was a signal heard or seen?
2 Discrimination—discriminate differences between two or more signals (was it this or that?).
3 Absolute identification—identify a specific signal.
4 Localization—determine where the signal is coming from.

The first two are the most important. A signal must be discriminated from background noise well enough to indicate that it is a warning and must then be identified as a warning about a specific hazard or event. The detection of an auditory warning depends on its intensity (louder is better up to a point); frequency (high frequency is more attention-getting, but does not carry as far as low frequency; and background noise (a signal should be as different as possible from the ambient noise). The concern about problems with hearing and noise relate specifically to the use of audible pedestrian signals for the visually impaired. These are discussed in the section on traffic control devices.

MOTOR ABILITIES/MOBILITY DISABILITIES

Pedestrian Trips

Older persons make fewer and shorter trips than younger persons.[31] Nevertheless, the elderly who do not have driving licenses make 20 to 40 percent of their trips by walking.[32] In one study, the most common trip purpose among older persons was "shopping/personal business"; few trips were work related.[31] Other frequently mentioned trip purposes were "relaxation/ enjoyment" and "religious activities." Many of these resources were reported to be beyond walking range. In San Francisco, food stores were beyond walking distance for most . . . they could only carry light loads because of hills.[32]

For those aged 65 to 80, 12 to 15 percent walk to shops; for those over age 85, 50 percent walk to shops.[33] Those over age 65 walk 45 km (28 mi) annually in the United States, 483 km (300 mi) in Denmark, 450 km (280 mi) in Germany.[34] Less than 12 percent of all trips for those under age 80 and 20 percent for those over age 80 are pedestrian trips.

Physical Limitations

Public Health Service Health Information Survey (HIS) data in 1983 show that less than 10 percent of people aged 65 to 74 reported they could not walk 0.40 km (1/4 mi); 7.9 percent of men aged 60 to 64 and 8.7 percent of men aged 70 to 74 reported that they could not walk 0.40 km (1/4 mi). Almost 40 percent of respondents over age 85 had difficulty in walking. However, 50 to 70 percent of those over age 65 had no difficulty with walking and related tasks.[35] These limitations suggest that provision should be made for seating and resting places for the elderly.

Physical Condition and Functional Impairments

As people age, there is a concurrent loss of physical strength, grip force, joint flexibility, agility, balance, coordination and motor skills, manual dexterity, stamina, stature, reach, and biomechanical motions, thermal sensitivity, difficulty in walking, sitting down, standing up, and turning. There is also an increase in fear for safety, and frequently physiological responses to medication. All and any of these deficits may limit an elderly pedestrian's activities.[37] Furthermore, there is a lack of systematic data on the characteristics and capabilities of older adults. In part this is because, as Staplin et al. have pointed out, it is difficult to specify the "normal" population of the aged.[2] Older adults display much greater variability than do other age groups. This presents problems for research design and sampling considerations. In cross-sectional studies that contrast older and younger subjects, differential performance may be due to cultural and historical experience rather than to age. In longitudinal studies that track performance of age cohorts over time, the problem is subject attrition. The least healthy die, leaving only the healthiest people in the sample.

Many of the elderly are also disabled, and use assistive devices such as wheelchairs, walkers, canes, crutches, or other prostheses. While there has been recent legislation affecting mobility issues of the disabled, little of the research has separated the needs of the elderly from the rest of the disabled population, and the needs of the disabled elderly from those of the elderly. Obviously, it is inappropriate to aggregate data for the elderly with those who are handicapped, e.g., 20-year-old vs 80-year-old in a wheelchair.

Stature

Older people are shorter in stature than younger adults. A 95th percentile male 18 to 24 years old is 1.88 m (74.4 in) tall. A male between the ages of 64 and 74 of the same percentile is about 0.76 m (3 in) shorter, 1.81 m (71.6 in). Some of this difference can be attributed to anatomical as well as postural changes. The reduction in stature may affect pedestrian stride length and/or walking speed as well as the design requirement for amenities such as handrails.

Arm Reach, Strength, and Agility

Functional arm reach may diminish because of decreased mobility of the joints. Similarly, strength and agility diminish and these physical changes are age or disease related. The 10 most prevalent chronic conditions, for all persons over age 45, increase with age.[37] For example, 40 percent of those between 65 and 75 years of age have arthritis compared to 30 percent between those aged 55 to 64, and 20 percent of those aged 45 to 54. In a study by Brody et al., 66 percent of elderly people with normal mental functioning had arthritis, 45 percent had foot trouble, and 33 percent had visual impairments.[38] These conditions significantly affect the ability of these pedestrians to operate door furniture, telephones, fare boxes, vending machines, drinking fountains, parking meters, handrails, and anything that requires physical manipulative strength and precision.[39] However, the extent of limitations imposed by these disabilities has yet to be determined.

Motor Skills

Speed of simple motor response diminishes with age.[2] However, the decrease is small and can be compensated for with practice. Any slower reaction time is probably a result of a slower decisionmaking process.

Walking Speed

Older pedestrians walk more slowly than younger ones. For example, Dahlstedt instructed a group of people aged 70 or older to cross an intersection at fast, very fast or normal speed.[40] Fast for about 60 percent of the group was less than 1.2 m/s (4 ft/s); normal for 90 percent of the group was also less than 1.2 m/s (4 ft/s), and the 85th percentile speed was about 0.6 m/s (2.2 ft/s) with 15 percent slower.

The *Manual on Uniform Traffic Control Devices* suggests an assumed walking speed of 1.2 m/s (4 ft/s) to be used in signal timing.[41] A literature review by McGee et al. suggests that many pedestrians—perhaps 30 percent of the population, many of whom are older—do not walk that fast normally.[42] In fact the MUTCD also notes that one-third of all pedestrians cross more slowly, with 15 percent at or below 1 m/s (3.5 ft/s). The *Manual* states that "those having slower walking speeds have the moral and legal right to complete the crossing once they have entered the intersection."

The *ITE Handbook* suggests that 0.9 m/s (3 to 3.25 ft/s) would be more appropriate.[43] ITE Committee 4A-6 conducted a survey at a Florida location with a large population of elderly pedestrians, and they recommended 0.75 m/s (2.5 ft/s) as an appropriate walk speed (for this type of location).[44] They found this to be adequate for 87 percent of those observed.

However, walk speeds depend on environmental, traffic, and pedestrian characteristics. The effects of terrain on walking speeds are unknown; one would expect the elderly to react more to gradient than do younger groups. Similarly, because of their fear of traffic, one would expect the elderly to react more strongly to vehicular density and traffic speed. Moore noted that the closer the approaching vehicle, the faster the mean crossing time—1.5 m/s (5 ft/s) if the approaching vehicle was 3 s away, 1.2 m/s (4 ft/s) if the approaching vehicle was not close.[45] Finally, pedestrian speed on sidewalks and crosswalks is strongly related to the number of pedestrians in the flow. The relationship between speed, flow, and space occupied for a representative population group has been set out by Fruin and others. The capabilities of the elderly in crowds has yet to be documented.[46]

Accidental Deaths and Injuries (Nontraffic)

Elderly people suffer a high rate of accidental injuries and fatalities. Among people 65 years and older, an average of 116 die per 100,000 population in that age group, as compared to 47.7 for all ages. After rank ordering the 49 most dangerous categories (excluding motor vehicle accidents) based on data from the National Electronic Injury Surveillance System, Czaja et al. concluded that floors, flooring materials, steps, and stairs are the most hazardous, accounting for 41 percent of all injuries.[47,48] Floors and flooring materials are the most hazardous category for ages 75 to 79, and the second most hazardous category for ages 60 to 74. Steps and stairs are the most hazardous category for ages 55 to 74, the second most dangerous category for ages 75 to 89 and 95 to 99, and the fourth most hazardous category for ages 90 to 94, perhaps because these age categories realize stairs are hazardous and avoid them.

Falls

In the United States, nearly 12,000 people die every year after a fall from one level to another or a fall on the same level.[49,50] In fact this estimate may be significantly low because death certificates may not list the fall as the primary cause of death.[51] According to the National Safety Council, about 12 million people in the United States are injured seriously enough every year from falls to require at least 1 day of restricted activity or medical attention.[49]

Motor vehicle accidents are the largest cause of accidental deaths every year in the United States (45,000). Falls are the second largest, causing more than twice as many deaths annually as drowning (5,000), or fires and burns (5,000).[49]

Injuries resulting from falls is an epidemic that plagues the elderly more than any other segment of the population. Three-quarters of those who die after falling are 65 years old or over. Of course, this may reflect their increased fragility or their decreased ability to recover from their injuries as much as their likelihood of falling.

Steps and Curbs

According to the U.S. Consumer Product Safety Commission, steps and stairs are the most dangerous products, apart from motor vehicles.[52] In 1991, in the United States, nearly 998,871 people received hospital treatment for injuries resulting from stair accidents, and about 45,948 were hospitalized.[47] From similar 1976 data, nearly 4,000 died.[53] Stair accidents that are serious enough to disable the victim after the fall amount to between 1.8 and 2.6 million per year.

Although most step and stair falls occur in the home, 25 percent do not. Three-quarters of those who die as a result of stair falls are 65 years old or over. Females are more likely to fall than males.

The general principles for safer step and stair design have been set out by Templer.[9] He notes the particular hazards connected with the occurrence of one or two steps in a walkway, where they may not be pérceived. This problem may be compounded by shadows and low lighting levels.

Curbs are a special variant of steps. They tend to be irregular in dimensions and not set flush with the sidewalk. Some high curbs may be beyond the physical strength of many elderly people, but these heights have yet to be determined. Some very low curbs may not be adequately visible.

Walkway and Pavement Surface Irregularities

With diminished agility, vision, and ambulatory skills, elderly people are more likely to fall as a result of walkway and pavement conditions—sidewalk cracks, tree roots, pavements and potholes, unstable surfaces, and similar environmental conditions. Furthermore, some frequently used walkway materials such as brick, stone, and concrete pavers may be inherently less regular. These conditions are treated by Templer, Lewis, and Sanford.[54]

Ramps

Ramps, particularly curb ramps, have become a ubiquitous component of our streets and buildings. They offer much less of a barrier to wheelchairs and shopping carts than steps and curbs. Ramps, however, are not for everyone. Many people who use crutches or have certain kinds of balance problems will avoid ramps and use steps if given the choice. Furthermore, there have been complaints that people with limited vision or no vision may unintentionally wander down a ramp into the street.

Ramp gradient and length are particularly significant dimensions for the elderly. The ability of the elderly to climb hills and ramps is related to their stamina and strength; these factors are discussed by Templer and Wineman.[55] Ramp gradient is also significant for strength, but is critical for avoiding injuries from slips. Curiously, the choice of appropriate coefficients of friction (COF) for ramps and sloping walkways has yet to progress beyond the speculative phase.[9]

Surface Smoothness, Slips, and Falls

It is unclear how many elderly people are injured as a result of slips on walkways. It has been suggested that the elderly are less likely to slip than the rest of the population because their walking speed is slower, and thus pacing distance is less, and there is a strong correlation between slips and pace. On the other hand, gait stability tends to decrease with age and more falls occur. Therefore, the elderly may be less able to abort a slip than younger people.

Slip resistance is affected by the characteristics of the floor surface, waste deposits and precipitation (ice, snow, rain, or hail) on the surface; temperature and humidity; the composition of the shoe materials; any coating on the floor material; and human factors. The minimum value of COF needed for safe locomotion is influenced by the fit of the shoes; individual gait and speed; age, physical condition, and walking skill level; direction of movement, type of task being performed (perhaps pushing something); and behavioral responses. Not all of these can be accurately assessed and certainly not their cumulative and interactive effects.

There is general agreement that a COF of 0.5 may be adequate for most people walking on the level (but perhaps inadequate for some people using walking aids). This figure may be inadequate for wet surfaces and therefore for external walkways. However, pedestrians normally decrease their walking speeds when the conditions appear to be slippery.

Fear for Safety

Two-thirds of older people in two metropolitan areas expressed fear for safety while walking.[(56,57)] They were afraid of being attacked, being hit by a car, or falling. These fears are not unrealistic. Elderly pedestrians are twice as likely as younger people to be involved in accidents.[(58)] Furthermore, they are more likely to be injured and their injuries are more serious.

COGNITION

In addition to the visual and auditory problems outlined earlier, the cognitive deficits that many older pedestrians experience must be considered. Higher mental processes are required to translate basic sensory information into the processes that control decision making and behavior. These processes include selective attention, stimulus recognition and comprehension, and response selection. The frontal lobes mediate vigilance, arousal, selective attention, screening of irrelevant information, visual search patterns, planning, organizing, initiation of complex activity, judgment and problem solving, and memory processes. In older people activity is decreased in frontal lobes. The major difficulties here are confusion, distraction, attention deficits, disorientation, forgetting, illiteracy, and limited intelligence. These problems can lead to limitations in understanding communications of all types.

Elderly pedestrians who have normal cognitive functioning for their ages also have some attentional and other cognitive limitations.[(59,60)] These can lead to difficulties noticing and locating visual information in visually cluttered environments. This is due to inefficient visual search as well as a tendency to be easily distracted by irrelevant input and to have more difficulty in unfamiliar environments. The ability to attend selectively, to divide attention, and to avoid distraction is known to diminish with age.

These difficulties affect the ability to understand all types of information and could lead to confusion and errors in judgment by older pedestrians.

Attention is frequently categorized into four types: divided attention—attending to two or more tasks simultaneously; attention switching—alternating between two or more inputs; sustained attention—attending over an extended duration; and selective attention—filtering out irrelevant stimuli.[61] An age deficit occurs in divided attention in all but the most simple tasks.[62] Studies of attention switching, however, have generally not found an age difference.[61] It is not clear whether there are age changes in sustained attention, but there does appear to be a significant decline with age in selective attention. Older people appear to be less able to attend to a single input in the presence of competing stimuli, perhaps because the irrelevant information has to be processed as part of the task, or because they have greater difficulty in discriminating between relevant and irrelevant stimuli.[63,64]

Complex problem solving also suffers with increasing age, and most pedestrian activity involves complex cognitive operations, where information must be perceived, integrated, interpreted, and acted upon. Intersections present a challenge as they involve perceptions, interpretations, and decisions that are interdependent.

Orientation problems can arise from confusion in unfamiliar environments. High "legibility" of an urban environment makes it easier for pedestrians and drivers to orient themselves, reducing the number of errors and possibly the number of street crossings needed in a trip. Memory for recent events diminishes with diseases of the Alzheimer's type (DAT). This may affect route following in unfamiliar areas as well as wayfinding (e.g., getting the correct return route) for pedestrians.

Cognitive deficits among the elderly frequently occur as a result of some form of dementia in as many as 15 percent of people over age 65, and 50 to 70 percent of the dementia in the elderly is attributable to Alzheimer's disease, a chronic progressive deterioration of memory, intellect, and communicative function. Problems include difficulty recognizing familiar objects and faces, poor contrast sensitivity, and impairment of selective attention.

Deficits in attention are marked in DAT. It is estimated that Alzheimer's disease affects 1.5 to 2.5 million people in the United States. The most important aspect of attention in driving is that component referred to as attention switching—the ability to shift one's attention from one element of the environment to another to acquire essential information. This deteriorates significantly in persons with DAT. Parasuraman and Nestor, in a summary of the literature on attention in driving, indicated strong correlations between driving performance (accident rate) and attention switching.[65] There is reason to believe that these same variables are the ones that will present difficulties to older pedestrians.

It would seem appropriate to apply driving research on this topic to the understanding of pedestrian behavior. Many people with such problems as DAT and visual deficits stop driving, but the same may not be true of their pedestrian activities. One may assume that stopping driving would lead to increased walking for transportation, at least on short trips, and more use of public transportation, which would necessitate more walking in the roadway environment to get to and from public transit.

Another aspect of cognitive deficits is the tendency for many pedestrians to be somewhat anxious about being in the roadway environment. These factors are difficult to quantify, but no doubt affect the ability of some to attend to and accurately process both visual and auditory information.

BEHAVIORAL FACTORS

Older Pedestrian Problems

There are three approaches to aging: biological, psychological, and sociological. The first two are relevant to the sensory and psychomotor functioning and to perception/cognition abilities. There are also numerous aging and disease-related pathologies that lead to a decline in functions that affect the ability of older pedestrians to cope with a complex traffic environment.

Surveys of difficulties encountered by older drivers have identified several factors that present problems. In a study of self-reported visual problems of drivers, Kosnik et al. identified three types of difficulties that could be relevant to a pedestrian's visual requirements: general visual problems (e.g., reduced quality of vision, slower on visual tasks, reading more slowly, trouble finding a familiar sign among other signs); problems with light sensitivity (e.g., problems seeing at dusk, trouble adjusting to bright lights); and problems with peripheral vision (e.g., bumping into things, especially those outside the field of view).[66] They report that many older people decide to limit or stop driving on the basis of failing vision. This may be less so with regard to their pedestrian activities. Significant declines in pedestrian activity are not likely to be influenced by these deficits until they are quite severe. In fact, those who stop or reduce their driving will probably walk more in the traffic environment, including the additional walking associated with using public transit.

The data on accidents indicate that older drivers have more right-of-way accidents. Reasons for this include decreases in visual scanning, reduced tracking ability, errors in speed estimation, and inappropriate problem-solving strategies.

According to McKnight, problems leading to accidents among older pedestrians include:

- Gap judgment (misjudging the distances of and intervals between approaching vehicles).
- Attention (stepping off the sidewalk when distracted).
- Visual search (watching the traffic light instead of the traffic).
- Expectation (misinterpreting vehicle movement and assuming drivers will yield).
- Haste (impatiently crossing after waiting or crossing midblock between parked cars).[(67)]

Pedestrian Behavior and Attitudes

A survey of older pedestrians involved in accidents in the United Kingdom provides some insights into the perceptual/cognitive and motor difficulties encountered by 473 older pedestrians, whose average age was 75 years.[(68)] All but 10 percent of the accidents occurred during the daytime and 93 percent of the pedestrians were crossing the road when hit. The locations involved were familiar to 95 percent of those surveyed. Failure to see the vehicle that struck them, or to see it in time to take evasive action, was reported by 63 percent. About two-thirds of those who saw the vehicle saw it only when it was within 27 m (30 yd); for 17 percent it was not more than a car length away when it was seen. These figures are powerful indicators that these older people did not perceive the hazard in time, most likely due to inattention or distraction.

The vehicle that struck them was doing something unusual, according to 41 percent of those who saw it before being hit. The most frequent explanations were: reversed into me (30 percent), expected the driver to stop or alter course (20 percent), thought it was not moving (11 percent), and came from behind corner, parked car, etc. (10 percent). It appears that errors in judging the speed or course of vehicles and unrealistic expectations about the behavior of drivers are central factors here. It is also possible that the reductions in peripheral visual information processing that older pedestrians suffer may be contributing factors.

When asked about difficulties in seeing, hearing, or walking, 34 percent of the participants indicated such problems—33 percent walking, 45 percent seeing, and 51 percent hearing. Only 20 percent of these thought their difficulties may have contributed to the accident. It is not known to what extent these were contributing factors, however. These pedestrians gave numerous suggestions when asked about how to avoid accidents such as theirs—look carefully each way (18 percent), use crosswalks (14 percent), wait until the road is clear (13 percent), and be more careful and concentrate (11 percent). One of the conclusions drawn by the authors was to teach speed judgment to pedestrians. In view of the fact that 22 percent of these pedestrians were going from shop to home, more needs to be known about the effects of carrying parcels and other encumbrances (e.g., children, luggage) on pedestrian behavior.

In another British survey, road safety officers were asked about the difficulties the elderly experience in coping with traffic.[69] Their observations, as they relate to perception/cognition, suggest the following problems experienced by pedestrians and drivers, with the percentages reported for each:

Difficulty	Pedestrians	Drivers
Inability to assess speed/distance	17	11
Failing eyesight	14	13
Failing hearing	7	8
Slowing down of reactions	4	16
Lack of awareness/anticipation/judgment	4	5
Lack of concentration	2	5

A German study assessed the attitudes and behavior of older pedestrians through 200 interviews and traffic observations of 800 elderly pedestrians.[70] The findings suggest that, although they know the rules and regulations, pedestrians interpret them generously as applied to themselves. Many accidents occur in familiar areas, where pedestrians have a subjective feeling of safety and where their attention and caution are low. Among the risky behaviors in traffic were: underestimating the speed and overestimating the distance of vehicles (especially on wide roadways), abrupt crossing after waiting a long time to cross, indecisive behavior when entering a pedestrian crossing, and walking in traffic under stress of time or emotion.

The author concludes that risks often arise from speed, variability, and complexity of modern traffic situations, which frequently lead to feelings of stress, anxiety, and incompetence. These feelings are enhanced by poor communication between elderly pedestrians and drivers. Mathey states that "Real acts of communication between elderly pedestrians and motor vehicle drivers are rare" (p. 26).

In examining pedestrian behavior at pelican crossings in England, Preston gathered data on accidents at or near 12 such crossings and observed pedestrian behavior at these locations.[71] She found that 34 percent of the casualties to males were to those who started to cross the road on the "steady green man" phase (i.e., when the pedestrian had the right of way), but the percentage for females in the same situation was 77 percent. Younger pedestrians were more likely to cross near (within 50 m [15 ft]) rather than at the crossing. Pedestrians age 60 and older were much more likely to cross during the proper phase of the pedestrian signal than were the two younger groups, with those aged 15 to 24 crossing most often during other phases of the signal. Females were more also compliant than males. This work suggests that older pedestrians are more compliant than others to traffic control devices.

In a Norwegian survey Schioldborg examined some of the attitudes of more than 2,500 road users.[72] Drivers evaluated "today's traffic" as more satisfactory than did "pure" pedestrians (those without driver licenses) and pedestrians who held driver licenses. Pure pedestrians were also more likely to indicate that traffic was frightful (24 percent) or reckless (14 percent) than were drivers. All three groups stated that inattentiveness was the major cause of pedestrian accidents (ranging from 61 to 69 percent). Drivers were more likely to attribute this problem to pedestrians. All three groups of road users indicated their own competence in the traffic environment to be greater than that of the other two groups. Feelings of security in the traffic environment were greatest for drivers and least for the pure pedestrians.

Velocity Estimation and Gap Acceptance

The most important, dangerous, and complex decision made by road users is when it is safe to cross the roadway when faced with potential conflict from approaching traffic. The task of crossing a roadway at an uncontrolled location involves judgment of the time available to complete the crossing and the time required to do so. This decisionmaking process is referred to as gap acceptance behavior. Acceptance of smaller (in terms of time) gaps implies higher risk.

Katz et al. studied five variables that influence the interaction between drivers and pedestrians crossing the street.[73] Trained pedestrians crossed the street under a number of conditions and the speed of drivers approaching the crossing was measured. For one location, the next nearest pedestrian crossing was 750 m (2,460 ft) away and for the other it was 225 m (738 ft) away. One of the two crosswalks studied was marked and the other unmarked.

No speed changes were observed at these crossings when there were no pedestrians, indicating that speed reductions are due to the presence of pedestrians. At the marked crossing, velocity of vehicles was much slower, speed reduction was greater, and stopping frequency was greater. Crossing velocities were generally slower when the distance between the vehicle and the pedestrian was far rather than near. Velocities were also slower when there was a group of three pedestrians as compared to a single one. Crossing velocities were less when the pedestrian was not looking at the oncoming vehicle at one of the two locations, suggesting that drivers expect pedestrians to be aware of their presence and to take evasive action in case of a conflict.

Sheppard and Pattinson surveyed 473 older pedestrians who had been in accidents.[68] When asked about their ability to judge speeds of approaching cars, 30 percent said they can do this "not well at all." This reply was much more common among those who had never driven or who had stopped driving. Only 44 percent said they could make this judgment "fairly well," the best response category. The problems are also reflected in the replies of 204 people who said the location of their accident was a difficult place to cross. Twenty-five percent reported that it was hard to see, 14 percent said the intersection was confusing, and 25 percent said the traffic comes too quickly. [Relevant to this point, it has been noted that older pedestrians often wait for the start of green phase, rather than start across part way through, to have maximum time available to cross.] These data indicate clearly that older pedestrians have difficulty making appropriate judgments about when it is safe to cross the roadway.

Salvatore studied the ability of children between the ages of 5 and 14 to judge the velocity of oncoming cars (as either slow, medium or fast).(74) Vehicles that the subjects could hear were more likely to be classified as fast, and inaudible vehicles as slow. Judgment of vehicle speed was slightly more accurate at near (82 m [250 ft]) distances than at far (164 m [500 ft]). Small- and medium-size cars were more likely to be correctly seen as moving fast than were large cars. Overall, fast velocities were more correctly identified than were medium velocities and these were more accurately seen than were slow ones. It is difficult to say how relevant this work is to the perception of car velocity by the elderly. Unfortunately, this study was done in the unrealistic setting of a deserted country roadway and involved a small sample. It is doubtful that the test scenario is comparable to the situation encountered by older pedestrians crossing a busy signalized intersection. The role of hearing in pedestrian safety is not well documented. And, the advent of more quiet running vehicles would suggest that any historical data might not be relevant today. Intuitively hearing may provide important cues in detecting turning vehicles approaching from the sides and rear. Given the "auditory clutter" found at many urban intersections—vehicles accelerating, vehicles stopping, and vehicles turning—it is not known if pedestrians of any age use auditory cues to any great extent. The role of hearing in pedestrian safety is not known.

Van Wolffelaar et al. examined merging decisions by elderly drivers in a series of experiments.(75) Drivers age 17 to 41 and 60 to 80 were measured for reaction time, field dependence, static acuity, and knowledge of traffic rules. The main field task was a measure of gap acceptance while in a car at an intersection. The task required the subjects to look up from the dash, scan the roadway both ways, mentally estimate the positions of vehicles in the coming seconds, estimate their own position in these seconds, and judge the probability of a conflict before deciding whether or not to merge. Both left and right merge decisions were required. Reaction time and signal detection analyses were done on these field data. A false alarm occurred when a "Yes" decision was made to an unsafe gap, while a "No" response to safe gap was a miss.

Older drivers performed worse on all the laboratory measures than did the younger subjects. Their gap acceptance mean reaction time was 2.4 s as compared with 1.6 s for younger subjects. There were no differences in accuracy of gaps accepted. Older drivers had a more defensive Yes criterion. Speed of judgment in the merging task was correlated with laboratory measures of reaction time, field dependence, and reaction time to the applied rules knowledge test. Laboratory measures of reaction time and field dependence accounted for 38 percent of variance in the merging task data. The older drivers were not inferior, just slower. The authors suggest that if older people must make decisions about merging as quickly as younger ones, they will make more errors, as they have less information available in a short time.

Among the findings associated with gap acceptance is that the minimum acceptable time gap is negatively correlated with oncoming vehicle speed for both old and young drivers.[76] Bottom and Ashworth report that older drivers are more variable than are the young.[77] Darzentas, McDowell, and Cooper confirmed this and found that older drivers are more cautious.[76] Merging drivers have been found to accept shorter gaps at night when street lighting was present.[78]

Scialfa et al. examined age differences in estimating velocity of automobiles by having observers watch an oncoming vehicle approach at each of eight speeds on a curved or straight track, while seated in the passenger seat of another car.[79] Sensitivity to velocity differences was less in the older subjects (age 55 to 74) as compared with those who were middle-aged or young. Subjects slightly underestimated speed at lower (24 km/h [15 mi/h]) velocities and overestimated at higher (88 km/h [55 mi/h]) speeds. At high speeds the estimates of older drivers were better than those of the young. The authors conclude by saying "Relative to the young, older adults tended to overestimate at lower speeds and underestimate at higher speeds" (p. 65).

A study of perception of vehicle (car and motorcycle) velocity and gap acceptance was carried out in Japan by Miura.[80] The data indicate that the temporal gap measure is a better predictor of gap acceptance behavior than is the distance measure. Differences were found between day and night temporal gap acceptance, with subjects being more conservative, accepting longer gaps on average, at night. Temporal gap size decreased with increasing vehicle velocity, possibly because the subjects underestimated higher velocities and overestimated lower velocities. It was also found that both temporal and distance gap sizes were smaller for motorcycles than for automobiles. Velocity estimation did not differ for the two types of vehicles, but distance to both types was overestimated.

Errors in velocity perception and gap judgment occur in collisions between trains and people (drivers and pedestrians) who are trying to "beat the train" across the tracks. They obviously believe they can cross the tracks before the train reaches them, except in the rare case where suicide is a motive for this behavior. A main reason for such a dangerous action is a misperception of the train's speed and distance.[81] Speed is judged to be slower than it actually is because the train is a large object. Research on the perception of velocity has shown that people tend to underestimate how fast large objects are moving. For example, a large aircraft approaching an airport runway seems to be moving slowly, while a very small aircraft seems to be traveling quite fast, even though they are approaching the runway at the same speed. This relates to the speed of movement with which the image of the object moves across our eyes. The same thing can happen with the perception of an approaching car.

Another perceptual phenomenon leading to errors in judgment in this situation is that people have difficulty judging the approach speed of a vehicle (e.g., car, motorcycle, train) when it is seen nearly head on. This is because the size of the image on the eye changes at a gradual rate until the vehicle is very close. The ability to detect a change in the visual image size on the eye (referred to as central movement in depth) has been shown to correlate more closely with traffic accidents than most other visual abilities, such as visual acuity, peripheral vision and depth perception—the ones measured on driver licensing examinations. When an approaching vehicle such as a train gets quite close, we suddenly realize just how fast it is traveling. By then it may be too late to avoid a collision.

The work on velocity estimation appears to be inconsistent with respect to accuracy. Some field studies indicate underestimation at high speeds and overestimation at low speeds, while others find the opposite.[82,80,79] Scialfa et al., in a laboratory study, found underestimation to be greater at high speeds, and Scialfa et al. report a slight tendency for overestimation at high speeds and underestimation at low speeds, in a field study.[23,79] Hills reported that older drivers tend to give lower speed estimates than do younger drivers.[82] However, in general, it appears that age differences are slight as they relate to gap perception and estimation of the speed of vehicles. Older people have been found to be less sensitive to speed differences.[79]

Much of the research on perception of velocity has been done in the laboratory, using two-dimensional presentation of stimuli and having subjects judge when a moving object would reach a certain point or collide with another object. Although these experiments show that people are good at subjectively scaling velocity, it is difficult to generalize these findings to perception of vehicle speeds in a road crossing situation. The presence of a restricted visual frame of reference and the absence of visual complexity found in the roadway environment make the lab situation artificial. In addition, lab measures are novel situations for most people, while adult pedestrians (especially if they are also drivers) have had a great deal of practice at estimating the velocity of vehicles in the roadway environment.

Traffic Control Devices

The major traffic control devices intended for pedestrians are pedestrian signals at intersections. There appears to be very little literature specifically on how older pedestrians understand these devices. However, any difficulties encountered by pedestrians in general will be even greater for the elderly.

Traffic engineers are of the view that these signals are often poorly understood. The ITE Technical Council Committee 4A-15 conducted a nationwide survey of government traffic engineers (291 completed questionnaires) to examine criteria and conditions used to justify installing various pedestrian controls at signalized intersections. When asked about pedestrian understanding of signals, they expressed that only 4 percent understand the flashing Walk indication, and that 39 percent understand the flashing Don't Walk signal.

Pedestrians are frequently confused about how to interpret Walk and Don't Walk signals in the steady and flashing modes. The use of these signals is not consistent across jurisdictions. Occasionally pedestrians, especially older ones, are confused about how to respond to the Don't Walk signal when it comes on after they are part way across the street. Some turn around and return to the curb, thinking they are in danger if they continue across. The intent of the message is to say "don't start across," but this is not at all obvious.

In an Australian study, Cairney evaluated pedestrian understanding of the flashing man signal to indicate the clearance interval for pedestrians.(83) There was concern that pedestrians thought the flashing red signal (the Australian standard) indicated they should hurry off the roadway, as they no longer had priority over motor traffic. Subjects shown color photographs of the signal indicated 95 percent of the time that they were not to begin walking or that the pedestrian phase was about to end. However, 41 percent mentioned the need to hurry across the road. They were then asked, in a multiple choice format, the meaning of the flashing red signal, and 26 percent mentioned hurrying.

The possibility of varying the flash rate of the signal was also examined using 12-year old children and elderly people. Sequences of signals at 0.5, 1, and 2 flashes per second, as well as a variable rate (changing from 0.5/s to 2/s), were displayed with color video. Subjects were asked to indicate how well each sequence conveyed the message "You may complete your crossing, but do not begin to cross." The slowest flash rate was considered the poorest and there were no differences among the others. Participants clearly favored the red over the green signal. Most of the children preferred the variable signal, while all but one of the older subjects said that flash rate did not matter.

Compliance with pedestrian signals is generally poor. In an Australian study, 15,000 pedestrians across 33 locations were videotaped at signalized crosswalks.(84) The pedestrian phase began with a Walk display followed by a flashing Don't Walk. This was followed by a steady Don't Walk to indicate the end of the pedestrian phase. It was found that 62 percent of the pedestrians stepped off the curb during the flashing Don't Walk, and 9 percent during the steady Don't Walk. Violations were correlated positively with pedestrian flow rate and negatively with duration of the flashing Don't Walk. Contrary to expectation, there was no relation between violations and either pedestrian delays or cycle times. Zegeer et al. have also suggested that fewer than 50 percent of pedestrians obey the flashing Don't Walk signal in most U.S. cities.(85)

Symbols have come into use on signals, as they have on signs. Robertson studied preference for and understanding of symbols for pedestrian signals and recommended the walking man for the Walk phase and the hand signal for the Don't Walk phase.[86] In another study, Robertson examined pedestrian response to several messages—steady and flashing Don't Walk, steady and flashing Walk and Don't Start.[87] The flashing Walk signal was used to warn of vehicles turning, but is no longer in the MUTCD. The flashing Don't Walk has been used to indicate a clearance interval (during which pedestrians should not start across the roadway). The data indicate no difference between steady and flashing Don't Walk, that Don't Start has no advantage over Don't Walk, and that the flashing Walk is not an effective warning about turning vehicles. Robertson and Carter showed that only 2.5 percent of a sample of 400 pedestrians understood the flashing Walk signal.[88] It is clear that uncertainty about signal information is a major problem for pedestrians. On the other hand, elderly drivers' responses to traffic control devices have been examined. Older drivers had no problem in learning and retaining symbolic signs, but required more time in processing symbol sign information. Those aged 65 to 77 responded to all test stimuli slower than those aged 19 to 29. Another study indicated that they would respond more quickly to verbal rather than symbolic signs—0.2 s average.

In a survey of elderly pedestrians in Florida, Bailey et al. found that they experienced feelings of anxiety and concerns for their safety at signalized intersections, and that they increased their walking speed when crossing the street.[89] They tended to lack information about the significance of signal phases and knowledge of proper crossing behavior. Over half avoided crossing the street during peak traffic hours and during low visibility. About one-fourth reported difficulty seeing the crosswalk display.

A variety of audible pedestrian signals has been used to aid the visually impaired, including buzzing, whistling, beeping, and chirping sounds. The buzzer and the bird call are most often used in the United States, but in the western United States the "peep-peep" and "cuckoo" are used most, according to a survey by Oliver et al.[90] However, there is a lack of consistency across locations, which would certainly be confusing to a widely traveled pedestrian with low vision. Audible signals can be pedestrian-actuated or automatic (activated by the cycle change at pretimed intersections). Oliver et al. noted that not all the organizations and people surveyed support their use.[90] Nearly one-third of the organizations of the visually impaired opposed these signals. The major objections were about their lack of reliability and the tendency for the visually impaired to become dependent on them.

Ulsan et al. examined the usefulness of auditory signals by having 27 blind people locate the pole and the pedestrian-actuated button on it, then cross the street, at each of four intersections.[91] From 12 to 44 percent encountered difficulties, depending on the intersection. Many went to the wrong pole, but a few of these were able to correct their error. Where there were two buttons on the same pole (e.g., one for each direction or one for pedestrians and one for cyclists), the wrong button was used on a number of occasions. Subjects with guide dogs were found to be at a disadvantage, as these dogs are trained to avoid obstacles such as poles. The authors conclude that audible signals can aid blind persons at complex intersections, but that training and practice are essential if they are to be effective.

Wilson's study of auditory warnings for pedestrians in England showed that their use did not cause delay, but decreased by 5 percent the time taken for pedestrians to cross on the Walk indication and fewer people failed to cross completely during the Walk phase.[92] It was concluded that there were positive safety effects, including a small but significant reduction in delay to nonhandicapped persons. Unfortunately, no data were obtained on the behavior of unaccompanied blind people. Such auditory information does not always indicate which direction to cross the road, creating a potential source of confusion.

There are a number of potential problems with the use of auditory pedestrian signals for the visually impaired. Locations where right turns are allowed on red signals are hazardous for all pedestrians, and more so for the elderly and visually impaired. There are problems with hearing signals in traffic noise, with the older pedestrians hearing high frequency sounds, and with auditory discriminating if different sounds are used. Obvious difficulties arise if such signals malfunction. Signs warning drivers of the possible presence of deaf or blind pedestrians are also used where large numbers of these people are likely to cross the street.

Medications and Alcohol Use

One aspect of pedestrian behavior that is frequently overlooked is the effect of drugs. The use of both prescription and over-the-counter drugs by the elderly is very high in the United States. For example, the elderly constitute about 10 to 11 percent of the population, but buy 25 percent of the prescription and over-the-counter drugs.[67] In addition, 75 percent of those over age 75 use prescribed drugs and the average number taken per day by people on Medicare is 10. Older people are 3 to 7 times as likely to suffer adverse reactions as are younger people. Tranquilizing drugs can reduce attention and concentration, which are already below average for many older pedestrians.

The literature suggests possible relationships between medication use and hearing problems. Some can change blood flow in the inner ear. Aspirin, antibiotics, diuretics, and some powerful anti-cancer drugs damage hair cells and other structures in the ear. Medications have also been found to increase problems with high frequency sounds and to reduce attention and concentration, which would reduce ability to process all types of information.

The human condition that has received the most attention in traffic safety is impairment by alcohol—specifically, the impaired driver. Relatively little attention has been paid to impaired pedestrians, despite the fact that significant proportions of pedestrian deaths occur among those with high blood alcohol content (BAC) levels.

Although the influence of alcohol is more prevalent among young and middle-aged pedestrians, it is still a significant problem with older ones. An examination of records of fatally injured pedestrians in the United States over a 2-year period (1977 to 1979) showed that 18.8 percent of those aged 65 to 74 and 6.7 percent of those age 75 and older had been drinking.[93] Alcohol abuse among older people may be more prevalent than previously thought. Another problem with older drinkers is that the tolerance for alcohol diminishes with age.

Jordan and Young have summarized the literature on alcohol use among injured pedestrians.[94] About half of all pedestrian fatalities have high (0.10 or higher) BAC levels, and the percentage of injured pedestrians with BAC's above 0.15 is higher than the percentage for drivers or motorcyclists, according to Jordan and Young. Impairment among pedestrians appears to be overrepresented among the young, middle-aged, semiskilled or unskilled workers, unmarried, divorced, and separated people. This does not appear to be a problem among elderly pedestrians, however. Jordan and Young report data from Australia that indicate "after dark" alcohol-related accidents to be somewhat fewer for those age 65 and older. This may be due to less pedestrian activity by these people after dark. Studies also show male pedestrian injuries are more likely to be associated with drinking than are females.

Emotional Factors

Mental and nervous disorders are common among the elderly, occurring in about 11 percent of those treated. Estimates of depression are about 25 percent in the elderly. The related cognitive effects that could impact pedestrian behavior include psychomotor slowing, lower concentration and attention, as well as memory deficits. If the affective aspects of driving that influence elderly drivers can be applied to pedestrians, then the latter will lack confidence, display stubborn and selfish behavior, underestimate the risk of being on the road, and be less willing to admit mistakes.[67]

Emotional disturbances influence driving, as shown by indepth accident investigations involving a "psychological autopsy" (an examination of the emotional state of the driver and other psychological factors prior to the accident). These often report that drivers were to some extent "impaired" by their emotions. Estimates are that between 10 and 35 percent of drivers in accidents are emotionally upset or tense at the time of the collision. Accident and violation rates have been found to be higher 6 months before and 6 months after drivers filed for divorce, as compared with their own earlier records and with the records of the general driving population.[95] There is reason to believe the same emotional factors that affect safe driving will also influence pedestrian safety.

CONCLUSIONS

Older pedestrians are clearly at a disadvantage in today's traffic environment for a number of reasons. Many of these are associated with their reduced ability to take in, process, and respond to information. Decrements in visual and auditory perception, as well as reduced attention and increased susceptibility to distraction and confusion, contribute to the problems of older pedestrians. The complexity of urban intersections and poor understanding of pedestrian traffic signals also make life stressful and dangerous for these road users.

Much of the literature reviewed was based on older drivers, as there is a dearth of relevant information about the older pedestrian. The application of older driver characteristics and behavior to the world of the older pedestrian may seem reasonable. However, this requires a certain leap of faith. For example, velocity judgment and gap acceptance when crossing a roadway without traffic control devices is likely to be different between these two groups of road users. The older pedestrian, in comparison with younger ones, will be relatively slower at crossing the roadway than will the older driver, as compared to younger drivers. Therefore, caution must be used in drawing conclusions about pedestrian gap acceptance from research on driver gap acceptance.

There is clearly a need for more research data on the older pedestrian, as it is hazardous to attribute to them the same behaviors and characteristics found in younger adults or children, with whom most of the useful research has been conducted. This brings up the need to define and research the "design pedestrian," just as the "design driver" has been the focus of attention in recent years by those concerned with traffic control devices, vehicle design, and other aspects of the highway transportation system. Something like the *Driver Performance Data Handbook*, produced by NHTSA in 1987, needs to be developed for pedestrians.

This discussion of the older pedestrian task and the possible role of age-related changes in the performance of that task has covered a wide variety of topics. Unfortunately, in most cases what is not known is how often the mental and physical changes that occur as people age actually have a significant effect on the performance of the pedestrian task. A significant effect could be considered as one that affects the safety and/or mobility of the older pedestrian. Further work is needed to identify factors that are actually associated with pedestrian accidents as well as factors that may adversely affect the mobility of older persons.

2. PROBLEM IDENTIFICATION ACTIVITIES

The task analysis and literature review identified a variety of potential problems that older pedestrians might experience. To identify specific problem areas that the project should address, it was decided to conduct a series of problem identification activities. These activities were efforts to identify specific older pedestrian characteristics that could be quantified by laboratory and/or field experimentation and used to change existing design standards and/or operational practices. Five problem identification activities were performed:

- Accident Characteristics of Older Pedestrians.
- American Association of Retired Persons (AARP) Survey.
- *Walking* Magazine Survey.
- Focus Group Discussions.
- Survey of Practitioners.

ACCIDENT CHARACTERISTICS OF OLDER PEDESTRIANS

To find out more about the specific problems older pedestrians have in traffic, two data bases were examined. The General Estimation System (GES) is based on a nationally representative probability sample selected from police-reported crashes. It is maintained by NHTSA. In 1981 and 1982, the Center for Applied Research, Inc. (CAR) conducted a detailed pedestrian accident and exposure data collection effort for the FHWA. That project, Pedestrian Trip-Making Characteristics and Exposure Measures, produced the only known estimates of pedestrians and risk.

Copies of the GES tapes for 1988, 1989, and 1990 were obtained and cross-tabulations were run of accident location by pedestrian age and accident type by pedestrian age. Some consideration was given to the selection of an appropriate comparison group for the older pedestrians. It was decided to use pedestrians age 40 to 64 because that age group represents individuals who have walking habits, attitudes, and values similar to those age 65 and older. Differences between these two groups would be most likely due to the physiological effects of aging. Using a comparison group of much younger pedestrians, i.e., age 20 to 40, would introduce questions about differences in lifestyle, being in a hurry, or attitudes toward risk taking. Table 1 shows the location of accidents for pedestrians age 40 to 64 and for pedestrians age 65 and older. The accident locations are categorized by traffic control, signal or stop sign; land use, urban vs rural; and relation to a junction. The GES defines junction as the "area formed by the connection of two roadways, includes intersections, interchange areas, and entrance/exit ramps." It should be noted that a few of the nonjunction locations do have signals and/or stop signs. Presumably these locations include those with midblock pedestrian signals and stop-controlled midblock pedestrian

Table 1. Accident locations for pedestrians age 40 to 64 and pedestrians over 65. (1988-1990 GES data)

Traffic Control	Land Use	Relation to Junction	Percentage of Pedestrians	
			Age 40-64	65+
			(n=49,599)	(n=24,937)
SIGNAL	Urban	Nonjunction	1.1	2.5
SIGNAL	Urban	Junction	22.4	22.0
SIGNAL	Rural	Nonjunction	1.5	0.5
SIGNAL	Rural	Junction	7.4	15.6
Signalized Locations: Subtotal			32.4	40.6
STOP	Urban	Nonjunction	0.2	0.2
STOP	Urban	Junction	3.6	3.5
STOP	Rural	Nonjunction	1.5	0.3
STOP	Rural	Junction	1.4	2.1
STOP Controlled Locations: Subtotal			6.7	6.1
NONE	Urban	Nonjunction	24.4	11.8
NONE	Urban	Junction	7.4	10.2
NONE	Rural	Nonjunction	19.1	18.6
NONE	Rural	Junction	5.2	7.1
Uncontrolled Locations: Subtotal			56.1	47.7
Others/Missing Data			4.8	5.6
GRAND TOTAL			100.0	100.0

crosswalks. It is apparent that the older pedestrian group has more accidents at signalized locations (40.6 percent) than do the younger pedestrians (32.4 percent). The majority of this difference is because more of the older group are struck at rural signalized intersections. Summing within the columns, it can be shown that only 47.4 percent of the younger pedestrians are struck at intersections of all types, while 60.5 percent of the older pedestrians are struck at intersections. Unfortunately, the data base does not contain any information about the presence or absence of pedestrian signals or the adequacy of the pedestrian crossing time.

The GES data were also used to generate table 2, a distribution of pedestrian accident types for the same two pedestrian age groupings. Most of the accident types listed are self-explanatory; definitions follow for those that are not self-explanatory. Midblock dash accidents involve a pedestrian running across the street, not at an intersection. Multiple threat accidents involve the scenario where one vehicle stops or yields to a pedestrians who is then struck by a vehicle in the next lane and traveling in the same direction as the yielding vehicle. Intersection dash accidents involve a pedestrian running across the street at an intersection. Dartout accidents involve pedestrians who were not visible to the driver until too late. Often a parked vehicle serves as a visual obstruction. First-half dartouts occur in the first half of the crossing. Second-half dartouts occur in the second half of the crossing. Some of the differences in the less frequently occurring accident scenarios are not surprising. There are fewer older pedestrians in situations involving disabled vehicles, working on the roadway, and walking along the roadway. Most interesting is the larger number of older pedestrians in turn-merge situations. This type involved 17.7 percent of those age 40 to 64 and 23.6 percent of those age 65 and older. The other notable difference in the distributions is the smaller number of older pedestrians (14.7 percent) in the "midblock, other" type compared to the younger group (18.5 percent).

Although the absolute frequencies are small, older pedestrians are also more likely to be struck in accident involving backing, pedestrian walking into vehicle (midblock), driver violation, trapped, multiple threat, and waiting to cross.

Accident type distribution seems to support the data from accident locations in table 1. Older pedestrians appear to have more problems at signalized intersections, which tend to be busier than unsignalized intersections and are more conducive to vehicle turn-merge conflicts where drivers are looking for a gap in traffic and fail to see the pedestrian. Older pedestrians may not be as attentive to the threat from turning vehicles as younger pedestrians.

The CAR exposure data tapes were reanalyzed to examine the relative risks associated with pedestrians age 40 to 64 and pedestrians age 65 and older. Hazard scores were generated using the percentage of accident involvement (for each age category and each variable) and the percentage of the pedestrians observed in a given age category. The larger percentage was divided by the smaller percentage for

Table 2. Pedestrian accident types for pedestrians 40 to 64 and pedestrians over 65 (in order of frequency among older pedestrians).

	Percentage of Pedestrians	
	40-64 Years Old	65+ Years Old
VEH TURN/MERGE	17.7	23.6
MIDBLOCK, OTHER	18.5	14.7
INTERSECTION, OTHER	15.1	14.5
BACKING	4.4	8.0
PED WALKED INTO VEH, MIDBL	1.8	5.3
DRIVER VIOLATION	2.6	5.2
MIDBLOCK DASH	3.1	2.8
TRAPPED	1.3	2.6
MULT THREAT, INTERSECTION	1.2	2.3
INTERSECTION DASH	3.7	2.3
NOT IN ROADWAY	4.2	2.1
OTHER-WEIRD	3.0	2.1
MIDBLOCK DARTOUT, FIRST HALF	1.3	1.9
MIDBLOCK DARTOUT, SECOND HALF	1.5	1.9
DRIVERLESS VEHICLE	1.2	1.5
WALK RD CAN'T SPECIFY	.6	1.3
WAITING TO CROSS	.5	1.3
INADEQUATE INFORMATION	1.3	1.3
WALK RD WITH TRAFFIC	4.0	1.0
WALK RD AGAIN. TRAFFIC	1.3	1.0
PED INTO VEH, INTERSEC	1.4	1.0
MIDBLOCK DART, CAN'T SPEC.	.9	.8
ENTERING/EXITING	1.1	.6
DISABLED VEHICLE	2.0	.4
WORKING ON ROADWAY	1.2	.4
MULTIPLE THREAT, MID	.9	.4
COMMERCIAL BUS	.6	.2
TO/FROM DISABLED VEH	.5	.2
EXPRESSWAY CROSS	1.4	.2
HOT PURSUIT	.1	.0
EMERGENCY VEHICLE	.2	.0

larger percentage was divided by the smaller percentage for each variable. If the accident involvement percentage was the larger number, the hazard score was assigned a positive value. If the exposure percentage was the larger value, the hazard score was assigned a negative value. A positive hazard score indicates that a particular variable is associated with increased risk. A negative hazard score indicates that the particular variable is associated with decreased risk. Although the data are relatively old (collected in 1982 and 1983), they are the only known information on pedestrian exposure. As shown in table 3, older pedestrians had a somewhat high hazard score of 2.5 at locations with major arterials. This indicates that there are 2.5 times more accidents than would be predicted on the basis of exposure for individuals in that age group. They are also overrepresented at signalized intersections, multilane roadways, places with medians, and places with left-turn channelization. Since there is no evidence of overrepresentation at 4-leg or multileg intersections, it would appear that older pedestrians have increased difficulties at wider, more complex intersections and not necessarily at all intersections.

Older pedestrians also appear to be at increased risk at places with no sidewalks, sidewalks on only one side, and places with no street lighting. However, each of these situations accounts for only a small percentage of the accidents. Older pedestrians are at a reduced risk in areas that are 100 percent residential. Pedestrian sex, accompaniment, and crossing location do not have major effects on the hazard involved. Crossing against the signal appears to be especially hazardous for older pedestrians. Unfortunately, it is not known if this involves starting to cross against the light or being "trapped" by a changing signal.

The accident type data are of limited usefulness because of the relative infrequence (i.e., less than 0.5 percent of pedestrians observed) of many potentially hazardous behaviors. It is interesting that right-turn-on-red, vehicle turn-merge, and multiple threat accidents combine to a total of 19 percent of the older pedestrian accidents, yet the field observers rarely saw pedestrians of any age exhibiting the behaviors associated with these accident scenarios.

Although the intersection type variable doesn't suggest any situations of especially high risk, older pedestrians did have moderately high hazard scores at 2-lane by 4-lane intersections (+2.7) and intersections with red-green-amber (RGA) signals (+2.2). The last four variables in the table—right-turn-on-red, left turns, crosswalks, and signs at intersections—do not indicate increased hazards for older pedestrians.

The GES accident data and the CAR exposure data provide some interesting insight into the problems experienced by older pedestrians. It appears that older pedestrians have more difficulty at relatively wide signalized intersections, especially those that have the increased hazards of channelization and the resulting conflicts from turning vehicles.

Table 3. Hazard scores for pedestrians age 40 to 64 and pedestrians over 65.

Variable	Pedestrians 40-64			Pedestrians 65+		
	Acci-dents,%*	Expo-sure,%*	Hazard Score**	Acci-dents,%*	Expo-sure,%*	Hazard Score**
Roadway Functional Class						
Major Arterial	17	5	3.4	33	13	2.5
Collector-Distributor	32	37	-1.2	40	40	1.0
Local Street	45	55	-1.2	22	46	-2.1
Number of Lanes						
2 or less	38	59	-1.6	17	50	-3.0
More than 2	62	41	1.5	83	50	1.7
Median						
None	84	93	-1.1	73	91	-1.3
Curb or Island	10	3	3.3	20	3	7.5
Painted Pavement	4	4	1.0	1	6	-8.1
Channelization						
None	81	81	1.0	58	83	-1.4
Left Turn	16	3	5.3	30	5	5.9
Right Turn	3	13	-4.3	10	6	1.5
Both Right and Left	-	4	-	2	5	-2.4
Ped. Accommodations						
No Sidewalks	2	7	-3.4	10	5	2.1
Sidewalks - One Side	9	8	1.2	5	3	1.8
Sidewalks - Both Sides	89	86	1.0	85	93	-1.1
Street Lighting						
None	1	2	-2.1	3	1	2.6
Regularly Spaced	97	89	1.1	93	94	1.0
Not Regularly Spaced	2	8	-3.8	4	5	-1.2
Land Use						
100% Residential	18	23	-1.3	9	20	-2.2
Commercial and Industrial	55	53	1.0	55	51	1.0
Mixed Residential	27	24	1.1	36	29	1.2

* Percentages shown are rounded.

** Hazard scores were computed before percentages were rounded.

Table 3. Hazard scores for pedestrians age 40 to 64 and pedestrians over 65 (continued).

Variable	Pedestrians 40-64			Pedestrians 65+		
	Acci-dents, %	Expo-sure, %	Hazard Score	Acci-dents, %	Expo-sure, %	Hazard Score
Pedestrian Sex						
Male	68	57	1.2	32	44	-1.4
Female	32	43	-1.4	68	56	1.2
Pedestrian Mode						
Walking	79	94	-1.2	96	99	1.0
Running	21	6	3.7	4	1	6.8
Crossing Location						
Crosswalk	48	66	-1.4	56	70	-1.3
Within 50 ft. of Crosswalk	27	71	4.0	10	13	-1.4
Diagonally	-	2	-	3	2	1.2
Midblock	25	25	1.0	32	14	2.2
Signal Indication						
Green	65	91	-1.4	69	92	-1.4
Red	35	9	3.8	32	8	4.0
Accident Type						
Sidewalk, No Crosswalk	7	29	-4.0	7	26	-4.0
Midblock, Crosswalk	8	10	-1.2	16	9	1.9
Intersection, Crosswalk	23	35	-1.6	24	51	-2.1
Midblock, Dartout	17	1	-1.6	15	2	10.2
Intersection Dash	9	4	2.5	7	3	2.1
Right Turn on Red	3	0	33.0	3	0	16.5
Vehicle Turn/Merge	14	0	70.5	14	0	142.0
Multiple Threat	2	0	12.0	2	0	5.7
Bus Stop Related	1	0	6.0	2	0	6.3
Exit/Enter Parked Vehicle	3	14	-4.7	2	5	-2.1
Walking Along Road	10	3	3.8	3	2	1.6
No. of Lanes at Intersection						
2 x 2	38	59	-1.6	17	50	-3.0
2 x 4	42	17	-2.6	50	19	2.7
4 x 4	20	24	-1.3	33	32	1.1

Table 3. Hazard scores for pedestrians age 40 to 64
and pedestrians over 65 (continued).

Variable	Pedestrians 40-64			Pedestrians 65+		
	Accidents, %	Exposure, %	Hazard Score	Accidents, %	Exposure, %	Hazard Score
Intersection Type						
4-leg	59	73	-1.3	74	78	-1.1
"T"	32	17	1.9	18	14	1.3
Multi-leg	7	6	1.0	2	4	-2.0
Other	3	3	1.0	7	4	1.6
Signalization						
None	58	60	1.0	40	54	-1.4
Red/Green/Amber (RGA)	13	8	1.5	25	11	2.2
RGA with Ped Signal	29	31	-1.1	35	34	1.0
Right Turn on Red						
Allowed	57	57	1.0	71	62	1.2
Not Allowed	44	43	1.0	21	38	-1.8
Not Allowed Cert. Times	-	-	-	7	-	-
Left Turns						
Allowed	63	53	1.2	71	76	-1.1
Not Allowed	37	43	-1.2	22	24	-1.1
Not Allowed Cert. Times	-	5	-	7	-	-
Crosswalks						
None	58	52	1.1	41	46	-1.1
Marked, One Roadway	2	9	-4.6	8	9	-1.1
Marked, Both Roadways	40	39	1.0	51	45	1.1
Signs at Intersection						
None	8	20	-2.3	22	34	-1.5
Stop Sign	79	73	1.1	66	57	1.2
4-Way Stop	13	7	1.8	2	8	-5.2
Yield Sign, Other	-	-	-	10	-	-

AARP SURVEY

A questionnaire was developed to survey the walking habits of older pedestrians and to identify difficulties they may have while walking. The American Association for Retired Persons (AARP) distributed this survey form to members at meetings in Utah Montana, Colorado, California, and Washington, DC. A copy of the form with the 412 tabulated responses is included as figure 1. The characteristics of the sample are very interesting. Nearly all wear glasses and one in four has cataracts. One in nine uses either a cane or a walker. The respondents seem to frequent a combination of urban, suburban, and rural areas. They walk and drive almost daily for trips of about 30 minutes each. About one-fourth of the respondents indicated they walked as a means of transportation while three-fourths walked for pleasure. Although no claims are made about the representativeness of the sample, this information suggests that the sample is probably somewhat better off, socioeconomically, than the "average" pedestrian.

Surprisingly, about 10 percent indicated they "often" or "always or almost always" walk along the edge of the roadway or along the shoulder. It should be noted that 3.6 percent of the older pedestrian accidents involved walking along the roadway. Not surprising is that most of the walking occurs on sidewalks and rarely at night. Older pedestrians also tends to cross at signalized intersections and rarely at midblock. This also supports their higher accident involvement in these locations.

Perhaps the most shocking result of the AARP survey is the level of misunderstanding of the meaning of the pedestrian signals. Only about one-fourth of those surveyed know that the flashing Don't Walk signal means that they shouldn't start to cross, but if they have begun, it is safe to finish crossing. This lack of understanding may be one reason why older pedestrians feel the signal doesn't give them adequate time to cross.

Responses to the back of the form (page 2 of figure 1) reveal that older pedestrians have some difficulty seeing and understanding traffic signals. About 35 to 40 percent indicated they either "sometimes," "often," or "almost/almost always" had a hard time seeing traffic signals, pedestrian signals, and traffic signs.

Four questions are related to difficulties caused by slippery or uneven walking surfaces. Between 25 and 35 percent indicated they "often" or "always/almost always" had difficulty with slippery or uneven surfaces, both in crosswalks and on sidewalks. The final two questions indicate that older pedestrians have far less difficulty crossing at signalized locations than they do at unsignalized locations.

We are conducting a project to make walking safer and more convenient for older pedestrians. We want to find out what kinds of problems you have when you walk outside. We value your opinion!

Age: x=73.2 Sex: M=23.2 F=76.8 AARP Chapter__________________

	Yes, %	No, %
Do you wear glasses?	93.9	6.1
Do you have cataracts?	24.9	75.1
Do you use a cane?	8.2	91.8
Do you use a walker?	3.6	96.4
Do you walk in urban areas?	64.5	35.5
Do you walk in suburban areas?	65.9	34.1
Do you walk in a small town	48.4	51.6
Do you walk in rural areas?	40.1	59.9
How often do you drive a car?	x = 6.1 times a week	17% never or almost never
How long is your average driving trip?	x = 27.5 minutes	
How often do you use public transit?	x = 0.7 times a week	80% never or almost never
How often do you walk outside the home?	x = 5.7 times a week	16% never or almost never
How long is your average walking trip?	x = 29.0 minutes	
How long is your longest walking trip?	x = 44.9 minutes	
Why do you walk outside?	23.1%, transportation	76.9%, exercise

	Never/Almost Never, %	Sometimes, %	Often, %	Always/Almost Always, %
How often do you:				
Walk along the edge of the roadway?	65.7	23.7	6.8	3.8
Walk along the shoulder?	67.3	23.5	7.4	1.8
Walk on sidewalks?	7.4	21.0	31.2	40.4
Walk at night?	78.5	16.2	2.8	2.5
How often do you:				
Cross at intersections with stop signs?	8.8	31.3	25.8	34.1
Cross at intersections with traffic signals?	8.3	27.3	26.8	37.6
Cross at intersections with pedestrian signals?	11.3	29.0	25.2	34.4
Cross in the middle of the block?	65.8	28.8	2.8	2.8

	Safe to Start Crossing, %	Safe to Finish Crossing, %	Wait; Do Not Cross, %	Don't Know, %
What does the Walk signal mean?	<u>94.1</u>*	3.3	2.0	0.5
What does the steady Don't Walk signal mean?	0.8	2.3	<u>96.1</u>	0.8
What does the flashing Don't Walk signal mean?	1.4	<u>25.8</u>	68.5	4.2
What does the walking man signal mean?	<u>81.7</u>	9.8	5.4	3.0
What does the upright hand signal mean?	10.3	5.7	<u>78.0</u>	6.0
What does the flashing upright hand signal mean?	4.3	<u>29.0</u>	55.6	11.1

* Correct responses are underlined.

PLEASE COMPLETE THE QUESTIONS ON THE NEXT SIDE

Figure 1. Pedestrian safety survey results.

When you are walking outside:	Never/Almost Never, %	Some-times, %	Often, %	Always/Almost Always, %
Are traffic signals hard to see?	63.0	30.5	4.1	2.4
Are traffic signals hard to understand?	75.9	21.1	1.6	1.3
Do traffic signals allow you enough time to cross?	19.9	44.8	8.0	27.3
Are pedestrian signals hard to see?	59.8	33.9	3.9	2.5
Are pedestrian signals hard to understand?	71.6	24.9	1.1	2.3
Do pedestrian signals allow enough time to cross?	22.3	48.2	8.5	20.9
Are traffic signs hard to see?	57.8	38.9	1.9	1.4
Are traffic signs hard to understand?	71.8	24.3	2.5	1.4
Is street lighting too dim?	32.1	49.6	14.1	4.2
Are curbs difficult to climb?	58.4	31.1	7.4	3.0
Does slippery pavement make crossing difficult?	18.8	56.0	14.4	10.9
Does uneven pavement make crossing difficult?	18.1	51.6	17.3	13.0
Do slippery sidewalk surfaces make walking difficult?	13.7	53.4	18.1	14.8
Do uneven sidewalk surfaces make walking difficult?	11.3	52.2	20.3	16.1
At signals do you sometimes have trouble telling when it is safe to cross?	59.3	34.8	3.5	2.4
At other places do you sometimes have trouble telling when it is safe to cross?	37.7	52.3	7.6	2.4

Please use this space to tell us what kinds of specific problems you have as a pedestrian.

____

____

____

____

____

____

How can walking be made safer and more convenient?

____

____

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____

____

Figure 1. Pedestrian safety survey results (continued).

On the back of the form, AARP members were asked to indicate the specific kinds of problems they have as pedestrians. Although 73.8 percent did not indicate a specific problem, the remainder mentioned a variety of problems, which are listed in table 4. Inadequate crossing time tops the list (n=28), but problems related to turning vehicles (n=15) and RTOR (n=12) were also mentioned.

Table 4. AARP survey summary of pedestrian problems. (n=493)

Issue	***Number of Responses***
Pedestrian crossing time too short	28
Turning vehicles' failure to yield to pedestrians	15
Inconsiderate drivers	13
Vehicles failure to yield to pedestrians	12
Uneven sidewalks/potholes in sidewalks	11
Bicycles on sidewalks	10
Failure to maintain sidewalks, including removal of ice, snow, sand, gravel	9
Speeding	7
Dogs	7
Vehicles stopped or parked in crosswalks	5
Confusion in presence of left-turning vehicles	4
Fear of criminals	4
Red light runners	4
Stop sign runners	3

The remaining question gave the respondents a chance to suggest ways to make walking safer or more convenient for older pedestrians. Again, about three-fourths (75.7 percent) of the sample failed to respond. Those who made suggestions did so in response to the problems they had indicated in the previous section. The most common suggestion was to lengthen the crossing time. The second most frequent suggestions involved repairing sidewalks. The summary of suggestions is presented in table 5.

Table 5. AARP survey summary of pedestrian suggestions to make walking safer/more convenient. (n=493)

Suggestion	***Number of Responses***
Lengthen pedestrian crossing time	23
Repair uneven sidewalks	21
Install more sidewalks	11
Install more street lighting	11
Reduce inconsiderate driving	9
Maintain sidewalks/clear sidewalks of snow and ice	8
Install walking paths, especially around retirement communities	7
Install more curb cuts	7
Control dogs	6
Keep bicyclists off sidewalks	6
Install benches for resting	4
Enforce speeding laws	4
Clear trees/shrubs from sidewalks	3

WALKING MAGAZINE SURVEY

The April 1992 issue of *Walking* Magazine printed an inquiry from The Center for Applied Research. Readers were encouraged to respond regarding "the types of problems common to older pedestrians crossing the street. Are traffic signs or signals hard to see? hard to understand? Do pedestrian signals allow enough crossing time? Are curbs too high? Is the roadway slippery? Are handrails needed? Do you have trouble telling when it is safe to cross at intersections? at midblock? Is the street lighting too dim?"

Given the magazine's readership of 450,000, we had hoped for hundreds of responses; we received only 7. Because of the limited number of responses, no attempt was made to analyze the data.

The disappointing response to our inquiry published in *Walking* Magazine may suggest that those who are healthy enough to walk as a recreational activity—and who read *Walking* Magazine—do not experience many serious problems as pedestrians, regardless of their age.

FOCUS GROUP DISCUSSIONS

Eight focus group discussions were held. Two groups each met in four cities: Washington, DC; Chapel Hill, North Carolina; Tampa, Florida; and Phoenix, Arizona. The focus groups involved 10 to 12 individuals, all 65 or older, who held 1½- to 2-h discussions of the problems they experienced as drivers and pedestrians. The following points were raised:

- The pedestrian signal is often too short to enable the elderly to cross the street safely, especially at wide streets.
- More pedestrian refuge islands are needed, especially on wide streets. Pedestrians feel safe when refuge islands are wider and/or protected by barriers.
- Vehicles turning right on red (RTOR) are a problem for pedestrians crossing on the Walk signal. Vehicles do not yield to pedestrians.
- Older pedestrians do not want a three-phase Walk—Don't Start—Don't Walk system.
- Focus group members indicated a preference for pedestrian-actuated Barnes Dance configurations to eliminate problems from turning vehicles.
- It was generally felt that pedestrian buttons do not work.
- The members generally liked curb cuts and felt that they made crossing the road easier, when properly located.
- Opinions were divided on the value of a "Yield to Pedestrian" sign. Some thought it was a good idea; others did not.
- Some group members liked audible pedestrian signals while others thought they were not a good idea.

SURVEY OF PRACTITIONERS

As another approach to identifying the problems experienced by older pedestrians, it was decided to conduct a survey of practicing traffic engineers and other highway safety professionals. At the annual Transportation Research Board (TRB) Meeting in Washington, DC during January 1992, a questionnaire was distributed to three interested professional groups: (1) TRB Committee A3B04—Pedestrians; (2) ITE Committee 5A-5—Design of Pedestrian Facilities; and (3) ITE Committee 5P-3—Pedestrian Characteristics. The questionnaire asked the committee members to rate the level of importance of 15 potential research topics on a 5-point scale. They were also asked to indicate the percentage of the research effort that should be devoted to each topic.

Table 6 contains the results of the practitioners' survey. The 15 research topics are listed on the left. The middle section indicates the percentage of the 33 responses that rated the topics on the following 5-point scale:

1 Critical importance.
2 Above average importance.
3 Average importance.
4 Below average importance.
5 Not important.

It is noteworthy that the first eight topics were rated as "critically" important by at least 25 percent of the committee members.

The righthand section of the table summarizes and rank orders the responses concerning the percentage of effort that should be devoted to each topic. With two notable exceptions, the average percentage of effort correlated very highly with the subjective ratings of importance. The committee members ranked "walking speed" second in suggested level of effort while it was fourth in the mean rating of importance. "Walking distance" ranked third in the level of effort of distribution while it was only eighth in the mean rating of importance.

Table 6. Practitioner survey: importance ratings and level of effort distribution.

Topic	Importance Ratings							Level of Effort Distribution						
	Mean Rating Score	Rank	% of Respondents Rating Topic					Rank	Mean % of Effort	Rank Order of Dist. of Effort				
			1	2	3	4	5			1	2	3	4	5
Signal comprehension/understanding	1.77	1	42	39	19	0	0	1	11.7	15	12	18	12	3
Sign comprehension/understanding	2.10	2	27	47	17	10	0	5	8.9	0	18	18	12	0
Decision sight distance requirements for intersections	2.17	3	31	34	21	14	0	5	8.9	12	6	9	12	9
Walking speed	2.17	4	31	41	10	14	3	2	9.2	9	9	3	15	0
Signal detectability/legibility	2.21	5	25	43	21	7	4	7	7.1	6	9	6	6	6
Nighttime illumination requirements	2.32	6	26	29	10	13	0	5	8.9	6	6	9	12	0
Decision sight distance requirements for midblock crossings	2.44	7	24	28	28	21	0	8	6.7	6	6	9	12	0
Walking distance	2.58	8	28	24	21	17	10	3	9.5	15	6	6	6	0
Need for slip-resistant surfaces	2.64	9	16	32	26	23	3	9	6.4	9	6	3	3	3
Curb height requirements	2.70	10	13	33	30	17	7	11	3.9	0	3	9	6	6
Sign detectability/legibility	2.71	11	11	39	25	18	7	10	5.1	0	3	6	0	6
Delineation detectability/legibility	3.00	12	8	30	35	19	8	13	2.7	0	3	0	0	6
Delineation/comprehension/understanding	3.04	13	8	24	36	20	12	14	2.3	0	3	3	3	0
Need for handrails, railing barricades	3.24	14	0	21	41	31	7	12	2.8	0	3	3	0	3
Overpasses/underpasses design requirements	3.53	15	0	14	36	32	18	15	2.0	0	0	3	0	0

CONCLUSIONS

A number of activities were undertaken to identify the problems experienced by older pedestrians. The accident data analysis indicated that older pedestrians have particular problems at signalized intersections and are involved in the vehicle turn merge accident type more than younger pedestrians. The pedestrian exposure data analysis provided evidence that some specific locations are especially hazardous for older pedestrians. These include: major arterials, intersections with left-turn channelization, places with no street lighting, and RGA signalized intersections.

The AARP survey found that older pedestrians claim to have few difficulties seeing or understanding signs, although the survey also found widespread misunderstanding of the flashing Don't Walk signal. The older pedestrians reported that their most serious problems involved signal times that are too short and difficulties with slippery or uneven pavement and sidewalk surfaces. Their most frequently requested actions to improve pedestrian safety was to lengthen crossing times and repair sidewalks. The focus group discussions also revealed that older pedestrians had problems with short signal times as well as turning vehicles at intersections.

The practitioners survey indicated that signal and sign comprehension were the two most important research issues for older pedestrians. Intersection decision sight distance requirements and walking speed were tied for third.

The most consistently identified problem areas involved older pedestrians crossing at signalized intersections and the concern that they do not have adequate time to cross safely. This lack of adequate crossing time could be due to slower walking speeds or the possibility that older pedestrians react more slowly to changes in signal display. In order to quantify the behavioral characteristics of older pedestrians crossing signalized intersections, it was decided to conduct a field study. The field study is described in the next chapter. This field study would measure pedestrians walking speeds and pedestrian startup times. Once quantified, these factors would be used to develop design guidelines for the design of pedestrian facilities that are sensitive to the mental and physical capabilities of older pedestrians. The design guidelines are presented in chapter 4 of this report.

The preceding project activities identified a variety of problem areas experienced by older pedestrians. Although they could not be addressed under the scope of the present project, they remain areas of concern for future research.

- Walking Surface Irregularities—How much unevenness on walking surfaces is troublesome to older pedestrians?

- Pedestrian Signal Comprehension—Misunderstanding of the three-phase pedestrian signal is widespread among all age categories. Something should be done to increase the comprehension of the flashing Don't Walk or clearance phase.

- Turning Vehicle Problems—Older pedestrians seem to have particular problems with vehicles turning across the crosswalk. This needs to be further studied and solutions identified.

- Pedestrian Intersection Sight Distance—More work needs to be done to quantify the sight distance requirements of pedestrians at intersections.

- Nighttime Illumination—Work is needed to determine if current intersection illumination specifications are adequate for older pedestrians.

- Slip-resistant Surfaces—More work needs to be done to determine if current crosswalk and sidewalk slip resistance characteristics are adequate for older pedestrians.

- Traffic Sign and Signal Visibility and Comprehension—Further research is needed to determine if older pedestrians have problems seeing and/or understanding traffic signs or signals.

- Role of Auditory Cues in Pedestrian Crossing Behavior—Further research is needed to determine the role of auditory cues in pedestrians crossing at intersection and nonintersection locations. The possible influences of age-related changes in the auditory capabilities of older pedestrians should be investigated.

- Role of Auditory Cues in Pedestrian Crossing Behavior—Further research is needed to determine the role of auditory cues in pedestrians crossing at intersection and nonintersection locations. The possible influence of age-related changes in the auditory capabilities of older pedestrians should be investigated.

3. FIELD STUDIES OF PEDESTRIAN WALKING SPEED, PEDESTRIAN STARTUP TIME, AND PEDESTRIAN STRIDE LENGTH

A series of field studies was conducted to quantify the walking speed, startup time, and stride length of pedestrians of various ages under different environmental conditions.

METHOD

Site Selection

Sixteen crosswalks in each of four urban areas (Richmond, Virginia; Washington, DC; Baltimore, Maryland; and Buffalo, New York) were selected. Sites were selected to have sufficient pedestrian volume so that 26 to 30 pedestrians over 65 years of age could be observed during an 8-hour data collection period. After pilot-testing, estimates of population variance were computed and a sample size of 26 to 30 was determined to be sufficient to quantify effects due to site-specific factors. A site characteristics form was completed during site selection. This form contained the following types of information:

- Street width.
- Posted speed.
- Curb height.
- Grade.
- Number of travel lanes.
- Signal cycle length.
- Pedestrian signal type.
- Street classification.
- Crosswalk type.
- Channelization.

A copy of the site form is included as figure 2.

SITE# _____

LOCATION:________________ URBAN/SUBURBAN:_______________STATE:____

DATE: ____________________ WEATHER CONDITIONS: ____________________

START TIME: _________ END TIME: ____________ OBSERVER:_______________

Curb to curb street width (ft): ____________
Site direction: ____________
Curb height: N/W ________ S/E____________
Curb cut height: N/W ________ S/E____________
Posted speed limit (mph):

Study leg:	___________	5-min vol count:	Study leg:	__________
Leg 2:	___________		Leg 2:	__________
Leg 3:	___________		Leg 3:	__________
Leg 4:	___________		Leg 4:	__________

Crossing grade: ___________
Number of lanes: ___________

Signal Timing:
Overall cycle length: ________________________
Ped. signal type: ________________________

Pedestrian Signal Length:

	Walk	Flashing Don't Walk	Steady Don't Walk
Main street:	_______________	________________	________________

Circle all that apply:

Street classification	Major	Collector	Local
Parking permitted	Yes	No	Restricted
Type of traffic control	Signal	Stop	Midblock
Actuated ped signal	Yes	No	N/A
Left turn arrow	None	Protected	Prot/Perm
RTOR permitted	Yes	No	N/A
Median	Raised	Level	None
Curb cut	Yes	No	One corner
Crosswalk	Standard	High Vis	Unmarked
Stop line	Yes	No	N/A
One-way street	Yes/Approach	Yes/Leaving	No

Figure 2. Elderly pedestrian crossing times data collection form.

Weather Conditions

Data were collected during three different types of weather conditions:

- Dry: Clear (no precipitation) with dry roads and dry sidewalk.
- Rain: Any type of rain from drizzle/mist to moderate rain with wet roads and wet curbs. Data were not collected during very heavy rain as no pedestrians tended to be out. Data were also collected immediately after the precipitation stopped when the road and sidewalk was wet but there was no precipitation.
- Snow: When there was snow and/or ice in the atmosphere and/or the road or sidewalk.

Data were collected on weekdays during daylight conditions. Weather surface conditions at the curb, in the crosswalk, weather conditions, and the estimated wind intensity were recorded for each observation.

Subject Selection

Data were collected on a subject group of pedestrians who appeared to be 65 years of age or older. Data on a control group of pedestrians under age 65 were also collected. The following individuals were specifically *not* observed:

- Children under 13 years of age.
- Pedestrians carrying children, heavy bags, or suitcases.
- Pedestrians pushing strollers or grocery carts.
- Pedestrians holding hands or assisting others across the roadway.
- Pedestrians using a tripod cane, a walker, or two canes.
- People in wheelchairs.
- Pedestrians walking bikes or dogs.

To accurately quantify "normal" walking speeds of the various subject groups, individuals who exhibited any of the following behaviors were also *not* observed:

- Pedestrians crossing diagonally.
- Pedestrians stopping/resting in/on the median.
- Pedestrians who entered the roadway running (anything faster than a fast walk).
- Pedestrians entering the roadway (leave the curb/curb cut) before crossing or while waiting for traffic to stop.
- Pedestrians entering or exiting the roadway more than 1.2 m (4 ft) outside the crosswalk.

The gender of the target pedestrian was recorded as well as whether the subject was walking alone or in a group. The size of the group was noted. A group was defined as two or more pedestrians crossing the roadway at about the same time, whether or not they were apparently friends or associates.

In addition, the subjects' path was monitored to determine whether they started and ended their crossing inside or outside the crosswalk. Inside the crosswalk meant within or on the painted crosswalk lines.

Compliance with the pedestrian signal (or traffic signal for sites without a pedestrian signal) was recorded to include which phase of the signal appeared at the beginning of the subject's crossing. If the signal phase changed during the crossing, that information was recorded along with an indication of when that change occurred (first or second half of the crossing). Cardinal direction of traffic was recorded indicating which direction the pedestrian was heading across the roadway. Nine other pedestrian behaviors were recorded when they occurred:

- Confusion (hesitation, change in direction of travel) exhibited prior to crossing.
- Confusion exhibited after entering the roadway.
- Cane used.
- Followed the lead of other pedestrians.
- Inattention when pedestrian signal changed to Walk.
- Stopped in the crosswalk during the crossing.
- Difficulty curb up.
- Difficulty curb down.
- Ran during part of the crossing (anything faster than a fast walk).

To verify the accuracy and reliability of the age estimating abilities of the observers, several field verifications were done. First, the age-estimating accuracy of several observers was measured. Then, correlations between the estimates of all of the observers were determined. The results of these verification procedures are discussed after the next section.

PROCEDURE

Pedestrian crossing times were measured with a digital hand-held electronic stopwatch. The watch was started as the target pedestrian stepped off the curb and stopped when the pedestrian stepped up on the opposite curb after crossing. At sites with a pedestrian signal, pedestrian startup times were also measured. Startup time was defined as the period from when the Walk signal came on to when the pedestrian first stepped off the curb to begin the crossing. Stride length was determined by counting the number of steps from the first step off the curb to the last step up onto the curb. The width of the roadway was subsequently divided by the number of steps counted to determine the mean stride length.

The field data were recorded on a form similar to figure 3. Each observation was recorded on a separate line of the form. The raw data were keypunched and formatted for analysis as shown in figure 4.

VERIFICATION OF OBSERVER AGE ESTIMATES AND STARTUP TIME MEASUREMENT

To determine the ability of the field observers to properly identify older pedestrians, a simple verification procedure was conducted. Five field observers estimated the ages of a randomly selected sample of nine pedestrians who ranged in age from 54 to 85 years. With one exception, a 62-year-old male, each observer correctly identified each pedestrian who reported his or her age as over 65 as being over 65. All five observers thought that the 62-year-old male was over 65; estimates ranged from 68 to 75 years old. Interrater reliability for age was assessed using intraclass correlations and Pearson *r* correlations. The intraclass correlation was 0.78 for the five raters. Pearson *r* correlations between individual raters ranged from 0.71 to 0.93 and between subjects' actual age and each rater ranged from 0.70 to 0.82. This indicates that the observers, as a group, were good at identifying pedestrians over the age of 65 and that there was a more than acceptable level of agreement between observers.

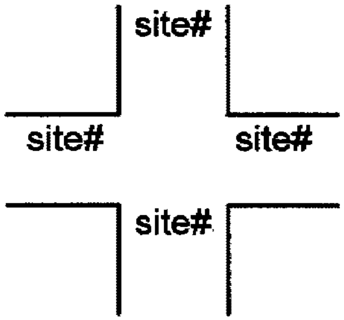
A similar procedure was used to verify the reliability of the stopwatch measurements of pedestrian crossing times. The crossing times of the same nine pedestrians were measured by the five field observers. Again intraclass correlations and Pearson *r* correlations were used to determine interrater reliabilities. The intraclass correlation was 0.998 for the five raters and all Pearson *r* correlations between individual raters were greater than 0.99. This indicates that the observers were each following the timing procedure in a very similar manner.

RESULTS

The overall objectives of the project dictated the orientation of the data analysis effort. The purpose of the effort was to gather descriptive information on the overall capabilities of older pedestrians. Thus the data analysis that follows is descriptive as opposed to analytical in nature. This section describes the walking speeds and startup times of young and older pedestrians across a variety of situation factors. Although many of the differences shown are statistically significant, it is important to consider the absolute effect or meaningfulness of these differences.

PEDESTRIAN WALKING SPEEDS

Table 7 presents the mean and 15th percentile walking speeds in feet per second for young and older pedestrians at different types of locations and under several different environmental conditions. The 15th percentile walking speed represents the speed that 15 percent of the pedestrians do not exceed and therefore the speed that 85



A: Confusion exhibited prior to x-ing
B: Confusion exhibited after entering road
C: Cane used to assist in mobility
D: Followed lead of other peds
E: Inattention when ped signal changed to WALK
G: Started x-ing during flashing "DON'T WALK"
H: Started x-ing during "DON'T WALK"
J: Stopped in the crosswalk
K: Other (specify)
L: Difficulty curb up
M: Difficulty curb zone

N: Ped signal turned to flashing "DON'T WALK" 1st half of crossing
O: Ped signal turned to flashing "DON'T WALK" 2nd half of crossing
R: Crossed on red to traffic (no ped signal present)
S: Crossed on green to traffic (no ped signal present)
T: Ped ran during part of crossing
*: Ped under 65 years old

Day of Week Codes
Mon=1 Tues=2 Wed=3 Thurs=4 Fri=5 Sat=6 Sun=7

State Codes
DC=District of Columbia MD=Maryland VA=Virginia

Day of Week:______Date:___________ Temp:________ Begin Time:________ End Time:__________ Observer:____________________

Site # & State Code	Start-up Time, sec	Sex, M/F	Start in X-walk, Y/N	N/S E/W	End in X-walk, Y/N	Crossing Time, sec	Group Size	Misc. Behavior	# of Steps	Under 65 Over 65	Weather Conditions Curb	X-Walk	Atmos-phere	Wind

Figure 3. Pedestrian crossing time data form.

Column			
1-2	Site number		numeric
3-4	City		alpha
	DC = Washington, DC	MD = Baltimore, MD	
	NY = Buffalo, NY	VA = Richmond, VA	
5	Day of week		numeric
	1 = Monday	5 = Friday	
	2 = Tuesday	6 = Saturday	
	3 = Wednesday	7 = Sunday	
	4 = Thursday		
6-9	Pedestrian startup time (seconds)		numeric
10	Sex		alpha
	F = Female	M = Male	
11	Start in crosswalk		alpha
	Y = In	N = Out	
12	Crossing direction		alpha
	N = North	S = South	
	E = East	W = West	
13	End in crosswalk		alpha
	Y = In	N = Out	
14-17	Crossing time (seconds)		numeric
18	Group size		numeric
19-22	Miscellaneous alpha codes		numeric

Left justify all items; leave blank if nothing appears

A = Confusion exhibited prior to crossing
B = Confusion exhibited after entering street
C = Cane used to assist in mobility
D = Followed the lead of other pedestrians
E = Inattention when pedestrian signal changed to Walk
G = Started crossing during flashing Don't Walk
H = Started crossing during Don't Walk
I = Crossed diagonally
J = Stopped in crosswalk
K = Other (specify)
L = Difficulty curb up
M = Difficulty curb down
N = Ped signal turned to Don't Walk during first half of crossing
O = Ped signal turned to Don't Walk during second half of crossing
R = Crossed on red to traffic (no pedestrian signal sites)
S = Crossed on green to traffic (no pedestrian signal sites)
T = Pedestrian ran during part of crossing
* = Pedestrians under the age of 65

Figure 4. Pedestrian crossing time (walking speed) coding format.

Table 7. Mean and 15th percentile walking speeds (in ft/s) for young and older pedestrians: all pedestrians.

Site/Environmental Factors	Number		Mean			15th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Significance*	Younger Peds	Older Peds
All Pedestrians	3458	3671	4.95	4.11	A	4.09	3.19
Pedestrian Sex					A, S, AxS		
Male	1701	940	5.11	4.31		4.28	3.36
Female	1757	1729	4.79	3.89		3.94	3.06
State					A, S		
DC	632	592	4.68	3.88		3.97	3.08
MD	642	702	4.74	3.84		3.97	3.07
VA	552	730	4.74	3.96		3.96	3.16
NY	1632	1647	5.20	4.38		4.29	3.36
Day of Week					A, S		
Monday	426	600	4.89	4.04		4.03	3.24
Tuesday	574	769	4.92	4.13		4.06	3.15
Wednesday	1087	989	4.88	4.09		4.04	3.17
Thursday	736	680	4.93	4.08		4.11	3.15
Friday	635	633	5.15	4.24		4.23	3.29
Start in Crosswalk					A, S, AxS		
Yes	3183	3340	4.91	4.08		4.09	3.18
No	275	331	5.41	4.41		4.47	3.35
End in Crosswalk					A, S		
Yes	2936	3054	4.91	3.95		3.98	3.10
No	552	615	5.15	4.34		4.23	3.28
Signal Compliance					A, S		
Start on Walk	1756	1975	4.79	3.95		3.98	3.10
Start Flashing Don't Walk	307	274	5.04	4.39		4.32	3.45
Start Steady Don't Walk	1016	963	5.25	4.46		4.33	3.47
Start Green (no ped sig.)	325	404	4.80	3.86		3.95	2.97
Start Red (no ped sig.)	54	55	4.96	4.17		4.23	3.29

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each of the Site factors. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

Table 7. Mean and 15th percentile walking speeds (in ft/s) for young and older pedestrians: all pedestrians (continued).

Site/Environmental Factors	Number		Mean			15th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Significance*	Younger Peds	Older Peds
Group Size					A, S, AxS		
Alone	2609	2698	5.04	4.15		4.19	3.23
With Others	849	970	4.66	4.00		3.86	3.12
Weather Conditions					A, S		
Dry	2262	2550	4.82	4.03		3.99	3.17
Drizzle	264	259	4.98	4.08		4.20	3.14
Rain	543	472	5.24	4.33		4.28	3.27
Snow	389	390	5.24	4.41		4.32	3.38
Wind					A, S, AxS		
Low (0-5 mi/h)	597	603	5.07	4.11		4.22	3.15
Med (6-10 mi/h)	787	775	5.15	4.28		4.19	3.24
High (11-40 mi/h)	722	707	5.12	4.38		4.24	3.50
Temperature					A, S		
Low (9-43°)	1093	1128	5.25	4.39		4.31	3.34
Med (45-58°)	707	652	5.02	4.15		4.15	3.23
High (60°+)	306	305	4.87	4.08		4.09	3.16
Street Classification					A, S, AxS		
Major Arterial	2281	2326	4.93	4.14		4.12	3.23
Collector-Distributor	265	370	4.52	3.86		3.80	3.07
Local Street	912	975	5.11	4.15		4.11	3.12
Pedestrian Signal					A, S		
None	379	459	4.82	3.90		3.97	3.02
Word	2392	2490	5.03	4.20		4.14	3.25
Symbol	687	722	4.73	3.93		4.04	3.15
Parking Permitted					A, S		
Yes	1763	1954	4.81	3.99		4.05	3.15
Restricted	1086	1090	5.14	4.27		4.18	3.23
No	609	627	4.99	4.22		4.11	3.26

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each of the Site factors. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

Table 7. Mean and 15th percentile walking speeds (in ft/s) for young and older pedestrians: all pedestrians (continued).

Site/Environmental Factors	Number		Mean			15th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Signifi-cance*	Younger Peds	Older Peds
Ped-Actuated Signal					A, S, AxS		
Yes	703	733	5.19	4.27		4.16	3.25
No	2376	2479	4.90	4.10		4.11	3.22
RTOR Permitted					A, S, AxS		
Yes	850	894	4.84	4.02		4.10	3.18
No	1192	1259	4.97	4.04		4.03	3.07
Median					A, S, AxS		
Yes	557	534	5.02	4.35		4.24	3.45
No	2901	3137	4.94	4.07		4.07	3.16
Curb Cut					A, S, AxS		
Yes	1969	2087	4.86	4.06		4.06	3.21
One Corner	1318	1406	5.10	4.19		4.15	3.16
No	171	178	4.77	4.05		3.92	3.23
Crosswalk Marking					A, S		
Standard	2470	2607	5.02	4.20		4.13	3.25
High Visibility	988	1064	4.76	3.91		4.00	3.10
Stop Line					A, S		
Yes	2363	2371	5.00	4.15		4.12	3.19
No	383	496	4.68	3.88		3.88	3.14
Roadway Width					A, S, AxS		
Narrow (27.7-42.5 ft)	1105	1222	4.74	3.76		3.92	3.00
Moderate (43.0-51.2 ft)	1053	1212	4.93	4.16		4.12	3.26
Wide (51.7-104.0 ft)	1300	1237	5.14	4.42		4.27	3.48
Number of Lanes					A, S, AxS		
2	1544	1688	4.96	4.04		4.04	3.12
3-7	1914	1983	4.94	4.18		4.13	3.26

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each of the Site factors. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

Table 7. Mean and 15th percentile walking speeds (in ft/s) for young and older pedestrians: all pedestrians (continued).

Site/Environmental Factors	Number		Mean			15th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Signifi-cance*	Younger Peds	Older Peds
Vehicle Volume (site st.)					A, S		
Low (<540 vph)	1120	1257	4.93	4.06		4.04	3.16
Med (552-850 vph)	1401	1426	5.02	4.19		4.14	3.24
High (936-1764 vph)	937	988	4.86	4.06		4.06	3.15
Signal Cycle					A, S		
Short (60-70 s)	1283	1313	5.09	4.30		4.23	3.33
Moderate (71-109 s)	1233	1380	4.97	4.12		4.09	3.21
Long (110-140 s)	942	978	4.73	3.84		3.97	3.07
Walk Time					A, S, AxS		
Short (6-12 s)	1507	1477	5.23	4.48		4.34	3.51
Moderate (13-26 s)	667	679	4.65	3.89		3.97	3.11
Long (27-74 s)	786	921	4.75	3.84		3.95	3.07
Flashing Don't Walk Time					A, S, AxS		
Short (6-10 s)	749	894	4.80	3.89		4.03	3.14
Moderate (11-15 s)	885	900	5.07	4.23		4.12	3.23
Long (16-30 s)	1445	1418	4.98	4.24		4.14	3.32
Steady Don't Walk Time					A, S		
Short (13-41 s)	1292	1344	4.99	4.18		4.15	3.27
Moderate (42-51 s)	818	823	4.81	4.00		4.01	3.14
Long (52-86 s)	673	738	4.73	3.89		4.00	3.09

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each of the Site factors. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS)

percent of the pedestrians do exceed. A total of 7,123 pedestrians were observed —3,458 pedestrians under 65 years of age and 3,665 pedestrians age 65 and over. These data describe all the pedestrians observed—those crossing in compliance with the signal as well as those crossing against the signal. As will be described later, those who cross against the signal tend to walk faster.

The table indicates that each of the site and environmental factors collected show a significant effect due to age and each of the site and/or environmental characteristics shown, using a two-way analysis of variance. For about half of the site factors collected, there was also a significant interaction between pedestrian age and the site factor. This is indicated by the use of an A X S notation in the Significance column. Although many of the mean differences shown are statistically significant, this is in part due to the relatively large number of observations made. When examining these tables, it is important to consider the relative magnitude of the differences and whether the differences are meaningful. Many of the differences were found to be "statistically significant" but are not of any practical difference from a facilities design standpoint. The following discussion highlights some of the walking speed differences observed for the entire sample of pedestrians observed.

The mean walking speeds for younger pedestrians was 1.4 m/s (4.95 ft/s) and 1.2 m/s (4.11 ft/s) for older pedestrians. The 15th percentile speeds were 0.9 m/s (4.09 and 3.19 ft/s) for younger and older pedestrians, respectively. These mean differences are significant at the 0.05 level.

- Young male pedestrians had the fastest walking speeds observed (1.53 m/s [5.11 ft/s]) while older females were the slowest (1.16 m/s [3.89 ft/s]). The differences between younger men and younger women (0.09 m/s [0.32 ft/s]) and between older men and older women (0.12 m/s [0.42 ft/s]) are about the same.

- As described, data were collected in four different cities. Pedestrians in both age categories were found to walk faster in Buffalo than they did in the other cities. This is quite possibly an artifact of the colder weather in Buffalo and the presence of other factors associated with faster walking speeds such as higher signal noncompliance.

- Day of week differences were consistent for both younger and older pedestrians. Both age groups tend to walk slightly faster on Fridays. It is not known if this is because of slightly heavier traffic volumes on Fridays, or if it is because people are in a hurry on Fridays for some other reason.

- Pedestrians who start their crossing outside of the crosswalk walk faster than those who start within the crosswalk.

- Pedestrians who end their crossing outside the crosswalk walk faster than those who stay in the crosswalk until they reach the curb.

- Pedestrians who start on the Walk signal walk slower than those who cross on either the flashing Don't Walk or the steady Don't Walk. The differences observed between the Walk and the flashing Don't Walk suggest that some pedestrians may understand the concept of the clearance phase. Specifically, that while it is dangerous to cross on the steady Don't Walk (and if they do so they should walk as fast as possible), it is slightly less dangerous to cross on the flashing Don't Walk. This is counter to the results of the AARP survey and the focus group discussions both of which indicated a general lack of understanding associated with the flashing Don't Walk. At sites with no pedestrian signal, pedestrians who started legally (on the green) also tend to walk more slowly than those crossing against the light (on the red). These differences between "compliers" and "noncompliers" have important implications in the design process. It is believed that the walking speeds of compliers provides a more appropriate basis for design purposes than does the walking speeds of those who are crossing illegally.

- The pedestrians observed were classified as being alone if they crossed by themselves. If they crossed with other pedestrians—even if there was no indication that they were walking together—they were coded as "with others." Pedestrians in a group were found to walk slower than individual pedestrians.

- Pedestrians of all ages were found to walk faster when it was raining, snowing, windy, or cold.

- The roadway classification also affected pedestrian walking speed. The slowest walking speeds were found on local streets while the fastest were on collector-distributors.

- Sites where parking was permitted had slower walking speeds than sites where parking was prohibited or restricted. This is probably because parking tends to be prohibited on busier, wider arterials, and collector-distributors.

- Sites with symbolic pedestrian signals had slower speeds than sites with word messages.

- Pedestrians tend to walk faster where there are pedestrian-actuated signals than at other locations.

- Pedestrians also tend to walk faster where RTOR is not permitted, where there is a median, and where there are curb cuts.

- Sites with high visibility crosswalk markings had slower walking speeds than sites with standard crosswalk markings. It is not known if this is due to the pedestrians' feeling that the high visibility crosswalks are safer or if the high visibility markings are installed at places where the pedestrians tend to walk slower anyway, i.e., local streets. Pedestrians also walk slower at locations with stop lines.

- Pedestrians in both age groups also tend to walk faster when crossing wider, multilane roadways.

- The data on vehicle volumes show some very interesting inverted U-shaped functions. Faster crossing speeds were found at sites with moderate traffic volumes than at sites with low or high vehicle volumes.

- Locations with longer signal cycles had faster crossing speeds. This is probably because such locations tend to be wider roadways.

- Shorter pedestrians signal times (Walk and flashing Don't Walk) also tend to be associated with faster walking speeds. It is not known if this relationship is causally related, i.e., the pedestrians walk faster because they know the crossing times are short, or if the shorter crossing times are typically displayed where pedestrians tend to walk faster, i.e., local streets. As might be expected, the walking speeds associated with the various steady Don't Walk cycle lengths are similar to those found with the overall cycle length.

Table 8 presents the mean and 15th percentile of walking speeds for younger and older pedestrians who were observed crossing with the signal, i.e., compliers. This subset included 4,460 pedestrians, approximately 62 percent of the pedestrians included in table 6. As a group, they tend to walk slower than the pedestrians who cross illegally. The mean crossing speed for the younger compliers was 1.43 m/s (4.79 ft/s) versus 1.48 m/s (4.95 ft/s) for all younger pedestrians observed. The older compliers averaged 1.18 m/s (3.94 ft/s) while all the older pedestrians observed averaged 1.23 m/s (4.11 ft/s). Both of these differences are significant at the 0.05 level (T test). The 15th percentile crossing speed for the younger compliers was 1.18 m/s (3.97 ft/s) while older compliers crossed at 0.92 m/s (3.08 ft/s). This difference was compared using the test statistic

$$\frac{X_{85} - X'_{85}}{1.539\,\sigma_{pooled}\sqrt{\frac{1}{N}+\frac{1}{N'}}} \qquad (1)$$

This produced a Z-ratio of 23.26 indicating that the 15th percentile values are significantly different at the <0.001 level.

The effect of site-related and environmental factors on walking speed are discussed.

- Younger females walk 0.09 m/s (0.32 ft/s) slower than younger males while older females are 0.12 m/s (0.40 ft/s) slower than older males.

- Compliers in Buffalo tend to walk faster than compliers in the other three cities but the magnitude of the differences is not as large (0.09 m/s [0.31 ft/s] versus 0.15 m/s [0.52 ft/s]) as was seen in table 7, all pedestrians.

Table 8. Mean and 15th percentile walking speeds (in ft/s) for young and older pedestrians: all compliers.

Site/Environmental Factors	Number		Mean			15th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Signifi-cance*	Younger Peds	Older Peds
All Pedestrians	2081	2379	4.79	3.94	A	3.97	3.08
Pedestrian Sex					A, S		
Male	984	1180	4.96	4.14		4.17	3.24
Female	1097	1198	4.64	3.74		3.88	2.97
State					A, S		
DC	568	535	4.66	3.85		3.95	3.06
MD	464	541	4.72	3.77		3.95	3.03
VA	367	499	4.73	3.96		3.91	3.16
NY	682	804	4.97	4.09		4.08	3.14
Day of Week					A, AxS		
Monday	298	404	4.78	3.91		3.98	3.22
Tuesday	349	514	4.73	3.89		3.91	3.06
Wednesday	664	673	4.77	4.02		3.93	3.11
Thursday	430	442	4.79	3.90		4.01	3.04
Friday	340	346	4.91	3.93		4.09	3.07
Start in Crosswalk					A, S		
Yes	1996	2225	4.77	3.93		3.97	3.08
No	207	316	4.82	4.10		3.98	3.19
End in Crosswalk					A, S, AxS		
Yes	1874	2061	4.79	3.91		3.97	3.06
No	207	316	4.82	4.10		3.98	3.19
Signal Compliance							
Start on Walk	1756	1975	4.79	3.95		3.98	3.10
Start Flashing Don't Walk	325	404	4.80	3.86		3.95	2.97
Start Steady Don't Walk	1016	963	5.25	4.46		4.33	3.47
Group Size					A, S, AxS		
Alone	2609	2698	5.04	4.15		4.19	3.23
With Others	849	970	4.66	4.00		3.86	3.12

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each Site factor. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

1 foot = 0.305 meters.

Table 8. Mean and 15th percentile walking speeds (in ft/s) for young and older pedestrians: all compliers (continued).

Site/Environmental Factors	Number		Mean			15th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Significance*	Younger Peds	Older Peds
Weather Conditions					A, S		
Dry	1470	1755	4.72	3.91		3.92	3.10
Drizzle	190	201	4.89	3.99		4.12	3.08
Rain	274	266	5.02	4.07		4.11	3.00
Snow	147	157	4.94	3.97		4.11	2.94
Wind					A, S		
Low (0-5 mi/h)	299	317	4.94	3.99		4.17	3.10
Med (6-10 mi/h)	383	406	4.83	3.92		4.02	2.94
High (11-40 mi/h)	371	369	4.99	4.15		4.07	3.19
Temperature					A, S		
Low (9-43°)	444	539	5.00	4.04		4.11	3.02
Med (45-58°)	443	432	4.87	4.01		4.01	3.15
High (60°+)	166	175	4.81	3.97		4.06	3.13
Street Classification					A, S, AxS		
Major Arterial	1382	1520	4.83	4.01		4.02	3.15
Collector-Distributor	163	256	4.54	3.87		3.86	3.07
Local Street	536	603	4.76	3.77		3.93	2.89
Pedestrian Signal					A, S		
None	325	404	4.80	3.86		3.95	2.97
Word	1207	1386	4.82	3.98		3.97	3.09
Symbol	549	589	4.71	3.90		4.03	3.15
Parking Permitted					A, S, AxS		
Yes	1248	1406	4.72	3.89		3.97	3.07
Restricted	518	583	4.92	3.97		3.97	3.05
No	315	390	4.83	4.07		3.97	3.19
Ped-Actuated Signal					A, S, AxS		
Yes	331	364	4.74	3.77		3.90	2.99
No	1425	1611	4.80	3.99		4.01	3.15
RTOR Permitted					A, S, AxS		
Yes	620	660	4.75	3.96		4.03	3.15
No	695	787	4.72	3.73		3.92	2.90

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each Site factor. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

1 foot = 0.305 meters; 1 mile = 1.61 kilometers.

Table 8. Mean and 15th percentile walking speeds (in ft/s) for young and older pedestrians: all compliers (continued).

Site/Environmental Factors	Number		Mean			15th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Signifi-cance*	Younger Peds	Older Peds
Median					A, S, AxS		
Yes	310	329	4.88	4.22		4.06	3.33
No	1771	2050	4.77	3.89		3.97	3.06
Curb Cut					A, S		
Yes	1285	1406	4.73	3.90		3.97	3.10
One Corner	735	879	4.92	4.00		4.00	3.06
No	61	94	4.51	3.86		3.91	3.09
Crosswalk Marking					A, S		
Standard	1323	1546	4.81	3.98		3.97	3.10
High Visibility	758	833	4.75	3.86		3.99	3.06
Stop Line					A		
Yes	1423	1540	4.81	3.92		4.00	3.05
No	257	347	4.68	3.90		3.86	3.14
One-Way Roadway					A, S		
Approaching Intersection	912	1013	4.87	4.02		4.07	3.16
Leaving Intersection	712	804	4.93	4.14		4.10	3.23
No	1834	1854	5.00	4.15		4.10	3.19
Roadway Width					A, S, AxS		
Narrow (27.7-42.5 ft)	893	1017	4.73	3.73		3.90	2.97
Moderate (43.0-51.2 ft)	514	670	4.77	4.01		4.01	3.16
Wide (51.7-104.0 ft)	674	692	4.88	4.18		4.06	3.31
Number of Lanes					A, S, AxS		
2	1009	1187	4.75	3.81		3.93	3.02
3-7	1072	1212	4.82	4.05		4.03	3.17
Vehicle Volume (site st.)					A, S		
Low (<540 vph)	635	821	4.82	3.96		3.98	3.12
Med (552-850)	842	880	4.86	3.97		4.01	3.08
High (936-1764 vph)	604	678	4.65	3.87		3.92	3.07

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each Site factor. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

1 foot = 0.305 meters.

Table 8. Mean and 15th percentile walking speeds (in ft/s) for young and older pedestrians: all compliers (continued).

Site/Environmental Factors	Number		Mean			15th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Signifi-cance*	Younger Peds	Older Peds
Signal Cycle					A, S		
Short (60-70 s)	615	757	5.00	4.15		4.09	3.16
Moderate (71-109 s)	697	815	4.71	3.89		3.97	3.09
Long (110-140 s)	769	807	4.69	3.78		3.91	3.04
Walk Time					A, S, AxS		
Short (6-12 s)	530	620	5.04	4.24		4.18	3.23
Moderate (13-26 s)	548	553	4.62	3.86		3.90	3.09
Long (27-74 s)	574	688	4.74	3.80		3.93	3.03
Flashing Don't Walk Time					A, S, AxS		
Short (6-10 s)	545	661	4.76	3.84		3.97	3.08
Moderate (11-15 s)	497	516	4.72	3.85		3.94	3.05
Long (16-30 s)	714	798	4.85	4.11		4.05	3.18
Steady Don't Walk Time					A, S		
Short (13-41 s)	679	605	4.91	4.05		4.07	3.15
Moderate (42-51 s)	576	605	4.68	3.90		3.91	3.09
Long (52-86 s)	491	548	4.72	3.84		3.98	3.07

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each Site factor. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

1 foot = 0.305 meters.

- The compliers also tend to walk faster on Fridays.
- Those who start or end their crossing outside the crosswalk tend to walk faster.
- Compliers crossing at locations with pedestrian signals are not walking faster than compliers crossing at locations with only a traffic signal.
- Single compliers also tend to walk faster than compliers walking in a group.
- Compliers in both age categories tend to walk faster when it is windy and when it is cold.

- Weather conditions have a significant effect on walking speed. Older pedestrians, especially, walk slower when it is snowing. One of the slowest 15th percentile values observed (0.88 m/s [2.94 ft/s]) was for older pedestrians crossing snow-covered roadways.

- Pedestrian crossing speeds are faster at locations with pedestrians signals with word messages than they are where there is either no signal or a symbolic signal.

- Compliers in both age groups walk faster when crossing major arterials. Younger compliers walk slower when crossing collector-distributors than they do on local streets. Older compliers walk slower when crossing local streets than they do when crossing collector-distributors.

- Parking restrictions, automatic as opposed to pedestrian-actuated signals, RTOR restrictions, medians, and curb cuts all tend to be associated with faster walking speeds in both age groups. However, the magnitude of these differences tend to be quite small.

- High visibility crosswalk markings, on the other hand, are associated with slower crossing speeds. Although the presence of stop lines was associated with slower crossing speeds in the all-pedestrian sample, there was no significant effect due to stop lines on the crossing speeds of the compliers.

- The compliers, like the all-pedestrian sample, tend to walk faster when crossing wider, multilane roadways. However, the magnitude of the differences is somewhat smaller.

- Although there are no real differences between the crossing speeds at locations with low and moderate traffic volumes, pedestrians of all ages tend to walk more slowly when crossing higher volume roadways.

- Longer signal cycle lengths appear to be associated with faster walking times.

- Compliers also tend to walk faster at locations with short and steady Walk and short flashing Walk cycle times.

- Longer steady Don't Walk cycle times, like longer total signal cycle length, appear to be associated with slower walking times.

A graph depicting the cumulative percentile values (5th through 95th) in 5-percentile increments is shown as figure 5.

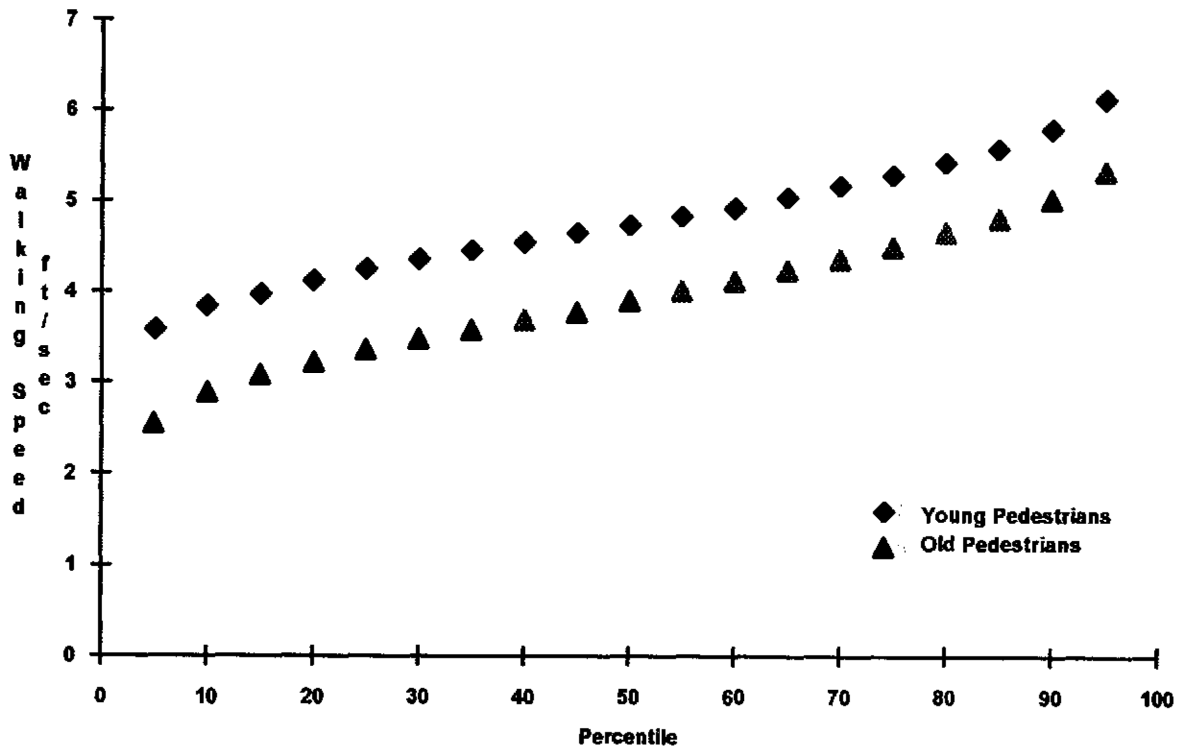


Figure 5. Distribution of the percentile values for young and older pedestrians: all compliers.

COMPARISONS WITH EXISTING DATA

The ITE Committee 5P-3 collected walking speed data on older pedestrians during April, June, and July 1991. The procedures used in this study were patterned after the ITE Committee procedures so that the data collected would be comparable. The ITE data were collected at 16 intersections in three cities: Phoenix, Arizona; San Diego, California, and Seattle, Washington. A total of 1,102 older pedestrians was observed; 379 in Phoenix, 658 in San Diego, and 65 in Seattle. To facilitate comparisons between the two data bases, it was necessary to select a comparable subset of data from this study (hereafter referred to as the CAR data). Only data collected in either clear or cloudy weather was included (i.e., no rain or snow data). Additionally, only pedestrians who were crossing in a marked crosswalk at signalized intersections were selected. However, pedestrians crossing both with the light (compliers) and against the light are included in both samples. The resulting sample included 995 older pedestrians from the ITE sample and 3,671 older pedestrians from the CAR sample. To compare the CAR and ITE samples and to make each sample representative of the cities involved, it was decided to weight the data from each city equally. Each city's data were adjusted to the arbitrarily selected sample size of 500 observations. For example, since there were 658 older pedestrians observed in San Diego, the data from that city had a weighting factor of 500 divided by 658 or 0.75. Since there were 65 older pedestrians observed in Seattle, the data from that city had a weighting factor of 500 divided by 65 or 7.69. If this was not done, the 658 pedestrians observed in San Diego would have had a disproportionate effect on the sample and the 65 observed in Seattle would have had very little effect on the characteristics of the sample. The resulting data from the ITE sample and the CAR sample are presented in table 9.

Since each city was weighted equally, the number of older pedestrians in the ITE sample (three cities) is shown as 1,500 and the CAR sample (four cities) is shown as 2,000. Both the means (3.99 for the ITE sample and 4.00 for the CAR sample) and the 15th percentiles (3.21 for the ITE sample and 3.16 for the CAR sample) are remarkably similar. Some differences were observed in the various cities. In the ITE sample, older pedestrians in Seattle walked faster than those in the other two cities. In the CAR sample, older pedestrians in Buffalo walked faster than those in the other three cities. Although both Buffalo and Seattle pedestrians walked significantly faster than the pedestrians in the other five cities, they were not significantly different (at the 0.05 level, using the Student-Newman-Keuls multiple range test) from each other.

The day-of-week differences in the unweighted data in tables 7 and 8 are also apparent in the CAR data in table 9. In the CAR data, older pedestrians walk faster on Fridays. For unknown reasons, older pedestrians in the ITE data walked slower on Fridays. Although there are no significant main effects due either to data base or day of week, there is a significant two-way interaction between data base and day of week.

Sex-related differences in the CAR data are also apparent in the ITE data. Females in both data bases walk slower. Although there is a significant main effect due to sex and a significant data base x sex interaction, the absolute differences between the speeds observed are only 8 percent of the fastest walking speed measured.

Old pedestrians walking alone, in both data bases, tended to walk slightly faster than pedestrians walking with others. The only significant effect is due to the size of the group and no significant interactions were found.

Roadway width had a similar effect on the walking speeds of pedestrians in both data bases. Older pedestrians walk more slowly when crossing narrower streets. Although there are significant main effects due to data base and roadway width, there is no significant interaction between the two. The most interesting aspect of the roadway width analysis is that the ITE data were collected on a larger number of wider streets than the CAR data. More than 90 percent of the ITE data collection locations in the weighted sample were on roads between 51.7 and 104 ft (15.76 to 31.72 m) wide. If the ITE data were as evenly distributed across the three roadway width categories as the CAR data, the aggregated mean walking speed would be somewhat lower. The

Table 9. Older pedestrian mean and 15th percentile walking speeds (in ft/s) for ITE sample and CAR sample.

Site/Environmental Factors	Number		Mean			15th Percentile	
	ITE Peds	CAR Peds	ITE Peds	CAR Peds	Signif.*	ITE Peds	CAR Peds
All Pedestrians	1500	2000	3.99	4.00		3.21	3.16
City					S		
Phoenix	500		3.96			3.07	
San Diego	500		3.84			2.88	
Seattle	500		4.18			3.63	
Baltimore		500		3.84			3.08
Buffalo		500		4.34			3.35
Richmond		500		3.96			3.16
Washington, DC		500		3.88			3.13
Day of Week					DxS		
Monday	196	444	3.97	4.02		3.04	3.25
Tuesday	334	471	3.98	3.96		3.45	3.12
Wednesday	729	558	4.02	3.94		3.18	3.08
Thursday	177	288	4.00	4.00		3.21	3.14
Friday	63	240	3.80	4.20		2.85	3.33
Pedestrian Sex					S, DxS		
Male	557	1074	4.14	4.17		3.24	3.29
Female	870	925	3.92	3.81		3.18	3.06
Group Size					S		
Alone	1090	1435	4.05	4.04		3.21	3.19
With Others	410	563	3.86	3.92		3.24	3.09
Roadway Width					D, S		
Narrow (27.7 to 42.5 ft)	34	657	3.46	3.76		2.12	3.03
Med (43.0 to 51.2 ft)	95	699	3.63	4.02		2.71	3.18
Wide (51.7 to 104.0 ft)	1370	645	4.03	4.23		3.24	3.38
Roadway Classification					DxS		
Major Arterial	1174	1423	3.98	4.02		3.21	3.18
Collector Distributor	205	264	4.06	3.89		3.29	3.07
Local Street	121	314	4.05	4.03		3.00	3.08
Ped-Actuated Signal					D, S, DxS		
Yes	673	278	4.22	4.03		3.60	3.09
No	827	1535	3.81	4.00		2.95	3.17

* T-test compared ITE vs CAR data base. Two-way analysis of variance assessed effects of the data base with each site factor. Significant effects at $p \leq 0.05$ are indicated for Data Base (D), Site (S), and Data Base by Site interactions (DxS).

1 foot = 0.305 meters.

data on roadway classification provide some interesting insight into the factors that may influence pedestrian walking speeds. There are no significant main effects due to data base or roadway classification. Although there was a significant interaction between data base and roadway classification, it is apparent that pedestrian walking speed is more influenced by the absolute width of the street than the roadway functional classification. The differences noted between the two data bases in terms of roadway width are not apparent in the distributions across roadway functional classification. About three-fourths of both samples are major arterials. This is notsurprising since major arterials in eastern cities tend to be narrower than major arterials in western cities.

The only site/environmental factor analyzed that had both a significant main effect due to the data bases and the site factor as well as a significant interaction between the two was the presence of pedestrian-actuated signals. The fastest walking times observed in the ITE data were for pedestrian crossing locations with pedestrian-actuated signals, 1.28 m/s (4.22 ft/s). It is interesting that nearly half of the ITE locations had pedestrians-actuated signals, while only about 13 percent of the CAR locations were similarly equipped. It is not known if the faster walking speeds are due to the characteristics of the streets where pedestrian signals tend to be installed, or if it is due to the pedestrians' lack of confidence in signal crossing time when it is pedestrian-actuated. Whatever the cause, it is important to recognize that the differences in observed walking speeds is only about 10 percent.

This comparison of the ITE data base with the data collected during this project strongly supports the contention that the data being reported are both reasonable and representative.

Discussion

Not surprisingly, the data set for all pedestrians who cross contains walking speeds that are significantly faster than the data set for those who cross with the light (compliers). For design purposes, it is appropriate to use the data based on compliers. The walking speeds for this subset show statistically significant variations across a variety of site and environmental conditions. However, both the mean and 15th percentile data are tightly clustered for both younger and older pedestrians. The 15th percentile value represents the walking speed that is exceeded by all but the slowest walking 15 percent of the older pedestrian population. The means for the younger pedestrians range from 1.35 to 1.53 m/s (4.51 to 5.12 ft/s) across all conditions with an overall mean speed of 1.43 m/s (4.79 ft/s). The means for the older pedestrians range from 1.11 m/s (3.73 ft/s) to 1.27 m/s (4.24 ft/s) with an overall mean speed of 3.98 (1.19). For design purposes, a mean speed of 1.2 m/s (4.00 ft/s) would appear appropriate.

The 15th percentile scores are also tightly clustered. For younger pedestrians, they range from 1.15 to 1.25 m/s (3.86 to 4.18 ft/s) with an average 15th percentile speed across all sites of 1.19 (3.97). For older pedestrians, they range from 0.87 to 0.99 m/s (2.90 to 3.31 ft/s) with an average 15th percentile speed across all sites of 0.92 (3.08). For design purposes, where a 15th percentile value is appropriate, it would appear that 0.9 m/s (3.00 ft/s) would be a reasonable value.

Since the CAR and ITE data are obviously quite similar, it was decided to conduct some limited analyses on the two data bases combined. Figure 6 presents a histograph of the combined data set. The combined data represents data from the seven cities weighted equally, (i.e., assumed 500 cases per city). The other parameters for the combined sample include:

Mean	4.000	Standard Deviation	0.854
Median	4.000	Variance	0.730
Mode	4.310	Skewness	0.285
Maximum	8.100	Standard Error (SE)	0.014
Minimum	1.140	SE Skewness	0.041
Range	6.960	SE Kurtosis	0.083

Percentile	Value	Percentile	Value	Percentile	Value
5.00	2.660	10.00	2.990	15.00	3.180
20.00	3.310	25.00	3.450	30.00	3.570
35.00	3.670	40.00	3.780	45.00	3.870
50.00	4.000	55.00	4.090	60.00	4.210
65.00	4.290	70.00	4.400	75.00	4.520
80.00	4.630	85.00	4.800	90.00	5.040
95.00	5.440				

A graph depicting the cumulative frequency distributions of the 5th through 95th percentile data is shown in figure 7.

Although this combined sample represents seven different cities that are geographically distributed, it includes data taken only during clear and/or cloudy conditions. As such, it may tend not to be representative of situations involving rainy and/or snowy conditions.

PEDESTRIAN STARTUP TIMES

Table 10 presents the mean and 15th percentile startup times for young and older pedestrians. Since startup times could be measured for only those pedestrians who waited for the signal to change before starting their crossing, these pedestrians are, by definition, compliers. Startup times were measured only at locations with a pedestrian signal and were defined as the elapsed time from the onset of the Walk signal to the

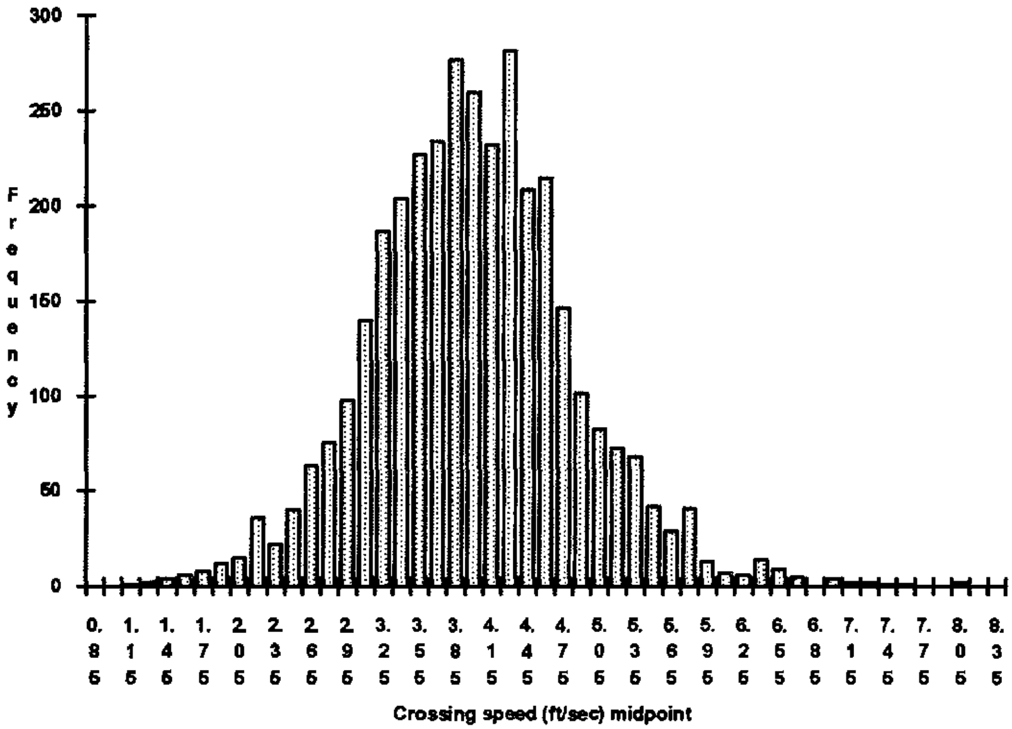


Figure 6. Histograph of combined ITE and CAR data.

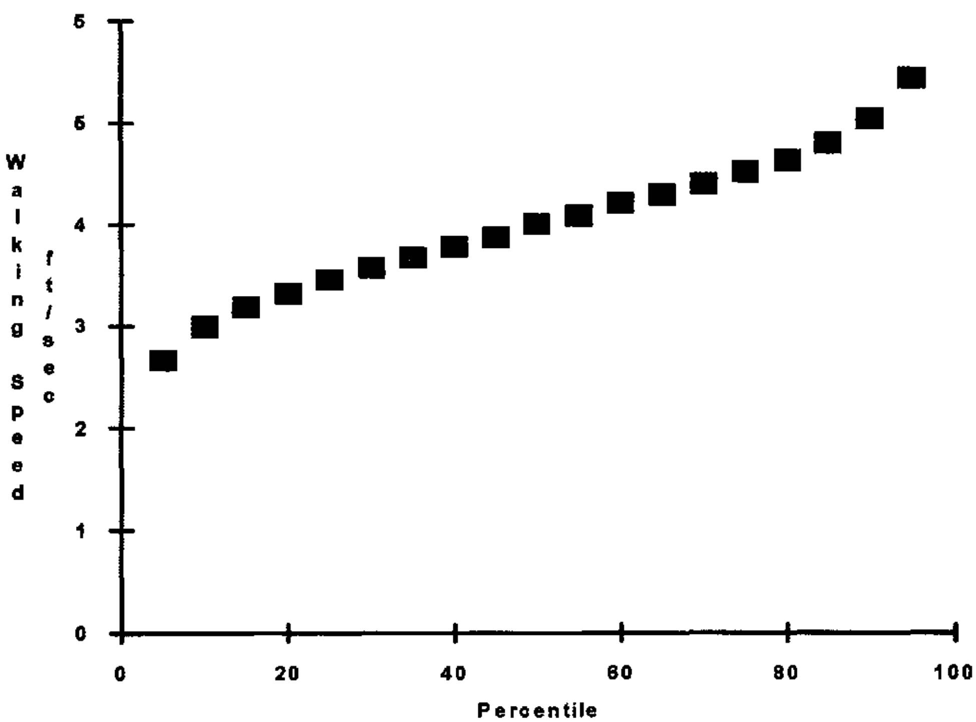


Figure 7. Distribution of the percentile values of the combined ITE and CAR data (older pedestrians only).

Table 10. Mean and 85th percentile startup times (in ft/s) for young and older pedestrians: all pedestrians.

Site/Environmental Factors	Number		Mean			85th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Significance*	Younger Peds	Older Peds
All Pedestrians	355	400	1.93	2.48	A	3.06	3.76
Pedestrian Sex					A		
Male	158	195	1.83	2.39		2.76	3.66
Female	197	205	2.01	2.57		3.31	3.95
State					A		
DC	287	260	1.87	2.47		2.76	3.75
MD	20	56	1.94	2.41		2.92	3.63
VA	25	40	2.35	2.88		4.15	5.92
NY	23	44	2.20	2.26		3.38	3.61
Day of Week							
Monday	58	62	1.93	2.44		3.31	3.47
Tuesday	90	109	1.97	2.35		3.11	3.61
Wednesday	104	121	1.68	2.56		2.75	3.84
Thursday	76	78	1.85	2.50		2.70	3.84
Friday	27	30	2.97	2.64		5.34	3.95
Start in Crosswalk							
Yes							
No							
End in Crosswalk					A		
Yes	336	348	1.90	2.48		2.79	3.76
No	19	52	2.46	2.45		4.12	4.02
Group Size					A		
Alone	264	284	1.93	2.50		3.09	3.77
With Others	91	116	1.93	2.43		2.96	3.61
Weather Conditions					A		
Dry	290	316	1.92	2.46		2.85	3.71
Drizzle	41	41	1.84	2.51		2.70	3.61
Rain	23	42	2.21	2.63		4.18	4.21

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each of the Site factors. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

1 foot = 0.305 meters.

Table 10. Mean and 85th percentile startup times (in ft/s) for young and older pedestrians: all pedestrians (continued).

Site/Environmental Factors	Number		Mean			85th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Signifi-cance*	Younger Peds	Older Peds
Wind					A, S, AxS		
Low (0-5 mi/h)	23	65	1.98	2.70		3.39	4.21
Med (6-10 mi/h)	57	47	2.18	2.72		3.31	4.85
High (11-40 mi/h)	28	36	1.89	2.39		2.82	2.86
Temperature					A		
Low (9-43°)	9	42	1.48	2.20		2.24	3.15
Med (45-58°)	64	65	1.97	2.88		2.85	5.44
High (60°+)	35	41	2.38	2.67		4.12	3.71
Pedestrian Signal					A		
Word	221	261	1.99	2.51		3.11	3.75
Symbol	134	139	1.82	2.42		2.70	3.83
Parking Permitted					A		
Yes	258	254	1.84	2.50		2.76	3.77
Restricted	39	60	1.97	2.31		3.38	3.32
No	58	86	2.31	2.55		3.73	3.84
Ped-Actuated Signal					A		
Yes	21	42	1.83	2.58		2.57	3.71
No	334	358	1.93	2.47		3.06	3.76
RTOR Permitted					A		
Yes	138	138	1.78	2.50		2.70	3.84
No	71	95	1.71	2.34		2.55	3.56
Median					A		
Yes	49	64	2.04	2.69		3.38	4.21
No	306	336	1.91	2.44		2.96	3.71
Curb Cut					A		
Yes	270	264	1.90	2.46		2.85	3.76
One Corner	78	188	1.89	2.47		2.82	3.79

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each of the Site factors. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

1 foot = 0.305 meters; 1 mile = 1.61 kilometers

Table 10. Mean and 85th percentile startup times (in ft/s) for young and older pedestrians: all pedestrians (continued).

Site/Environmental Factors	Number		Mean			85th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Significance*	Younger Peds	Older Peds
Crosswalk Marking					A		
Standard	200	212	1.95	2.49		3.07	3.75
High Visibility	155	188	1.89	2.47		2.82	3.79
Stop Line					A		
Yes	235	269	1.85	2.45		2.66	3.75
No	22	37	2.01	2.89		3.54	5.95
One-Way Roadway					A		
Approaching Intersection	549	6733	4.97	3.93		4.02	3.08
Leaving Intersection	401	492	4.80	4.01		3.97	3.17
No	1131	1214	4.78	3.91		3.97	3.05
Roadway Width					A, S		
Narrow (27.7-42.5 ft)	73	94	2.32	2.63		3.54	3.76
Moderate (43.0-51.2 ft)	89	107	1.97	2.42		2.76	3.59
Wide (51.7-104.0 ft)	193	199	1.76	2.44		2.79	3.79
Number of Lanes					A		
2	115	149	1.90	2.51		2.96	3.66
3-7	240	251	1.94	2.46		3.11	3.79
Vehicle Volume (site st.)					A		
Low (<540 vph)	15	50	2.39	2.77		3.54	5.44
Med (552-850 vph)	170	161	2.01	2.45		3.09	3.59
High (936-1764 vph)	170	189	1.80	2.43		2.82	3.76
Signal Cycle					A		
Short (60-70 s)	18	42	2.44	2.29		4.12	3.61
Moderate (71-109 s)	109	125	1.96	2.57		3.12	4.06
Long (110-140 s)	228	233	1.87	2.47		2.76	3.69
Walk Time					A		
Short (6-12 s)	91	126	2.01	2.30		3.27	3.63
Moderate (13-26 s)	218	218	1.86	2.50		2.82	3.68
Long (27-74 s)	46	56	2.10	2.82		3.39	4.25

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each of the Site factors. Significant effects at $p \le 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

1 foot = 0.305 meters

Table 10. Mean and 85th percentile startup times (in ft/s) for young and older pedestrians: all pedestrians (continued).

Site/Environmental Factors	Number		Mean			85th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Significance*	Younger Peds	Older Peds
Flashing Don't Walk Time					A		
Short (6-10 s)	44	57	2.00	2.70		3.14	3.95
Moderate (11-15 s)	183	178	1.82	2.33		2.72	3.75
Long (16-30 s)	128	165	2.06	2.57		3.06	3.69
Steady Don't Walk Time					A		
Short (13-41 s)	63	88	1.99	2.54		2.96	3.69
Moderate (42-51 s)	164	182	1.98	2.59		3.14	3.79
Long (52-86 s)	123	128	1.85	2.30		3.11	3.63

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each of the Site factors. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

1 foot = 0.305 meters

time that the pedestrian stepped off the curb and started the crossing. Startup times were taken on only those pedestrians who stopped at the curb and waited for the signal to change before starting to cross.

It is interesting that the same site/environmental factors that almost always showed significant interactions with walking speeds (tables 7 and 8) did not (with the exception of roadway width) have a significant interaction with startup time. However, with the single exception of Day of Week, the startup times for older pedestrians were always significantly longer than those of younger pedestrians.

One could hypothesize that being in a group might affect startup time. The presence of others could conceivably delay startup or, alternatively, one might expect that the group would start crossing as soon as the quickest pedestrian in the group starts. The data indicate that there is no such effect. Younger pedestrians had identical mean startup times (1.93 s) whether alone or in a group. Older pedestrians had nearly identical startup times of 2.50 s when alone and 2.43 s when in a group.

Some of the site/environmental factors included in tables 7 and 8 are not included in table 10. This is because the distribution of the sample across some of the categories did not have sufficient *n* to allow meaningful comparisons. For example, all but 11 of the 355 younger pedestrian observations occurred on major arterials, so there were insufficient cases on either collector-distributors or local streets to conduct meaningful analyses. This was due to the fact that pedestrians rarely wait for the pedestrian signal unless they are forced to do so by oncoming traffic. Only two site/ environmental variables showed either a significant main effect of significant interaction (two-way analysis of variance at $p \leq 0.05$). During windy conditions it was found all pedestrians were affected somewhat more. It is suspected that this effect may be because older, more frail pedestrians may tend to avoid windy conditions, so startup times measured under those conditions involve a different subset of older pedestrians.

A similar association between startup times and cold weather was also evident in the data. That effect, however, was not significant. The second significant site factor effect involved roadway width. Pedestrians in both age groups tend to have faster startup times at locations with wider roadway widths. It is not knows if the faster startup times are due to increased vigilance or anticipation in response to the prospect of crossing a wider street or if there are some subject selection effects. For example, some older pedestrians may avoid wider crossings so we may be measuring slightly different populations at different locations. Since this same effect was also apparent among the younger pedestrians observed, it is suspected that the effect is one of anticipation, increased preparedness at the wider crossing locations.

Discussion

The startup times for the pedestrians observed did not show the same variability across site and environmental conditions observed for the walking speed data. This was largely due to the limited variability between the sites where startup time could be measured. Startup time could be measured only if the pedestrians chose to wait for the signal before starting their crossing. This typically happens only at locations where pedestrians are forced to wait because of oncoming traffic.

The mean startup times for younger pedestrians varied from 1.83 s for males to 2.01 s for females, with an overall mean value of 1.93 s. For older pedestrians, the mean values ranged from 2.39 s for males to 2.57 s for females with an overall mean value of 2.48 s. For design purposes, it would appear that a mean value of 2.50 s would be appropriate.

The 85th percentile values for younger pedestrians ranged from 2.76 s (males) to 3.31 s (females) with an overall value of 3.06 s. For older pedestrians, startup times varied from 3.66 to 3.95 s with an overall value of 3.76 s. For design purposes, an 85th percentile value of 3.75 s would be appropriate.

PEDESTRIAN STRIDE LENGTH

During the development of the field data collection procedures, it became obvious that the walking speeds of the older pedestrians were likely to be somewhat slower than those of the younger pedestrians. At that time, it was hypothesized that the slower speeds could be due to the older pedestrians' taking either shorter steps or slower steps. To test these hypotheses, it was decided to count the number of strides taken by the pedestrians observed. Since this was not a major part of the research effort, only one observer in each city collected data on stride length. The width of the roadway, in fact, was divided by the number of steps taken to determine the average stride length. Stride length data may be of use to those designing pedestrian facilities and in quantifying factors associated with walking on irregular or slippery surfaces.

Table 11 presents the mean and 15th percentile values of 476 younger pedestrians and 464 older pedestrians on which this information was collected. The stride length data, like the walking speed data, show a great deal of significant interactions with the various site/environmental factors listed. With few exceptions, where pedestrians tend to walk faster, they also tend to take longer steps. Perhaps most interesting is that pedestrians in both age groups do not take shorter steps when the roadway is wet or snow covered and more likely to be slippery. This may be because pedestrians who choose to walk during inclement weather are less bothered by the potentially hazardous walking conditions.

Table 8 indicated that younger pedestrians walk 1.43 m/s (4.79 ft/s) while older pedestrians walk 1.20 m/s (3.94 ft/s) or about 82 percent as fast. In table 11 the stride lengths for younger pedestrians are listed at 0.74 m (2.42 ft) versus 0.64 m (2.09 ft) for older pedestrians. The stride lengths of all older pedestrians are about 86 percent of younger pedestrians. Similarly, older male pedestrians walk 83 percent slower than younger male pedestrians and have stride lengths 87 percent shorter. Older females walk 80 percent slower and have 84 percent shorter stride lengths. This suggests that the slower walking speeds of older pedestrians are largely due to their shorter stride lengths. Apparently only a small proportion of the slower speeds is due to slower step frequency or rate.

Table 11. Mean and 15th percentile stride length (in ft/s) for young and older pedestrians: compliers.

Site/Environmental Factors	Number		Mean			15th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Significance*	Younger Peds	Older Peds
All Pedestrians	476	464	2.42	2.09	A	2.06	1.70
Pedestrian Sex					A, S		
Male	227	228	2.57	2.24		2.24	1.88
Female	249	236	2.28	1.93		2.00	1.59
State					A, S, AxS		
DC	77	69	2.34	1.97		2.02	1.66
MD	137	144	2.34	1.93		2.02	1.57
VA	116	103	2.36	2.06		2.03	1.82
NY	146	148	2.57	2.31		2.17	1.91
Day of Week					A, S, AxS		
Tuesday	62	61	2.50	2.09		2.09	1.78
Wednesday	142	146	2.46	2.22		2.08	1.82
Thursday	173	164	2.36	2.00		2.03	1.63
Friday	99	91	2.40	2.01		2.02	1.62
End in Crosswalk					A		
Yes	433	404	2.42	2.08		2.07	1.70
No	43	60	2.39	2.10		2.03	1.76
Group Size					A, S		
Alone	373	336	2.45	2.10		2.09	1.71
With Others	103	128	2.31	2.06		2.00	1.70
Weather Conditions					A, S		
Dry	250	264	2.38	2.06		2.03	1.71
Drizzle	79	94	2.40	2.09		2.07	1.75
Rain	103	73	2.48	2.08		2.10	1.58
Snow	44	33	2.54	2.28		2.17	1.83
Wind					A, S		
Low (0-5 mi/h)	129	125	2.36	2.03		2.03	1.70
Med (6-10 mi/h)	72	82	2.49	2.08		2.07	1.64
High (11-40 mi/h)	198	188	2.46	2.17		2.10	1.77

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each Site factor. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

1 foot = 0.305 meters

Table 11. Mean and 15th percentile stride length (in ft/s) for young and older pedestrians: compliers (continued).

Site/Environmental Factors	Number		Mean			15th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Signifi-cance*	Younger Peds	Older Peds
Temperature					A, S		
Low (9-43°)	167	156	2.51	2.22		2.16	1.71
Med (45-58°)	134	123	2.40	2.07		2.06	1.75
High (60°+)	98	116	2.34	2.00		1.99	1.70
Street Classification					A, S		
Major Arterial	343	331	2.46	2.16		2.07	1.78
Collector-Distributor	33	31	2.24	1.85		1.91	1.50
Local Street	100	102	2.33	1.93		1.98	1.55
Parking Permitted					A, S		
Yes	248	254	2.36	2.02		2.05	1.64
Restricted	145	138	2.52	2.19		2.10	1.77
No	83	72	2.41	2.15		2.03	1.82
Ped-Actuated Signal					A, S, AxS		
Yes	137	144	2.34	1.93		2.02	1.57
No	339	320	2.45	2.16		2.07	1.79
RTOR Permitted					A, S		
Yes	41	44	2.47	2.18		2.17	1.91
No	190	197	2.32	1.93		2.00	1.57
Median					A, S, AxS		
Yes	117	103	2.55	2.36		2.13	1.94
No	359	361	2.38	2.01		2.05	1.64
Curb Cut					A, S		
Yes	295	293	2.34	2.03		2.01	1.64
One Corner	181	171	2.55	2.18		2.16	1.77
Crosswalk Marking					A, S, AxS		
Standard	298	286	2.43	2.15		2.07	1.78
High Visibility	178	178	2.40	1.98		2.05	1.62
Stop Line					A, S		
Yes	274	276	2.46	2.11		2.10	1.70
No	116	103	2.36	2.06		2.03	1.82

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each Site factor. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

1 foot = 0.305 meters

Table 11. Mean and 15th percentile stride length (in ft/s) for young and older pedestrians: compliers (continued).

Site/Environmental Factors	Number		Mean			15th Percentile	
	Younger Peds	Older Peds	Younger Peds	Older Peds	Significance*	Younger Peds	Older Peds
One-Way Roadway					A		
Approaching Intersection	136	132	2.42	2.08		2.07	1.77
Leaving Intersection	86	85	2.36	2.04		2.01	1.65
No	254	247	2.44	2.11		2.05	1.70
Roadway Width					A, S, AxS		
Narrow (27.7-42.5 ft)	170	175	2.32	1.92		2.00	1.57
Moderate (43.0-51.2 ft)	148	142	2.46	2.12		2.07	1.77
Wide (51.7-104.0 ft)	158	147	2.48	2.26		2.08	1.86
Number of Lanes					A, S, AxS		
2	138	145	2.34	1.93		2.02	1.57
3-7	338	319	2.45	2.16		2.07	1.81
Vehicle Volume (site st.)					A, S		
Low (<540 vph)	174	167	2.37	1.97		2.00	1.62
Med (552-850 vph)	182	173	2.53	2.25		2.17	1.84
High (936-1764 vph)	120	124	2.31	2.02		2.02	1.75
Signal Cycle					A, S, AxS		
Short (60-70 s)	146	148	2.57	2.31		2.17	1.91
Moderate (71-109 s)	116	103	2.36	2.06		2.03	1.82
Long (110-140 s)	214	213	2.34	1.94		2.02	1.60
Walk Time					A, S		
Short (6-12 s)	183	190	2.53	2.23		2.17	1.84
Moderate (13-26 s)	119	107	2.31	2.01		2.02	1.71
Long (27-74 s)	174	167	2.37	1.97		2.00	1.62
Flashing Don't Walk Time					A, S		
Short (6-10 s)	141	136	2.40	2.00		2.05	1.62
Moderate (11-15 s)	78	86	2.34	1.98		2.02	1.66
Long (16-30 s)	257	242	2.45	2.17		2.07	1.78
Steady Don't Walk Time					A, S		
Short (13-41 s)	287	284	2.49	2.16		2.10	1.71
Moderate (42-51 s)	111	94	2.29	1.95		2.01	1.62
Long (52-86 s)	78	86	2.34	1.98		2.02	1.66

* T-test compared young vs old pedestrians. Two-way analysis of variance assessed the effects of Age with each of the Site factors. Significant effects at $p \leq 0.05$ are indicated for Age (A), Site (S), and Age by Site interaction (AxS).

1 foot = 0.305 meters

4. DEVELOPMENT OF RECOMMENDED CHANGES TO HIGHWAY DESIGN AND OPERATIONAL PRACTICES

Several areas warrant changes to highway design and operational practices to accommodate the older pedestrian. This section reviews the results from this study relative to their significance in modifying highway design and operational practices. Several key documents for design and operational practice are also examined to see where changes could be made to heighten the designer's attentiveness to older pedestrians. Based on these evaluations, specific recommendations are made regarding highway design, and operational practices and standards that benefit older pedestrians. Suggested changes are made for each of the following documents:

- *AASHTO Policy on the Geometric Design of Highways and Streets.*
- *Manual on Uniform Traffic Control Devices.*
- *Traffic Control Device Handbook.*
- *Manual of Traffic Signal Design.*
- *Highway Capacity Manual.*
- *Model Pedestrian Safety Program—Users' Guide.*
- *Planning, Design, and Maintenance of Pedestrian Facilities.*

REVIEW OF RESULTS FROM PREVIOUS TASKS

Of all of the data gathered during the research effort, the most pertinent for making changes to highway design and operational practices are those related to pedestrian walking speeds and pedestrian startup times.

Based on the abundance of literature on the subject, it would appear that pedestrian walking speeds have been studied by many different researchers. However, many differing results are presented regarding older pedestrian walking speeds. There is also little or no information on the ranges or distributions of these older pedestrian walking speeds. Further, if specific studies are examined in terms of number of observations, the age of the subjects, and the range of conditions, it is clear that prior to this study, a definitive walking speed study, especially for older pedestrians, had not been done.

Information on pedestrian startup time is important in many aspects of design, yet there are no documented studies on this subject. Therefore, the results from this study provide a basis for selecting reliable pedestrian walking speeds and pedestrian startup times.

The walking speed and startup time data sets include information on both compliers and noncompliers. Compliers are pedestrians who cross during an appropriate traffic signal indication, and noncompliers are pedestrians who violate the traffic signal indication. Pedestrians who violate signal indications likely do so knowingly. They are aware of the increased danger to themselves, and because of this, they choose to leave the sidewalk area or walk at a speed that is different from the speed they might choose if they were crossing with the signal. For this reason, the only information appropriate for design purposes are the data on pedestrian compliers (table 8).

Data were collected on walking speeds and startup times relative to several different site/environmental factors, which are discussed below:

- **Group size**—If pedestrians are traveling as a group, the size of that group has implications for pedestrian gap acceptance and crossing delay studies relative to pedestrian startup times. However, it is generally assumed that group size does not influence walking speed.
- **Weather Conditions**—If weather is shown to influence pedestrian behavior, then designers in areas with above-normal rain or snow could choose appropriate weather-based parameters for signal timing. Or, a wet walking surface could be the default condition selected for design.
- **Pedestrian Signal**—Designers would be interested to know if the presence or absence of a pedestrian signal head or the type of message used for the pedestrian signal influences walking speeds or startup times.
- **Street Classification**—Functional classification is a fundamental concept in geometric design. If walking speeds differ by class of roadway, designers can specify appropriate operational controls based on highway functional classification.
- **Parking Permitted**—It would aid designers to know if the presence or absence of on-street parking influences walking speeds or startup times.
- **Pedestrian-Actuated Signal**—While this factor would not be expected to affect pedestrian behavior, the decision to include or exclude this type of device is in the hands of the designer and knowledge of its effects is important.
- **Right Turn on Red Permitted**—If pedestrians are aware of this factor, it could influence startup times as they hurry to get into the crosswalk before a turning vehicle or hold back looking for an appropriate gap in the turning traffic.

- **Median**—If medians are provided, giving the pedestrian a feeling of security because the crossing maneuver is simplified, they might start up and walk slower than when there are no mid-crossing refuge areas.

- **Curb Cut**—While the effects of properly installed curb cuts on disabled pedestrians are known, their impact on the walking speeds or startup times of older pedestrians is unknown.

- **Crosswalk Marking**—It would be interesting for the designer to know if pedestrians start up and cross slower in a marked crosswalk because of an increased sense of security.

- **Stop Line**—It would also be interesting to know if stop lines contribute to an increased sense of security. If a pedestrian believes a driver knows where to stop without encroaching into the pedestrian's area, the pedestrian might be more likely to start up before an approaching vehicle comes to a complete stop, for example.

- **Roadway Width**—Intuitively, one would think that pedestrians would start up and walk at a quicker pace on wider crossings. However, based on existing information, their behavior is unknown.

- **Number of Lanes**—This factor is essentially a surrogate measure for curb width; however, it is easier to catalog.

- **Vehicle Volume (site street)**—Vehicle volume would be a surrogate measure of the various pedestrian indications discussed below.

- **Vehicle Volume (cross street)**—The vehicle flows on the cross street can be a surrogate measure of the number of potential pedestrian-vehicle conflicts. Pedestrian startup and walking speeds might be influenced by the number of potential conflicts.

- **Signal Cycle**—It would be of interest for the designer to know how pedestrians react to different cycle lengths. They may quicken their pace during short cycles because of quick indication changes at the intersection, or they may speed up during longer cycles knowing that if they become trapped on a median, it will be a long time before their indication sequences through again.

- **Walk/Flashing Don't Walk/Steady Don't Walk Indication Times**—The length of the various pedestrian phases could certainly be expected to influence pedestrian walking speeds.

In most instances, the designer's interest in pedestrian startup times and walking speeds is twofold. First, to design a safe geometric layout and operational situation, the designer needs a true representation of how much time pedestrians of all ages and capabilities require to cross specific sections of roadway. Second, the designer wants the design to operate as efficiently as possible, which usually means minimizing the time necessary to accommodate the pedestrian and maximizing the time available for vehicular traffic movement. With better information on startup times and walking speeds relative to site/environmental factors, the designer can consider the effect of many different elements relative to the two major design objectives.

In examining the data, there are statistically significant differences between startup times and walking speeds by age category for most of the site/environmental factors just discussed. It is also noted that the "intuitive directionality" of the startup times and walking speeds (i.e., the times and speeds change in the direction one would expect given an intuitively based supposition of the influence of the factor) follow general expectations. However, in every case, the differences between times and speeds, while statistically significant, are not meaningful from a design point of view. For example, for curb width, the results are considered to be statistically significant and the mean walking speed increases as the curb width increases. That is, pedestrians walk faster when they have a wider street to cross. This follows the intuitive directionality mentioned above. However, the differences would have little influence on actual design parameters. For an exceptionally wide crossing (e.g., 22.9 m [75 ft] without a median), the influence of the 1.1 m/s (3.73 ft/s) walking speed for the "low" curb width street and the 1.3 m/s (4.18 ft/s) walking speed for the "high" curb width street on the minimum pedestrian phase time would be only 2 s. This should be compared to an overall minimum pedestrian phase for this road of 20 s. While this may seem like a important difference (e.g., a 2-s time shortage would mean the older pedestrian would only be one-third of the way across the last lane), as conditions get worse (i.e., a wider roadway width), the walking speeds increase, thereby minimizing the problem.

Given the small overall differences between startup times and walking speeds by age category for most of the site/environmental factors, it is recommended that the designer focus on the aggregated times and speeds for all complying walkers.

Past studies have shown that there are no defensible criteria for acceptable minimum levels of human performance. Many researchers have suggested that performance be set at some arbitrary value such as 15/85 percent (nominally the elbow/knee/break points in the cumulative ogive plot of normally distributed data). With no better guidance, it is recommended that the 15th percentile values for older pedestrians for both startup times and walking times be adopted as the standard for these parameters (tables 8, 9, and 10).

While the data on pedestrian startup times and walking speeds provide a beginning point for geometric and operational design, the designer must also be aware of the myriad of problems faced by older walkers as evidenced in the discussions of accident characteristics, focus group, and survey results. The problems at wider, more complex intersections with channelization and separate turning lanes are well documented. Threats from turning or merging vehicles are also a critical problem. Older pedestrians' problems seeing and understanding pedestrian signal indications are other important design factors.

RECOMMENDED CHANGES TO HIGHWAY DESIGN AND OPERATIONAL PRACTICES

Based on the data gathered in the field studies, recommendations are made for guidelines related to highway design and operational practices. The specific wording for these suggestions, however, should be considered and approved by the appropriate oversight bodies.

AASHTO Policy on the Geometric Design of Highways and Streets

This design policy has essentially become the design standard for highways and streets in this country. It is often the only source that designers consult to obtain information on the design of different roadways. Given its prominence in the design process, "the Green Book" should provide accurate guidance regarding the accommodation of older pedestrians. Based on the results of this study, suggested changes are given below.

Since older pedestrians have shown a marked preference for curb ramps, it is suggested that the sentence in the text on p. 99, line 3 be changed from:

> *Pedestrian facilities include sidewalks, crosswalks, traffic control features, special walkways found on some portions of freeway right-of-way, and curb cuts (depressions) and ramps for the handicapped.*

to the following:

> *Pedestrian facilities include sidewalks, crosswalks, traffic control features, special walkways found on some portions of freeway right-of-way, and curb cuts (depressions) and ramps for* ***older walkers and*** *the handicapped.*

As discussed in a previous chapter, older people experience many changes related to psychomotor factors. Therefore, the characterization that:

...the elderly appear inattentive or defiant toward motor vehicles and drivers. (P. 99, para. 6, line 3)

could be changed to the following:

...the elderly ***are affected by limitations in sensory, perceptual, cognitive, and motor skills brought on by the aging process.***

The results of this study could be used to make some additions to a fairly complete list of countermeasures that would aid the older pedestrian. The section below (p. 99, para. 7) currently reads:

The following have been suggested as measures with potential to aid the elderly pedestrian:

- *Assess alternate designs at pedestrian crossings to protect elderly pedestrians.*
- *Lower walking speed criterion, particularly at wide signalized intersections.*
- *Provide refuge islands at wide intersections.*
- *Provide lighting at locations which (sic) require multiple information gathering and processing, and eliminate glare sources.*
- *Consider the traffic control system in the context of the geometric design to assure compatibility and to provide adequate advance warning of situations that could surprise or adversely affect the safety of elderly drivers and pedestrians.*
- *Use enhanced standard traffic control devices.*
- *Provide oversized, retroreflective signs with suitable legibility.*
- *Consider increasing sign letter size to accommodate individuals with decreased visual acuity.*
- *Use properly located signals with large signal indications.*
- *Provide enhanced marking and delineation.*
- *Use repetition and redundancy.*

This could be changed to the following:

The following have been suggested as measures with potential to aid the elderly pedestrian:

- ***Use simple designs that minimize crossing widths and minimize the use of more complex elements such as channelization and separate turning lanes. When these features are necessary,*** *assess alternate designs that will protect elderly pedestrians.*

- ***Assume*** *lower walking speeds.*

- *Provide refuge islands* ***of sufficient width*** *at wide intersections.*

- ***Consider the use of flared curbs at intersections.***

- *Provide lighting or reduce glare at locations* ***where the crossing maneuver is complicated or there is potential for many pedestrian-vehicle conflicts.***

- *Consider the* ***function, detectability, legibility, and comprehensibility of all traffic control devices*** *in the context of the design to assure compatibility* ***with geometric elements*** *to provide* ***sufficient information to allow the pedestrian to enter and cross the street safely.***

- *Provide oversized signs with* ***greater retroreflectivity and*** *suitable legibility.*

- *Consider increasing sign letter size to accommodate individuals with decreased visual acuity.*

- *Use properly located signals with large signal indications.*

- *Provide enhanced marking and delineation.*

- *Use repetition* ***in providing information to the pedestrian.***

Knowing that many elderly pedestrians use devices, such as canes, walkers, or shopping carts, and that they are more often accompanied by other pedestrians, an additional paragraph could be added to the section on body area on p. 101. It could read:

Older pedestrians may need to use canes or walkers to assist them in walking. Some pedestrians may have devices such as shopping carts or baby strollers with them that may increase the effective body area to be used in design. In addition, older pedestrians as well as small children are more likely to be accompanied by an adult walking side by side, also resulting in an increase in effective body area.

These increased body areas could have implications for the design of pedestrian refuge areas. Therefore, the section that reads:

For the design of sidewalks, stairs, or transit-loading areas, a knowledge of the width and depth of the body is most useful. (p. 101, para. 1, line 2).

could be changed to read:

*For the design of sidewalks, **ramps, crosswalks, refuge areas,** stairs, or transit-loading areas, a knowledge of the width and depth of the body **or the effective body area** is most useful.* (p. 101, para. 1, line 2).

With additional information on walking rate, the entire section on walking rate should be amended. The current text is as follows:

There is a broad range of walking speeds among pedestrians. The rates when crossing a street are significant in design. Average walking speeds range from approximately 2.5 to 6.0 ft/s with the Manual on Uniform Traffic Control Devices (MUTCD) assuming a normal walking rate of 4.0 ft/s. Older people will generally be in the slower part of this range.

Walking rates are faster at midblock than at intersections, are faster for men than women, and are affected by steep grades. Air temperature, time of day, trip purpose, and ice and snow all affect the pedestrian walking rate. Age is the best identified cause for slower walking rates, and in areas where there are many older people, a rate of 3 (sic) ft/s should be considered.

An amended text could be as follows:

*There is a broad range of walking speeds among pedestrians. The rates **used to determine how long it will take a pedestrian to cross a street can be** significant in design. **A comprehensive***

FHWA study, Publication No. FHWA-RD-93-177, containing observations of more than 7,000 pedestrian crossings found that mean walking speeds range from approximately 3.94 to 4.79 ft/s. The 15th percentile walking speed for younger pedestrians (under 65 years of age) was 3.97 ft/s and the 15th percentile walking speed for older pedestrians (over 65 years of age) was 3.08 ft/s. For design purposes, values of 4.0 ft/s for younger pedestrians and 3.0 ft/s for older pedestrians can be assumed.

Walking rates are somewhat influenced by a variety of factors including: the functional classification of the street being crossed, the vehicle volumes on the street being crossed, the street width, weather conditions, the number of pedestrians crossing in a group, the signal cycle length, the lengths of the various pedestrian phases, permitted right turn on red, and the presence or absence of pedestrian signals, medians, curb cuts, crosswalk markings, stop lines, on-street parking. However, for each of these factors, the effect on crossing speeds, while statistically significant, is not meaningful from a design point of view.

Manual on Uniform Traffic Control Devices

As the only accepted national standard on signs, signals, and markings for streets and highways, the MUTCD provides primary guidance to designers in providing traffic control. The results of this study have provided some direction toward specific areas that could be changed to be more responsive to the needs of older pedestrians.

Many of the pedestrian-oriented devices in the MUTCD need to be used judiciously to respond to several general conclusions that were reached as part of this study. There should be a firm understanding on the part of the designer that some of the pedestrian-oriented traffic controls are not well understood by older pedestrians (e.g., the flashing Don't Walk signal indication). Further, many older pedestrians have little confidence in many of these devices, e.g., pedestrian signal push buttons. Also, it should be remembered that the size and placement of pedestrian-oriented devices at intersections is critical. All traffic controls must be conspicuous and legible even across wide streets.

Given that older pedestrians are sometimes confused by complicated situations, a change may be necessary to the section of the Manual that discusses provisions for pedestrians (sec. 4B-28). Part 1a (p. 4B-21) of that section now reads:

c. vehicular indications for conflicting movements that can be conveniently viewed by pedestrians, and from which pedestrians can readily and accurately deduce when they have the right-of-way.

It may be better to include some additional information as follows:

c. vehicular indications for conflicting movements that can be conveniently viewed by pedestrians, and from which pedestrians can readily and accurately deduce when they have the right-of-way. ***However, this method may cause some confusion for very young and older pedestrians.***

To counteract the general lack of confidence in pedestrian push button detectors, the word "may" in the following section could be changed to "should" or "shall":

A pilot light or other means of indication ***may*** *be installed with a pedestrian push button and normally should not be illuminated. Upon actuation, it shall be illuminated until the pedestrian's green or WALK indication is displayed.* (sec. 4B-29 Pedestrian Detectors, p. 4B-21, para. 3)

The section on the minimum pedestrian volume signal warrant should be changed so that the slower walking speeds of older pedestrians are considered. The part that reads:

...there shall be 60 gaps per hour in the traffic stream of adequate length for pedestrians to cross... (sec. 4C-5 Warrant 3, Minimum Pedestrian Volume, p. 4C-5, para. 2, line 1)

could be changed to:

...there shall be 60 gaps per hour in the traffic stream of adequate length, ***based on a pedestrian walking speed of 3.0 feet per second,*** *for pedestrians to cross...*

Based on the information that older pedestrians have problems locating and seeing certain pedestrian-oriented traffic controls, it might be necessary to change the section on design requirements so that the older pedestrian needs are highlighted. The section now states:

1. Pedestrian indications should attract the attention of, and be readable to, the pedestrian (both day and night) at all distance from 10 feet to the full width of the area to be crossed. (sec. 4D-4, Design Requirements, p. 4D-2)

A possible change could be:

> *1. Pedestrian indications should attract the attention of, and be readable to, the pedestrian (both day and night) at all distance from 10 feet to the full width of the area to be crossed.* ***Careful consideration of this requirement shall be made relative to the needs of older pedestrians.***

As one of the principal aims of this study was to establish definitive walking speeds for older pedestrians, the parenthetic note on walking speeds in sec. 4D-7, Pedestrian Intervals and phases, which now reads:

> *...(normal walking speed is assumed to be 4 feet per second).*

should be amended to:

> *...(normal walking speed* ***for younger adults [under 65 years of age]*** *is assumed to be 4 feet per second* ***while normal walking speed for older adults [over 65 years of age] is assumed to be 3 feet per second).***

Traffic Control Device Handbook

This companion document gives interpretive guidance for complying with the standards set out in the MUTCD. While pedestrian related issues are not covered extensively, some minor adjustments could be made based on the results of this study.

With detailed data on pedestrian walking speeds, several changes could be made. In the section on pedestrian signal timing, the handbook states:

> *The MUTCD cites an assumed normal walking speed of 4 feet per second. However, research verifies that one-third of all pedestrians cross streets at a rate slower than 4 fps and 15 percent walk at or below 3.5 fps.* (p. 4-105, para. 3, line 1)

This could be changed to:

> *The MUTCD cites an assumed normal walking speed of 4.0 feet per second.* ***This value is appropriate for younger pedestrians (under 65 years of age). However, research has shown that older pedestrians (over 65 years of age) walk at or below 3.0 feet per second.***

Given this change, table 4-18 (p. 4-106) should be changed to include a column of clearance intervals based on a walking speed of 3.0 ft/s. The interval values would be 8.3, 11.7, 15.0, 18.3, 21.7, 25.0 s for street widths of 30, 40, 50, 60, 70, 80 ft, respectively.

Regarding the pedestrian WALK indication, the MUTCD suggests that the range of times for this interval should be 4 to 7 s to allow the pedestrians to leave the curb before the change interval is shown. This is likely based on the assumption that pedestrians startup times for individual pedestrians and groups of pedestrians range from 4 to 7 s. The results of this study have shown that the 85th percentile startup times for younger adults is 3 s, while the 85th percentile startup times for older pedestrians (over 65) is 4 s. In light of these results, it is believed that no changes are necessary to the current practice for selecting a minimum WALK interval. This "no change" recommendation would also hold for similar information in the *Traffic Control Devices Handbook* and the *ITE Manual of Traffic Signal Design*.

Manual of Traffic Signal Design

This ITE publication covers the fundamental concepts and standard practices related to traffic signal design. Many of the findings of this study are related to information found in this publication.

The manual reviews the same traffic signal warrants that are in the MUTCD. As with the MUTCD, this manual should change some of the information about Warrant 3, Minimum Pedestrian Volume. The manual states:

> *In addition to the minimum pedestrian volume, there shall be less than 60 gaps per hour (of adequate length for pedestrians to cross) during the period when the pedestrian count is satisfied. (p. 9, para. 3, line 1)*

It would be more responsive to the needs of older pedestrians if it were changed to:

> *In addition to the minimum pedestrian volume, there shall be less than 60 gaps per hour (of adequate length for pedestrians to cross),* ***based on a pedestrian walking speed of 3.0 feet per second,*** *during the period when the pedestrian count is satisfied.*

With current data on pedestrian walking speeds, changes could be made to the section on pedestrian signal timing, the manual states:

> *The typical walking speed of 4 ft/s, as cited in the MUTCD, is assumed to represent the "normal" pedestrian. There are, however, various categories within the general population that walk at a slower*

rate. For example, some female pedestrians walk slower than some male pedestrians; very young children, the elderly, and the handicapped also walk at a slower rate. Research on pedestrian characteristics verify that over 60% (sic) of all pedestrians move slower than 4 ft/s and 15% (sic) walk at or below 3.5 ft/s.

Although this may imply that lower walking speed (3.5 ft/s) should be used in calculating pedestrian timing, many engineers argue that the slower rate creates longer cycle lengths, ultimately resulting in longer vehicle delays. Table 11-2 presents typical minimum pedestrian clearance intervals for various streets widths based on 4 and 3.5 ft/s pedestrian walking speeds. (p. 145, para. 3, line 1)

This could be changed to:

The typical walking speed of 4 ft/s, as cited in the MUTCD, is assumed to represent the "normal" pedestrian. This value is appropriate for younger pedestrians (under 65 years of age). However, research has shown that older pedestrians (over 65 years of age) walk at or below 3.0 ft/s.

*Although this may imply that the lower walking speed **(3.0 ft/s)** should be used in calculating pedestrian timing, many engineers argue that the slower rate creates longer cycle lengths, ultimately resulting in longer vehicle delays. Table 11-2 presents typical minimum pedestrian clearance intervals for various street widths based on 4.0, 3.5, and **3.0 ft/s** pedestrian walking speeds.*

Given this change, table 11-2 (p. 145) should be modified to include a column of clearance intervals based on a walking speed of 3.0 ft/s. The interval values would be 8.3, 11.7, 15.0, 18.3, 21.7, 25.0 s for street widths of 30, 40, 50, 60, 70, 80 ft, respectively.

Model Pedestrian Safety Program—Users' Guide

This document provides the means for establishing and monitoring a program that assesses the safety element of pedestrian operations. While this is a pedestrian-oriented publication, there are only a few areas where information gathered in this study would be useful in making some additions to the text.

In the section on implementation considerations (p. 20), some additional information could clarify certain points. For example, in this section the second bulleted item reads:

- *Signal timing should also consider pedestrians with special cycles where needed (e.g., longer crossing times in areas with substantial volumes or older adults or handicapped pedestrians).*

It could be changed to read:

- *Signal timing should also consider pedestrians by use of special cycles where needed (e.g., longer crossing times may be needed in areas with substantial volumes or older adults or handicapped pedestrians).* ***At these locations, lower walking speeds [on the order of 3 ft/s or less] may be appropriate to determine minimum phase lengths).***

Planning, Design, and Maintenance of Pedestrian Facilities

This is the most current compilation of the state of the art in the design and operation of pedestrian facilities. Information from the current study could be used to make additions or changes to parts of this handbook.

The second chapter of the handbook presents a rather detailed section on walking speeds (chapter 2, p. 4). This section covers general information on walking speeds, distributions of walking speeds, and the walking speeds of several specific user groups (e.g., older pedestrians, younger pedestrians). Based on the new information gathered as part of this study, this entire section should be rewritten. However, unlike many of the references discussed above, the current level of detail on walking speeds is so great that a simple correction of the information already in the handbook may diminish or leave out some important detail from one of the previous studies cited. Therefore, it would be more appropriate for the original authors of the handbook to be made aware of the new data gathered for this project. They should be encouraged to include this new information in any subsequent updates of their original text.

In a later section dealing with refuge islands the handbook states:

...at a signalized intersection, an island should be considered if the entire crosswalk cannot be traversed, using a speed of 3.5 ft/sec (1.1 m/sec), within the walk cycle of the signal and the signal timing cannot be lengthened or an alternate crossing designated. (p. 124, first bulleted item, line 6)

This section would be more sensitive to the needs of older pedestrians if it were modified to read:

...at a signalized intersection, an island should be considered if the entire crosswalk cannot be traversed, ***using a speed of 3.0 ft/s (0.9***

***m/s)**, within the walk cycle of the signal and the signal timing cannot be lengthened or an alternate crossing designated.*

There is also a rather detailed section related to traffic signals (p. 155). Much of the information therein is based on material from the MUTCD. If the changes to the MUTCD, which are suggested above, were made, then the appropriate sections of the handbook would change as well.

APPENDIX A

A DESCRIPTION OF THE PEDESTRIAN'S TASK
(Adapted from H. H. van der Molen et al.)

1 DETERMINING JOURNEY PURPOSE(S) (the why)
- 1.1 Determine journey purpose(s)
- 1.2 Define whether temporary unplanned deviations from the purpose(s) are acceptable

2 DETERMINING DESTINATION AND ROUTE (the where and along where)
- 2.1 Define destination(s) appropriate to the purpose(s)
  - 2.1.1 Define desired time at which the destination must be reached
- 2.2 Define roughly routes to destination(s)
- 2.3 Select destination with due regard to
  - safety of the destination
  - safety of the route (roughly)
  - distance of the route
  - degree in which the destination is appropriate to the purpose
- 2.4 Select route to the selected destination with regard to
  - safety of the route (more specified)
  - distance of the route (more specified)
  - legal regulations
  - convenience (multiple purposes)
- 2.5 Define which tasks occur on the selected route
- 2.6 Define on the basis of the required tasks whether the selected route can be used (if so, carry out Task 3)
- 2.7 If 2.6 is negative : select alternative route : carry out Task 2.4, etc.
- 2.8 If there is no alternative route : seek guidance
- 2.9 If no guidance : abandon destination
- 2.10 Select, if possible another destination : carry out Task 2.3, etc.
- 2.11 If there is no other destination possible : abandon purpose of journey

3 PREPARING FOR JOURNEY
- 3.1 If the selected route can be used (Task 2.6 positive) : define necessary preparations for the execution of the selected route
- 3.2 Carry out these preparations
  - 3.2.1 Define time of commencement of movement so that there is no need to hurry
    - 3.2.1.1 Avoid if possible rush hour traffic
    - 3.2.1.2 Avoid if possible commencement of movement under very difficult weather conditions
  - 3.2.2 If it is raining ensure that clothing, umbrella, etc. does not hamper vision

        3.2.3 If it is misty, twilight, or dark : wear if possible conspicuous clothing and aids to increase visibility
        3.2.4 Inform friends/family : of time of departure; destination and time of expected return

4 EXECUTING THE ROUTE (the how)
    4.1 Recognize what is the street and crossing
    4.2 Maximize not being on the street by carrying out Tasks 22, 11, 8 and 18 with preference for Task 19 (being elsewhere) about Task 14 (being on the side of the streets)
    4.3 Minimize the number of street crossings

5 BEING IN THE STREET
    5.1 Recognize the difference between "being along the side of the street" and "being in the middle of the street"
    5.2 Maximize "being along the side of the street"

6 BEING IN THE MIDDLE OF THE STREET
    6.1 Identify the possibility of carrying out activities on the side of the street or elsewhere (see also Task 4.2)
    6.2 If this is a possibility, make use of it
        6.2.1 Carry out Task 7
        6.2.2 Carry out Task 8
    6.3 Take precautions and action to notice the approach of traffic
        6.3.1 Isolate directions from where traffic can approach
        6.3.2 Define detection strategy to notice the approach of traffic
    6.4 Plan action in case traffic approaches
    6.5 In the event of traffic approaching : take action to avoid collision
        6.5.1 Carry out Task 7
        6.5.2 Carry out Task 8
        6.5.3 Make yourself noticeable

7 GOING FROM THE MIDDLE OF THE STREET TO ALONG THE SIDE OF THE STREET
    7.1 Carry out Task 9

8 GOING FROM THE MIDDLE OF THE STREET TO ALONG THE SIDE OF THE STREET
    8.1 Carry out Task 14

9 BEING ON THE STREET ALONG THE SIDE OF THE STREET
    9.1 Take precautions and action to notice the approach of traffic (see 6.3)
        9.1.1 Isolate directions from where traffic can approach
        9.1.2 Define detection strategy to notice the approach of traffic (see 6.3.2)

9.2 Plan action in the event that other road users approach (see 6.4)
9.3 In the event that traffic approaches : take action to avoid collision
    9.3.1 Carry out Task 10
    9.3.2 Carry out Task 11
    9.3.3 Make yourself noticeable for other road users
    9.3.4 Go closer to the side of the road
        9.3.4.1 Walk one behind the other instead of by the side of each other unless you are walking hand in hand
9.4 Identify the possibility of carrying out activities on the side of the street or elsewhere
9.5 If this is a possibility, make use of it
    9.5.1 Carry out Task 11
    9.5.2 Carry out Tasks 11, 14, 18
    9.5.3 Carry out Tasks 10, 6, 8
    9.5.4 Carry out Tasks 11, 14, 15, 21, 22
9.6 If there is not possibility of carrying out the activities elsewhere (9.4) use the bicycle path if present and pedestrians are allowed
    9.6.1 If the bicycle traffic is hindered, walk one behind the other instead of side by side unless you are walking hand in hand
    9.6.2 If (9.4) is not possible, but there are bicycle paths on either side, use the left-hand bicycle path. Carry out Tasks 12, 21, 23, if appropriate
9.7 If (9.4) or (9.6) is not possible, walk on the left-hand side of the road and carry out Tasks 12, 21, 23, 9 (going to the left) if appropriate

10 GOING FROM ALONG THE SIDE OF THE STREET TO THE MIDDLE OF THE STREET
    10.1 Carry out Task 6

11 GOING FROM ALONG THE SIDE OF THE STREET TO THE MIDDLE OF THE STREET
    11.1 Carry out Task 14

12 STARTING TO CROSS FROM ALONG THE SIDE OF THE STREET
    12.1 Select a suitable place to cross over
    12.2 Carry out Task 9 until the place is reached if appropriate
    12.3 Isolate directions from where the traffic can approach
    12.4 Select point where approach of traffic can be optimally noticed
        12.4.1 If there is a suitable point on the side of the street, carry out Tasks 11 and 15
        12.4.2 If there is a suitable point on the side of the street, define line of vision and take standpoint on this line of vision
    12.5 Carry out Task 21

13 NOT BEING ON THE STREET

13.1 Recognize the difference between the side of the street and elsewhere

13.2 Maximize being elsewhere

13.3 Recognize entrances and exits of driveways

13.3.1 Take precaution and action to notice approaching traffic
If there is no approaching traffic, then carry on

13.3.2 Minimize presence in entrances and exits of driveways

13.3.3 If traffic approaches : wait until this traffic has stopped or has disappeared in an entrance or exit driveway

14 BEING ON THE SIDE OF THE STREET

14.1 Take precautions and action to stay on the side of the street

14.1.1 Keep sufficient distance from the street

14.1.2 Avoid activities which could easily lead to running suddenly onto the street

14.2 Isolate presence and siting of footpath

14.3 Make use of footpath if present

14.3.1 If a footpath is not present and a footpath is present on the other side : carry out Tasks 15, 21, 22

14.3.2 If a footpath is not present on either side of the road, use as much as possible the left-hand side of the street and carry out Tasks 15, 21, 22 if appropriate

14.4 Identify the possibility of carrying out activities elsewhere

14.4.1 If possible carry out Task 18

14.5 In case of roadblocks or end of side of street, carry out Task 3 or 16 or 18

15 STARTING TO CROSS FROM SIDE OF THE STREET

15.1 Select suitable place to cross over

15.1.1 If a pedestrian bridge or tunnel is present, make use of it

15.1.2 If (15.1.1) is not present and there is a regulated pedestrian crossing close by, make use of it

15.1.3 If (15.1.1 or 15.1.2) is not present, select a place to cross from which all directions can be seen

Consider :

- Selecting a place with optimal field of vision by avoiding obstacles
- Selecting a straight piece of road
- Selecting a place some distance away from stationary vehicles
- Selecting a place with a useable side of street (preferably a footpath) on the opposite side of the street
- Selecting a place where the roadways are divided by a traffic island
- Minimizing the number of traffic lanes which have to be crossed one at a time

- Selecting a place where many pedestrians cross over
- Minimizing traffic intensity and maximizing the traffic intensity variation

In twilight/darkness :

- Selecting a place with optimal street lighting

15.2 Carry out Task 14 if appropriate until the selected place is reached
15.3 Isolate directions from where traffic can approach
15.4 Select point where approach of traffic can be optimally noticed
15.5 If there is a suitable point on the side of the street, use it
   15.5.1 Keep sufficient distance from the street
   15.5.2 Carry out Task 2
15.6 If there is no suitable point on the side of the street define line of vision along the street
   15.6.1 Take precaution and action to determine whether traffic can come between the side of the street and the line of vision
   15.6.2 If traffic may approach : either wait until this is no longer the case, or carry out Task 15.1 again
   15.6.3 If no traffic may approach : take position at the line of vision
   15.6.4 Carry out Task 21

16 GOING FROM THE SIDE OF THE STREET ALONG THE SIDE OF THE STREET
   16.1 Take precautions to notice the approach of traffic along the side of the street
   16.2 Determine the possibility of going to the middle of the street without coming in contact with traffic
   16.3 If this is possible, carry out Task 9

17 GOING FROM THE SIDE OF THE STREET TO THE MIDDLE OF THE STREET
   17.1 Take precautions and action to notice the approach of traffic
   17.2 Define the possibility of going to the middle of the street without coming in contact with the traffic
   17.3 If this is possible : carry out Task 6

18 GOING FROM THE SIDE OF THE STREET TO ELSEWHERE
   18.1 Carry out Task 19

19 BEING ELSEWHERE
   19.1 Stay within the boundaries
   19.2 If activities cannot be carried out elsewhere, carry out Task 20

20 GOING FROM ELSEWHERE TO THE SIDE OF THE STREET
   20.1 Carry out Task 14

21 CROSSING
   21.1 Define suitable crossing strategy for situation specified in Task 15.1 or 12.1

21.2 Carry out crossing strategy

21.2.1 Carry out detection and assessment

21.2.1.1 Detection: observe (look and listen) all traffic whether moving or stationary in all relevant directions

21.2.1.1.1 Take into account the number of directions of traffic and the type of intersection. Take also into account the usage of the traffic lanes

21.2.1.1.2 Consider visual detection can be hindered by:
- light conditions (twilight, darkness, counterlight) in combination with absence of or inferior street lighting
- rain, mist, fog, snow
- color of road surface combined with color and type of vehicle; often together with certain light conditions and types of boundaries
- consider that auditory detection can be hindered by noise

21.2.1.2 Assessment

21.2.1.2.1 Decide whether vehicle are moving or stationary

21.2.1.2.2 Decide whether the crossing task can be carried out without coming into conflict with approaching traffic

21.2.1.2.3 Decide whether stationary vehicle can move away

21.2.1.2.3.1 Consider the following aspects of moving traffic and of the road:
- distance
- speed
- direction
- traffic lane in which the traffic is or will be
- communications
- activities (such as increase of speed/decrease of speed, overtaking swerving or pulling out)
- width of roadway
- road surface (wet, snow, ice)

21.2.1.2.4 Adapt assessment to bad lighting conditions, bad vision and noise

21.2.2 Decide the moment of starting to cross on the basis of the present traffic situation and the predicted changes in the traffic situation

21.2.3 Start to walk, after ascertaining that for all directions the traffic situation has not essentially altered during the decision process

21.2.3.1 Continue detection and assessment

21.2.3.2 Walk in steady, albeit quiet tempo, unless 21.1 or 21.2.3.4 indicates otherwise

21.2.3.3 Cross as much as possible at right angles

21.2.3.4 If something unexpected happens, then carry out evasive action by stopping, walking on, or stepping back as quickly as possible depending on circumstances and possibilities. In these cases try to communicate with the driver and communicate your own intentions. Use the traffic lane markings as refuge if possible.

21.3 Conclude crossing task by carrying out Task 22, if possible

21.3.1 If not possible, then by carrying out Task 23

22 ENDING THE CROSSING ON THE SIDE OF THE STREET

22.1 Carry out Task 14

23 ENDING THE CROSSING ALONG THE SIDE OF THE STREET

23.1 Carry out Task 9

CROSSING STRATEGIES

Presence of raised and sufficiently wide division of roadway	Always use the division to carry out detection and assessment before crossing the next traffic lane
Presence of not raised but sufficiently wide division	Idem, but only when traffic does not enter or cross the division
Presence of separate bicycle path	Idem, always use a bicycle path roadway division if wide enough
Zebra crossing	If car stops, walk to new line of vision, carry out detection and assess whether traffic is stopping or can stop
Traffic lights with an indicated crossing	If red light shows for the traffic on the roadway to be crossed, quickly note whether traffic has stopped or will stop. Note especially the traffic turning from behind and in front
Pedestrian lights	Idem, if pedestrian light is green. By flashing green light do not begin to cross over. If crossing maneuver has already begun when green light begins to flash, quickly complete crossing
Pedestrian lights with press-button installation	Press button and wait until light has turned green. Otherwise similar to crossing with pedestrian lights
Traffic police control	Quickly detect relevant traffic and assess whether this has stopped or will stop, taking into account the Traffic Officer signals. Note especially the traffic turning from behind and in front
Traffic lights without an indicated crossing	Cross over if light for the oncoming traffic is red. Quickly detect traffic and assess whether this has stopped or will stop. Note especially turning traffic!

Traffic flow with high intensity and little variation (few gaps)	If there is no regular crossing place, do not cross here
Traffic flow with high intensity and high variation (acceptable gaps)	Wait for gap in the traffic flow
Slippery road surface	Only cross over if there is no traffic approaching
Reduced visibility (through mist, serious rain storm, bad light conditions, etc.)	Only cross over if there is no traffic approaching
Unassessable situations	Only cross over if there is no traffic approaching
Main roads and roads with high traffic speeds	Only cross over if there is no traffic approaching
Oncoming traffic with emergency signals is heard	Do not start to cross. If crossing maneuver has already begun, end it on the first following traffic lane division or side street. Do this as quickly as possible.
Crossing before an intersection	Take into account that on the second traffic lane or second half of the traffic lane, traffic may come from more than one direction
Crossing after an intersection	Take into account that on the first traffic lane or first half of the traffic lane, traffic may come from more than one direction
Interaction signals given by the drivers that crossing can take place	Quickly carry out detection and assessment. If possible walk until line of vision, repeat detection and assessment with regard to overtaking traffic
Flow of pedestrians crossing over	Walk with the flow; do not loiter behind or walk in front. Make sure detection, etc., is carried out
Crossing under supervision of older person (adult or child)	Hold hands and walk along; carry out detection and assessment together with adults

Other situations	Carry out crossing over maneuver following description in Task 21

REFERENCES

1. Committee for the Study on Improving Mobility and Safety for Older Persons 1988. *Transportation in an Aging Society: Improving Mobility and Safety for Older Persons.* Vol. 1, Committee Report and Recommendations, Transportation Research Board, National Research Council, Washington, DC.

2. Staplin, L.; Breton, M.; Haimo, S.; Farber, E.; and Byrnes, A.M. 1986. Age-Related Diminished Capabilities and Driver Performance. Working paper submitted on FHWA contract DTHF61-86-C-00044, Federal Highway Administration, Washington, DC, unpublished.

3. Swanson, A.; Dewar, R.; and Kline, D. 1991. Literature Review and Focus Group Study for Problem Symbolic Signs. Working paper submitted on FHWA Contract DTFH61-91-C-00018, Federal Highway Administration, Washington, DC, unpublished.

4. "Safety and Mobility of Older Drivers." *Human Factors* 33 (5), 1991 and 34 (1), 1992.

5. van der Molen, H.H.; Rothengatter, J.A.; and Vinje, M.P. 1981. "Blueprint of an Analysis of the Pedestrian's Task-I." *Accident Analysis and Prevention* 13 (3):175-191.

6. van der Molen, H.H. 1981. "Child Pedestrian Exposure, Accidents and Behaviour." *Accident Analysis and Prevention* 13 (3):193-224.

7. Faletti, M.V. 1984. "Human Factors Research and Functional Environments for the Aged." From Altman, Irwin; Lawton, M. Powell; and Wohlwill, Joachim F. *Elderly People and the Environment*, pp. 191-235. New York: Plenum Press.

8. Hale, A.R., and Glendon, A.I. 1987. *Individual Behaviour in the Control of Danger.* Amsterdam: Elsevier Science Publishers.

9. Templer, J.A. 1992. *The Staircase: Studies of Hazards, Falls and Safer Design.* Cambridge, MA: MIT Press.

10. Gibson, J.J. 1966. *The Senses Considered as Perceptual Systems.* Boston: Houghton Mifflin.

11. Klein, R. 1991. "Age-Related Eye Disease, Visual Impairment, and Driving in the Elderly." *Human Factors* 33:521-525.

12. Shinar, D., and Schieber, F. 1991. Visual Requirements for Safety and Mobility of Older Drivers. *Human Factors* 55:507-519.

13. Henderson, R., and Burg, A. 1974. *Vision and Audition in Driving*, National Highway Transportation Safety Administration, DOT-HS-801 265, Washington, DC.

14. Bailey, I.L., and Sheedy, J.E. 1988. "Visual Screening for Driver Licensure." In *Transportation in an Aging Society: Improving Safety and Mobility for Older Persons*, Vol 2., pp. 294-324. Transportation Safety Board, National Research Council, Washington, DC.

15. Yee, D. 1985. "A Survey of the Traffic Safety Needs and Problems of Drivers Age 55 and Over." In *Needs and Problems of Older Drivers: Survey Results and Recommendations*, J.L. Malfetti (ed). AAA Foundation for Traffic Safety, Falls Church, VA.

16. Elliott, D.B. 1987. "Contrast Sensitivity Decline with Aging: A Neural or Optical Phenomenon?" *Ophthalmic and Physiological Optics* 7:415-419.

17. Johnson, C.A., and Keltner, J.L. 1983. "Incidence of Visual Field Loss and Its Relationship to Driving Performance." *Archives of Ophthalmology* 101:371-375.

18. Carter, J.H. 1982. "The Effects of Aging on Selected Visual Functions: Color Vision, Glare Sensitivity, Field of Vision, and Accommodation." In *Aging and Human Visual Function*, R. Sekuler, D.W. Kline, and K. Dismukes (eds), pp. 121-130. New York: Alan R. Liss.

19. Burg, A. 1967. "Light Sensitivity as Related to Age and Sex." *Perceptual and Motor Skills* 24:1279-1288.

20. Wolf, E. 1960. Glare and Age. *Archives of Ophthalmology* 64:502-514.

21. Schieber, F., and Williams, M.J. 1990. The Effects of Age and Glare Upon Spatiotemporal Contrast Thresholds. *The Gerontologist* 30, 71.

22. Sekuler, R., and Ball, K. 1986. Visual Localization and Practice. *Journal of the Optical Society of America* (Section A) 3:864-867.

23. Scialfa, C.; Kline, D; Lyman, B.; and Kosnik, W. 1987. Age Differences in Judgments of Vehicle Velocity and Distance. *Proceedings of the Annual Meeting of the Human Factors Society*, New York, Human Factors Society.

24. Ball, K.; Owsley, C.; and Beard, B. 1990. "Clinical Visual Perimetry Underestimates Peripheral Field Problems in Older Adults." *Clinical Vision Sciences* 5:113-125.

25. Treat, J.R., Tumbas, N.S., McDonald, S.T., Shinar, D., Hume, R.D., Mayer, R.D., Stansifer, R.L., and Castallen, N.J., 1977. Tri-level Study of the Cause of Traffic Accidents. Report No. DOT-HS-034-3-535-77 (TAC), Indiana University.

26. Malfetti, J.L. (ed) 1985. *Needs and Problems of Older Drivers: Survey Results and Recommendations,* AAA Foundation for Traffic Safety, Falls Church, VA.

27. Clark-Carter, D.D.; Heyes, A.D.; and Howarth, C.I. 1986. The Efficiency and Walking Speed of Visually Impaired People. *Ergonomics* 29 (6):779-789.

28. Beggs, W.D.A. 1991. "Psychological Correlates of Walking Speed in the Visually Impaired." *Ergonomics* 34 (1):91-102.

29. Fozard, J.L. 1990. "Vision and Hearing in Aging." In *Handbook of the Psychology of Aging,* J.E. Birren and K.W. Schaie (eds), 3d. ed., pp.150-170. San Diego: Academic Press, Inc.

30. Kryter, K.D. 1985. The Effects of Noise on Man (2d ed). Orlando: Academic Press.

31. Ernst, U., and Everett, C. 1981. Elderly Mobility and Transportation Services: Some New Survey Evidence. Presented at the 60th Annual Meeting of the Transportation Research Board, Washington, DC.

32. Rosenbloom, S. 1988. The Mobility Needs of the Elderly. In *Transportation in an Aging Society: Improving Mobility and Safety for Older Persons.* Vol. 2, Technical Papers, Transportation Research Board, National Research Council, Washington, DC.

33. "Aging in the Eighties: National Personal Transportation Survey." Public Health Service, Hyattsville, MD, 1987.

34. *Traffic Safety of Elderly Road Users* 1985. Organization for Economic Cooperation and World Health Organization, Paris, France.

35. "Aging in the Eighties: Ability to Perform Work-Related Activities." No.136. *Advance Data from Vital and Health Statistics.* Public Health Service, Hyattsville, MD, 1987.

36. Czaja, S.J. Safety and Security of the Elderly: Implications for Smart House Design, *International Journal of Technology and Aging*, Vol.1, No.1, Spring/Summer 1988, 49-66.

37. U.S. Senate, Special Committee on Aging 1987. Aging in America: Trends and Projections, U.S. Government Printing Office.

38. Brody, E.M., and Kleban, M.H. Day-to-Day Mental and Physical Health Symptoms of Older People: A Report on Health Logs, *The Gerontologist* 23 (1):75-85, February 1983.

39. Templer, J.A. 1980. *Provisions for Elderly and Handicapped Pedestrians: Vol. 2, Hazards, Barriers, Problems, and the Law*. Federal Highway Administration, Washington, DC.

40. Dahlstedt, S. Walking Speeds and Walking Habits of Elderly People. National Swedish Road and Traffic Research Institute, Stockholm, Sweden. Undated.

41. *The Manual on Uniform Traffic Control Devices for Streets and Highways 1986*. Federal Highway Administration, Washington, DC.

42. McGee, H.W.; Hooper, K.G.; Hughes, W.E.; and Benson, W. 1983. *Highway Design and Operations Standards Affected by Driver Characteristics: Final Technical Report*. Report FHWA/RD-83/015. Federal Highway Administration, Washington, DC.

43. Dewar, R.E., 1992. Driver and Pedestrian Characteristics. In Pline, J. (ed.), *Traffic Engineering Handbook* (4th ed). Englewood Cliffs, NJ: Prentice Hall., pp. 1-28.

44. ITE Committee 4 A-6. *Traffic Control Devices for Elderly and Handicapped Pedestrians*. Institute of Transportation Engineers, Washington, DC. Undated.

45. Moore, R.L. 1956. Psychological Factors of Importance in Traffic Engineering. Presented at the International Study Week in Traffic Engineering, Stresa, Italy.

46. Fruin, J.J. 1987. Pedestrian Planning and Design. Mobile, Ala.: Elevator World.

47. National Electronic Injury Surveillance System 1980. *Injuries Associated with Selected Consumer Products Treated in Hospital Emergency Departments*. U.S. Consumer Product Safety Commission.

48. Czaja, S.J.; Hammond, K.; and Drury, C.C. 1982. Accidents and Aging. Report prepared for the Administration on Aging.

49. National Safety Council, *Accident Facts*, (1989 edition), Chicago.

50. Lambert, D.A., and R.W.Sattin. Deaths from Falls, 1978-1984, in *CDC Surveillance Summaries*, MMWR 1988; 37 (SS-1).

51. Baker, S.P.; O'Neill, B.; and Karpf, R.S. 1984. *The Injury Fact Book*. Lexington, MA: Lexington Books.

52. US Consumer Product Safety Commission, 1991.

53. Archea, J.; Collins, B.; and Stahl, F. 1979. *Guidelines for Stair Safety*, NBS Building Science Series 120. Washington, DC: National Bureau of Standards.

54. Templer, J.A.; Lewis, D.; and Sanford, J. 1985. *Ground and Floor Surface Treatments*. U.S. Architectural and Transportation Barriers Compliance Board, Washington, DC.

55. Templer, J.A., and Wineman, J.D. 1980. *The Feasibility of Accommodating Physically Handicapped Individuals on Pedestrian Over- and Undercrossing Structures*. Federal Highway Administration, Washington, DC.

56. Carp, F.M. 1971. Pedestrian Transportation for Retired People. In *Highway Research Record 356*, Highway Research Board, National Research Council, Washington, DC.

57. Carp, F.M. 1972. The Older Pedestrian in San Francisco. In *Highway Research Record 403*, Highway Research Board, National Research Council, Washington, DC.

58. Erlich, P.H. Elderly Pedestrian Involvement. 1985. In *Highway Mobility and Safety of Older Drivers and Pedestrians: Report of a Workshop*. Highway Users Federation for Safety and Mobility, Washington, DC.

59. Cerella, J. Aging and Information Processing rate 1990. In *Handbook of the Psychology of Aging*, J.E. Birren and K.W. Schaie (eds), 3d. ed., pp. 201-221. San Diego: Academic Press.

60. Salthouse, T.A. 1985. Speed of Behavior and Its Implications for Cognition. In *Handbook of the Psychology of Aging*, J.E. Birren and K. W. Schaie (eds).

61. McDowd, J.M., and Birren, J.E. 1990. Aging and Attentional Processes. In *Handbook of the Psychology of Aging*, J.E. Birren and K.W. Schaie (eds), 3d ed, pp. 222-233. San Diego: Academic Press.

62. McDowd, J.M., and Craik, F.I.M. 1988. Effects of Aging and Task Difficulty on Divided Attention Performance. *Journal of Experimental Psychology: Human Perception and Performance* 14:764-769.

63. Wright, L.L., and Elias, J.W. 1979. Age Differences in the Effects of Perceptual Noise. *Journal of Gerontology* 43:704-708.

64. Plude, D.J., and Hoyer, W.J. 1985. Attention and Performance: Identifying and Localizing Age Deficits. In *Aging and Performance*, N. Charness (ed), pp.47-99. New York: Wiley.

65. Parasuraman, R., and Nestor, P.G. 1991. Attention and Driving Skills in Age and Alzheimer's Disease. *Human Factors* 33:539-557.

66. Kosnik, W.D.; Sekuler, R.;and Kline, D.W. 1990. Self-Reported Visual Problems of older drivers. *Human Factors* 32 (5):597-608.

67. McKnight, J. Driver and Pedestrian Training 1988. In *Transportation in an Aging Society: Improving Mobility and Safety for Older Persons.Transportation in An Aging Society*, Vol. 2, Transportation Research Board, Special Report #218, 101-133.

68. Sheppard, D., and Pattinson, M. 1986. Interviews with Elderly Pedestrians Involved in Road Accidents. *Transportation and Road Research Laboratory Research Report 98*, TRRL, Crowthorne, United Kingdom.

69. Sheppard, D., and Valentine, S.D. 1979. The Provision of Road Safety Instruction for the Elderly. *Transportation and Road Research Laboratory Supplementary Report 533.*

70. Mathey, F.J. 1983. Attitudes and Behavior of Elderly Pedestrians. *International Journal of Aging and Human Development* 17 (1):25-28.

71. Preston, B. 1989. The Behavior and Safety of Pedestrians at Pelican Crossings in Greater Manchester. *Traffic Engineering and Control*, 596-599.

72. Schioldborg, P. 1979-80. Driver and Pedestrian - Two Different Worlds? *Voice of the Pedestrian XII*, International Federation of Pedestrians, The Hague.

73. Katz, A.; Zaidel, D.;and Elgrishi, A. 1975. An Experimental Study of Driver and Pedestrian Interaction During the Crossing Conflict. *Human Factors* 17:514-527.

74. Salvatore, S. 1974. The Ability of Elementary and Secondary School Children to Sense Oncoming Vehicle Velocity. *Journal of Safety Research* 6 (3):118-125.

75. van Wolffelaar, P.C.; Rothengatter, T.; and Brouwer, W. 1991. Elderly Drivers' Traffic Merging Decisions. In A.G. Gale et al. *Vision in Vehicles-III.* Amsterdam: Elsevier Science Publishers. B.V., 247-255.

76. Darzentas, J.; McDowell, M.R.C.; and Cooper, D. 1980. Minimum Acceptable Gaps and Conflict Involvement in a Simple Crossing Manoeuvre. *Traffic Engineering and Control* 21:186-189.

77. Bottom, C.G., and Ashworth, R. 1978. Factors Affecting the Variability of Driver Gap-Acceptance Behavior. *Ergonomics* 21:721-734.

78. Darzentas, J.; Holms, V.; and McDowell, M. 1980. Driver Behavior at a T-Junction in Daylight and Darkness. *Traffic Engineering and Control* 21 (9):186-189.

79. Scialfa, C.T.; Guzy, L.; Leibowitz, H.; Garvey, P.; and Tyrrell, R. 1991. Age Effects in Estimating Vehicle Velocity. *Psychology and Aging* 6 (1):60-66.

80. Miura, T. 1980. A Preliminary Study of Gap Acceptance Behavior and Its Perceptual Factors. *Bulletin of the Faculty of Human Sciences,* Osaka University. Vol. 6, 36-77.

81. Leibowitz, H. 1985. Grade-Crossing Accidents and Human Factors Engineering. *American Scientist* 73:558-562.

82. Hills, B.L. 1980. Vision, Visibility, and Perception in Driving. *Perception* 9:183-216.

83. Cairney, P.T. 1988. Should the Flashing Man be Red or Green? *Australian Road Research* 18 (1):38-40.

84. Barker, D.J.; Wong, Y.W.; and Yue, W.L. 1991. "Pedestrian Violations at Signalized Crossing Facilities." *Australian Road Research* 21 (1):22-29.

85. Zegeer, C., Opiela, K.S. and Cynecki, M.J. 1982. Effects of Pedestrian Signals and Signal Timing on Pedestrian Accidents. *Transportation Research Record 847*:62-72.

86. Robertson, D.H. 1972. Pedestrian Preferences for Symbolic Signal Displays. *Transportation Engineering.*

87. Robertson, D.H. 1977. Pedestrian Signal Displays: An Evaluation of Word Message and Operation. *Transportation Research Record 629,* 19-22.

88. Robertson, D.H., and Carter, E.C. 1984. The Safety, Operational, and Cost Impacts of Pedestrian Indications at Signalized Intersections. *Transportation Research Record 959*, pp. 1-7.

89. Bailey, S.; Jones, S.; Stout, R.; Bailey, J.; Kass, S.; and Morgan, B.B. "Issues of Elderly Pedestrians." Paper presented at the Annual Meeting of the Transportation Research Board. Washington, DC, January 1992.

90. Oliver, M.B.; Fegan, J.V.; and Ardekani, S.A. 1990. Audible Pedestrian Signals - Current Practices and Future Needs. *ITE Journal* 60 (6):35-37.

91. Ulsan, M.M.; Peck, A.F.; and Waddell, W. 1988. Audible Traffic Signals: How Useful Are They? *ITE Journal* 59 (9):37-43.

92. Wilson, D.G. 1980. The Effects of Installing an Audible Signal for Pedestrians At a Light Controlled Junction. *Transportation and Road Research Laboratory Report 917.* TRRL, Crowthorne, United Kingdom.

93. Wolfe, A.C., and O'Day, J. 1981. *Factbook on U.S. Pedestrian Accidents.* Ann Arbor, MI: Highway Safety Research Institute.

94. Jordan, P.W., and Young, W. 1982. The Incidence of Alcohol Amongst Injured Pedestrians. *Proceedings of the 11th Australian Road Research Board Conference* (Part 5), Melbourne, Australia, 87-99.

95. McMurray, L. 1970. Emotional Stress and Driving Performance: The Effect of Divorce. *Behavioral Research and Highway Safety* 1:100-114.